CANADA'S MARINE FISHERIES:

Status, Recovery Potential and Pathways to Success

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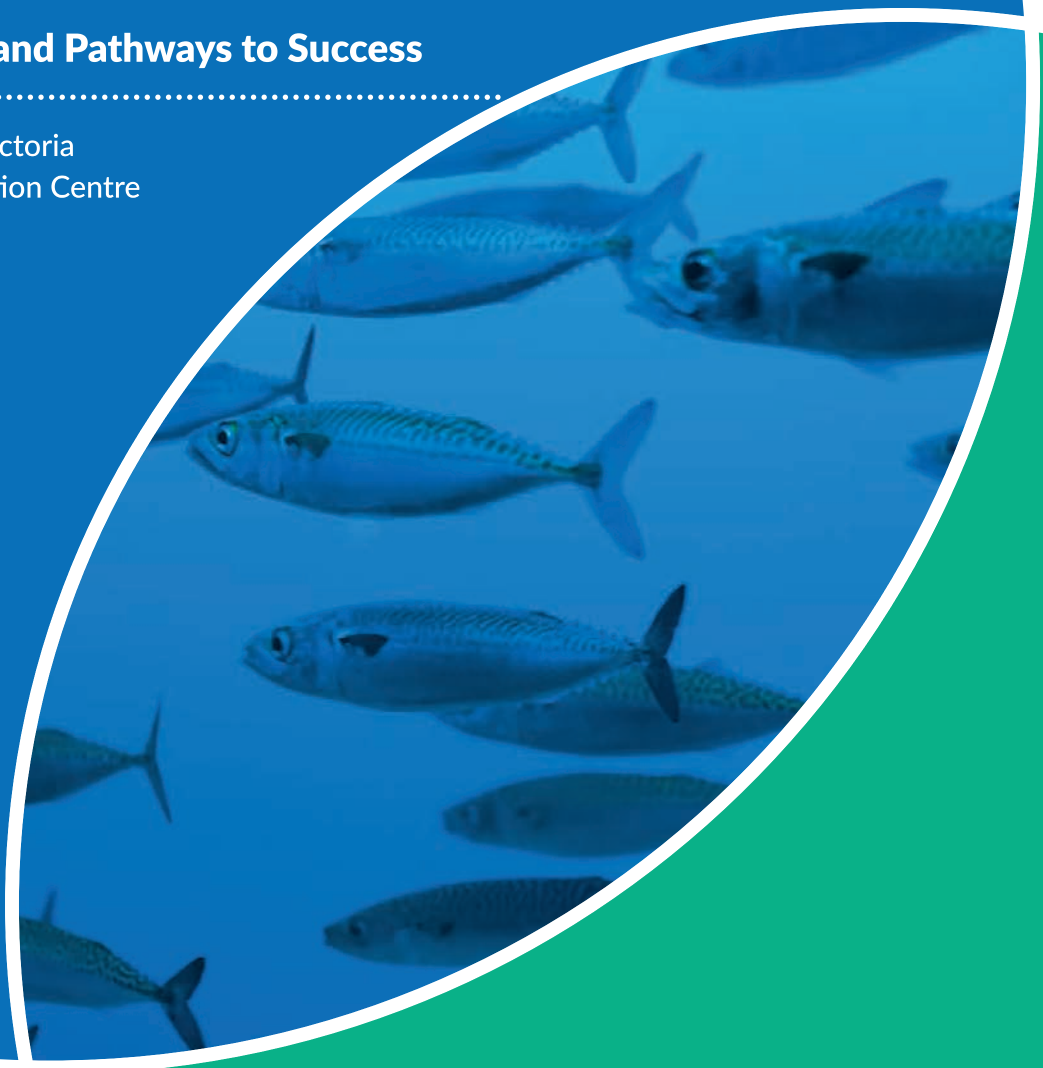

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EXECUTIVE SUMMARY

Canada's marine fisheries are highly valuable, both economically and culturally. Despite their significance, Canada has a poor track record of effectively managing its fisheries and preparing for the future. Although the collapse of northern cod is a notorious example of Canada's fisheries mismanagement, this species is just one of many that have been overexploited and experienced massive declines in Canada. Forty exploited marine species are assessed as endangered or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are being considered for listing under Canada's *Species at Risk Act*.

Despite extensive overfishing, the overall value of Canadian fisheries is at an all-time high, because high-value shellfish fisheries dominate harvests, especially on the East Coast. This prosperity belies a serious problem. Canada has maintained its fisheries prosperity through a process of serial depletion: by intensifying fishing pressure on new stocks after depleting the previous ones, rather than through sound management and successful population rebuilding.

Canada has a relatively strong national and international legal and policy framework to manage its fisheries, but it has typically failed to implement the instruments that are in place to prevent overfishing and to ensure recovery where it is needed. Until now, Canada's *Species at Risk Act* has failed to protect marine species. In addition, although the *Oceans Act* could be invoked to help recover depleted marine fish populations, it is rarely used for this purpose.

Canada's *Fisheries Act* needs to be updated to include modern management principles, such as precautionary and ecosystem-based fisheries management approaches. It should be amended to include legal requirements to prevent overfishing and to rebuild fish stocks within clearly defined timelines and with pre-identified recovery targets.

Fisheries and Oceans Canada (DFO) uses the Precautionary Approach Framework to classify populations into four zones – healthy, cautious, critical or unknown – based on their stock status relative to a set of reference points. Marine fish that COSEWIC has assessed as being threatened or endangered should immediately be considered in the critical zone in this framework, with associated management measures implemented as an urgent priority.

A suite of non-governmental mechanisms contributes to scientific advice and could be further leveraged to help inform Canada's fisheries management decisions. These include: co-management agreements between fishing communities and entities and DFO; collaborative research networks; and market-based approaches.

We highlight a disturbing lack of transparency in Canadian fisheries science and management. Stock assessments are sometimes inaccessible or opaque, and management decisions are often not publicly available. Moreover, management decision-making processes for marine species have often been circumvented by stakeholders with competing interests who communicate directly with the Minister of Fisheries, Oceans and the Canadian Coast Guard's office or with regional fisheries directors. This is made possible largely as a result of the broad discretionary powers of the Minister that are inherent in the *Fisheries Act*. DFO should make its data and management decisions available and foster a new culture of transparency.

In preparing this report on the current state of Canada's fisheries, we developed a list of 165 Canadian marine fish and invertebrate stocks, including the most important commercially harvested stocks and those designated as being of conservation concern. Recent stock status data were available for 125 of these 165 populations. Of the 125 stocks examined, 82 are found on Canada's Atlantic coast (n=28 species total) and 43 are on Canada's Pacific coast (n=18 species total). For 79 stocks, there is an estimate of abundance. Accurate estimates of fishing intensity are important for managing and recovering wild populations, yet only one-quarter of the reviewed stocks had an estimate of fishing mortality or exploitation rate. Moreover, there are 22 stocks without any existing measure of abundance or relative abundance.

The infrequency with which assessments are conducted and the lack of Research Documents for some recent assessments should be regarded as significant impediments to sound fisheries management and recovery in Canada. Scientific capacity must be restored within DFO if the department is to meet the scientific and management requirements of the broad suite of species under its mandate.

Our analysis of 125 Canadian marine stocks reveals that less than one-quarter (24 per cent) of Canada's marine fish and invertebrate stocks are currently considered healthy by DFO: 15 stocks on the Atlantic coast and 13 on the Pacific coast. Also of concern are a full 45 per cent of Canadian stocks whose status is currently unknown.

Eighteen stocks in Canada are considered critical. On the West Coast, only three stocks are considered critical. However, the status of all elasmobranchs and forage fish on this coast is unknown, making it impossible to determine the true status of the fished community. In the Atlantic, 15 stocks are considered to be in a critical state. Unsurprisingly, these include five cod stocks. Three American plaice, one witch flounder, one white hake, four redfish stocks, and mackerel are considered to be in critical condition. To make matters worse, a dangerous gap exists between the scientific advice for Canada's mackerel quota and that which management currently allows. The implemented quota needs to be brought in line with the scientific advice if this stock is going to have a chance to recover.

We also highlight a striking discrepancy between our results and those of the 2016 Environment and Climate Change Canada (ECCC) report on the status of Canada's stocks, which presents a much more optimistic portrait regarding the proportion of stocks reported as healthy (48 per cent) and those with an unknown status (15 per cent). The opacity of ECCC's methodology makes it impossible to discern the basis of these discrepancies: the report does not state which individual stocks it evaluated; nor is DFO's Fisheries Checklist, upon which the document is based, publicly available.

Overfishing remains the primary reason why many of Canada's commercially harvested marine fish and invertebrate stocks are depleted and in need of recovery. Successful fisheries recovery requires a suite of integrated approaches, including science-based estimates of abundance, reference points, effort control, reduced fishing mortality and rebuilding plans with legally binding timelines and targets. As soon as overfishing is detected, fisheries managers must sufficiently reduce exploitation levels by setting and enforcing science-based catch limits. Precautionary harvest control rules also should be established to ensure that there is adherence to science-based decision-making.

Climate change impacts will need to be considered when developing recovery plans, and Canadian fisheries management currently does not do an adequate job on this front. Biological characteristics such as species life history and trophic level must also be taken into consideration.

Recovery of overfished marine populations has been achieved for a variety of species and can occur relatively quickly if fishing mortality is sufficiently reduced. Within Canada, Atlantic halibut stands out as one of the few fish species that has recovered. Examples of recovered fisheries in the U.S. and Europe include Atlantic scallop, Georges Bank haddock, Norwegian spring spawning herring and Northwest Atlantic swordfish.

Within Canada, we recommend that recovery efforts focus on the following species groups: groundfish and benthic elasmobranchs (a suite of species on the Atlantic coast, and rockfish on the Pacific coast); forage fish (mackerel on the Atlantic coast and eulachon on the Pacific coast); and apex predators (Atlantic bluefin tuna and blue shark). The species groups are chosen strategically with a focus on species where – with concerted effort – either recovery or significant conservation improvements could be made within a time frame of approximately 10 years.

Fisheries rebuilding must become a political priority, and fisheries managers must be guided in making decisions toward long-term ecosystem health, rather than short-term economic gains. This is imperative if Canada is to build the resilience of marine ecosystems, the fishing industry and coastal communities and move beyond the boom-and-bust nature that has plagued Canadian fisheries in the past.

There are indications of a willingness to restore lost science capacity and provide political leadership for improved management of Canada's fisheries and oceans. One example is a recent reinvestment in Canadian fisheries science in the form of 135 marine scientist job openings with DFO in May 2016. Another example is the stated commitment to science-based decision-making in the federal Ministerial Mandate Letters in 2015. Furthermore, the Canadian government has made a commitment to meet at least one of its international targets under the Convention on Biological Diversity, by protecting 10 per cent of Canada's marine and coastal areas. Engagement of the public and stakeholders in oceans could serve to mobilize governments and the fishing industry to work toward fisheries recovery in Canada.

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Finally, we dedicate this report to Ransom Myers, our PhD advisor, who continues to inspire our drive to conserve the ocean.

GLOSSARY AND ACRONYMS

AFS
Aboriginal Fisheries Strategy

AICFI
Atlantic Integrated Commercial Fisheries Initiative

ATIP
Access to Information Process

B0
Virgin spawning biomass, typically as estimated from a model.

B_{lim}
Biomass below which serious harm is occurring to the stock.

B_{MSY}
Biomass that enables a fish stock to deliver the maximum sustainable yield (MSY).

$B_{recover}$
Lowest historic biomass level from which the stock has recovered readily.

CBD
Convention on Biological Diversity

CCPFH
Canadian Council of Professional Fish Harvesters

CHP
Conservation Harvesting Plan

COSEWIC
Committee on the Status of Endangered Wildlife in Canada

CPRS
Conservation Plan and Rebuilding Strategy

CSAS
Canadian Science Advisory Secretariat

DFO
Fisheries and Oceans Canada (formerly the Department of Fisheries and Oceans and commonly referred to by its previous acronym)

EEZ
Exclusive Economic Zone

ENGO
Environmental Non-Government Organization

ERAF
Ecological Risk Assessment Framework

Exploitation Rate
The proportion of the numbers or biomass of stock removed by fishing.

F
Fishing mortality rate: catch relative to the size of the fish stock, or the proportion of fish caught and removed by fishing. It is typically an instantaneous rate, but it can also be translated into a yearly exploitation rate.

F_{MSY}
Maximum rate of fishing mortality resulting in a population size of B_{MSY}.

FAO
Food and Agriculture Organization of the United Nations

FIP
Fisheries Improvement Project

HCR
Harvest Control Rule

IATTC
Inter-American Tropical Tuna Commission

ICCAT
International Commission for the Conservation of Atlantic Tunas

IFMP
Integrated Fisheries Management Plan

IPHC
International Pacific Halibut Commission

ITQ
Individual Transferable Quota

IUU
Illegal, Unreported and Unregulated catch

LRP
Limit Reference Point

MSC
Marine Stewardship Council

MSY
Maximum Sustainable Yield: The largest yield (catch) that can be taken from a specific fish stock over an indefinite period under constant environmental conditions. Measured in tonnes.

NAFO
Northwest Atlantic Fisheries Organization

NMFS
National Marine Fisheries Service

NOAA
National Oceanic and Atmospheric Administration

NPFC
North Pacific Fisheries Commission

NSERC
National Science and Engineering Research Council

PA
Precautionary Approach

PICFI
Pacific Integrated Commercial Fisheries Initiative

RFMO
Regional Fisheries Management Organization

RPA
Recovery Potential Assessment

SAR
Stock Assessment Report

SARA
Canada's *Species at Risk Act*

SBA
Sensitive Benthic Area

SFF
Sustainable Fisheries Framework

SSB
Spawning stock biomass: The total weight of the fish in a stock that are old enough to spawn, typically estimated as the biomass of all fish beyond the age or size class in which 50 per cent of the individuals are mature.

TB
Total biomass

TMGC
Canada – U.S. Transboundary Management Guidance Committee

TRP
Target Reference Point

UNFSA
United Nations Fish Stocks Agreement

USR
Upper Stock Reference Point

1. INTRODUCTION

Fish in Canada's Atlantic, Pacific and Arctic waters have long been sources of food and commerce and have shaped social and cultural identities. Once replete with marine life, our oceans have supplied First Nations and Inuit communities with important sources of protein and have been deeply embedded in cultural practices and beliefs. Meanwhile, European vessels came to Canada as early as the 1500s to harvest the extraordinarily abundant cod stocks. Because of the significance of fisheries to Canada's history, economy and society, Canada's success in managing them has been the subject of both academic and government reviews.

In 2012, the Royal Society of Canada convened an Expert Panel on Sustaining Canadian Marine Biodiversity: Responding to the Challenges Posed by Climate Change, Fisheries, and Aquaculture. The resulting report (Hutchings et al. 2012) assessed Canada's performance in fisheries management relative to several other industrialized countries. It concluded that Canada fell far below other countries in maintaining fish stock biomass at a level that could produce maximum sustainable yield (MSY), with an overall decline in fish biomass of 55 per cent since 1970.

Although Canada has a relatively strong national and international legal and policy framework to manage its fisheries, it typically fails to fully implement these instruments. Moreover, the *Fisheries Act*, one of Canada's oldest pieces of legislation, has not been modernized to include basic principles of good management and does not provide a legal obligation to rebuild depleted fish populations. Many of Canada's commercially targeted species, including iconic populations of Atlantic cod and bluefin tuna, have declined significantly – from 65 per cent to 99 per cent – since the 1960s. As such, many commercially exploited species are now assessed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2010, 2011) and are being considered for listing under Canada's *Species at Risk Act* (SARA).

Despite the fact that many of Canada's fish populations have been depleted, the overall value of Canadian fisheries has increased, particularly over the past decade, because high-value shellfish fisheries now dominate harvests, especially on the East Coast. Broadly speaking, Canada has maintained the overall prosperity of its fisheries through a process of serial depletion – intensifying fishing pressure on new stocks after depleting the previous ones – rather than through sound management and successful stock rebuilding.

Without a distinct shift in how fisheries are managed and the application of science-based decision-making, Canada's commercially harvested marine fish are unlikely to recover and invertebrate populations will likely decline. As a result, coastal communities will continue to feel economic and cultural losses as a result of dwindling resources.

Continued overfishing poses the single greatest threat to recovering Canada's depleted fisheries. However, the impacts of climate change are also being felt and will intensify in the future, underscoring the need for a precautionary approach to fisheries management. It is possible to reduce the ecosystem impacts of fisheries with appropriate management actions, so there is potential for Canadian fisheries to recover and increase in abundance, or at the very least maintain their current contribution to Canada's economic and environmental health.

In the context of global fisheries and Canada's role as a net fisheries exporter, well-managed, wild fisheries could provide an important renewable resource that supports coastal communities over the long-term.

This report provides an overview of Canadian fisheries, including their social and economic importance; existing legal and policy frameworks that could enable fisheries recovery; Canada's track record of implementing these instruments; and additional tools outside of government policy frameworks that may lead to fisheries recovery.

We have reviewed the availability and quality of stock status information for 165 Canadian marine fish and invertebrate populations, including the most important commercially harvested populations and ones designated as being of conservation concern. Of these, we found recent stock assessments (within the past five years) for 125. In this report, we assess the status of the 125 stocks, including the state of their stock size and exploitation levels relative to reference points (where available), and the overall status of Canada's fisheries.

We also present eight national and international case studies that serve as examples of where recovery either has been achieved or could be achieved with proper fisheries management. Finally, we have addressed the drivers of overfishing in Canada, assessed the potential for recovering Canada's overexploited marine fish and invertebrate populations and made concrete recommendations for improving fisheries management and outcomes in Canada.

2. WHY DOES CANADA NEED HEALTHY FISHERIES?

2.1 The seafood industry

Canada's fisheries have provided food security and trade opportunities for First Nations and Inuit for millennia and have been an integral part of our culture, economy and society both pre- and post-colonization. The abundance of fish on Canada's Atlantic continental shelf brought vessels from Spain's Basque region in the early 1500s. For much of the next five centuries, it seemed that Canada had been blessed with an inexhaustible supply of wild protein. The importance of fishing to Canada is underscored by the fact that the federal government's second act, after confederation in 1867, was the *Fisheries Act*, passed in 1868. The Act was designed to provide a legal mechanism to allocate fisheries resources, and ostensibly to conserve them, with an initial focus on salmon and inshore fish.

Since the start of industrial fisheries, global technological innovations and improvements have resulted in increased fishing capacity and efficiency and, with that, overfishing and depletion (Pauly et al. 2001). For example, the advent of the factory trawler shortly following World War II greatly increased the fishing efficiency on Canada's East Coast. By the 1990s, Atlantic Canada's fisheries were severely depleted compared to the previous several hundred years of active fishing (Hamilton et al. 2004). The 1977 extension of the national fishing boundary from a 12-mile to a 200-mile limit meant that Canada no longer had to contend with international fishing vessels within 200 miles of its shores. Given the strong opposition to the unsustainable fishing practices of distant-water fishing fleets, this offered a new opportunity for improved management of Canada's marine resources.

However, 15 years of Canadian jurisdiction over the fishing grounds in Atlantic Canada resulted in the largest-ever fisheries collapse in the world: the collapse of the Northern cod fishery in 1992. Today, Canada continues to ignore scientific advice, and recovery of depleted groundfish fisheries – including Northern cod – remains elusive. Canada's current Atlantic fishery is dominated by catches of crustaceans, including shrimp, lobster and crab (Frank et al. 2005) and small pelagics, including herring (Frank et al. 2013).

According to the most recent available statistics, almost two-thirds (65 per cent) of Atlantic Canadian fisheries landings now consist of invertebrates, followed by small pelagics, large pelagics and other fisheries (23 per cent) and groundfish (12 per cent) (Figure 2.1, DFO 2015a). Nationally, Atlantic Canadian invertebrate fisheries account for over half the volume (54 per cent) of Canada's total fisheries landings and 97 per cent of all invertebrate landings (Figure 2.1, DFO 2015a).

Canada's West Coast has been dominated by salmon fisheries, which continue to be deeply embedded in the social and cultural experience of West Coast First Nations communities. Exploitation of salmon through increasingly efficient gear and the opening of canneries throughout the British Columbia coast in the early 1900s led to the decline of wild salmon and the establishment of salmon hatcheries to restock depleted rivers.

Fishing for Pacific halibut, and the need to divide this resource between Canada and the United States, led to one of the first international fisheries agreements, through the Pacific Halibut Council. Today, Canada's West Coast has a diverse groundfish fishery, as well as fisheries for shrimp and wild salmon (Figure 2.1). The majority of landings are comprised of groundfish (52 per cent), followed by small pelagics, large pelagics and other fisheries (38 per cent) and invertebrates (8 per cent) (Table 2.1).

Figure 2.1: Volume of Canadian fisheries landings in 2014 in metric tonnes (Mt), by region (Atlantic Canada and the Arctic in blue, British Columbia in green) and species group: a) groundfish, b) small and large pelagics, c) invertebrates (Source: DFO 2015a). Within each plot, all species with landings over 5,000 metric tonnes (Mt) (in the Atlantic and/or in British Columbia) are shown, along with the total for the species group. Note the different y-axis scales.

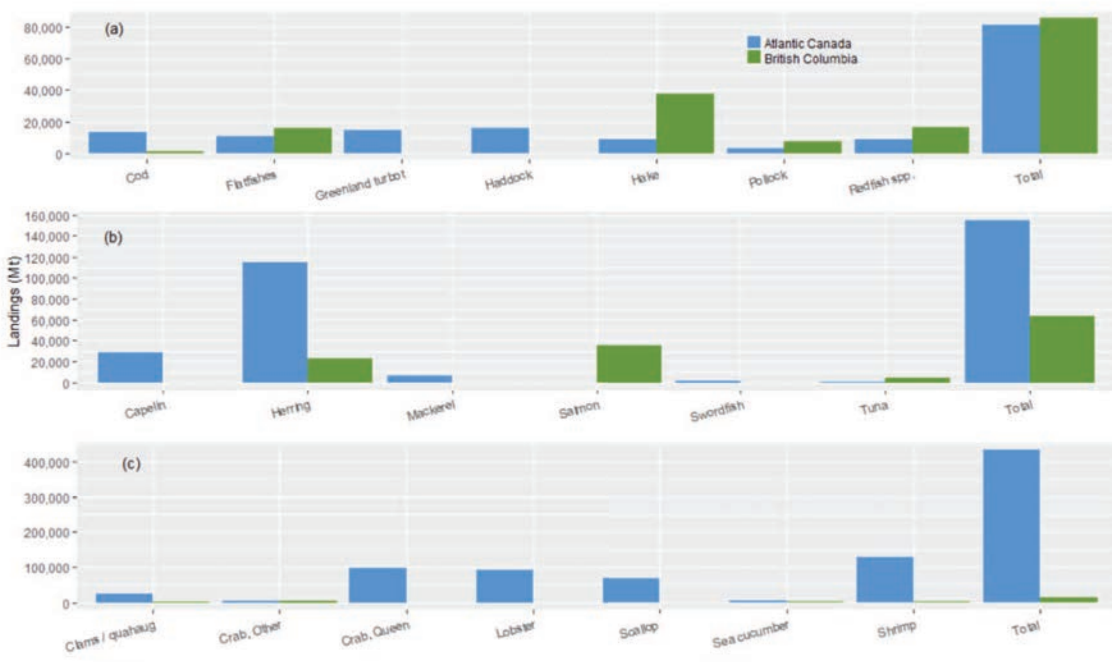


Table 2.1: Volume of Canada's Atlantic (including Arctic) and Pacific fisheries as of 2014 in metric tonnes (Mt) (Source: DFO 2015a). The % Fishery columns show how much the regional fishery for each taxa contributes to the national fishery for that taxa (by weight). The % Total Fishery column shows how much the national fishery for each taxa contributes to the total national fishery (by weight).

Taxa	Atlantic (Mt)	% Fishery	Pacific (Mt)	% Fishery	Canada (Mt)	% Total Fishery
Groundfish	81,263	49	86,054	51	167,318	20
Small and large pelagics, other fish	154,963	71	63,430	29	218,394	26
Invertebrates	433,218	97	13,484	3	446,702	54
Total volume	**669,445**		**162,969**		**832,414**	

Arctic fisheries have long been a source of food security for Inuit. However, in the late 1980s, Canada's commercial fisheries expanded further north into the Arctic, exploiting Greenland halibut (turbot) and shrimp. This expansion northward was due in part to the decline in groundfish off Newfoundland (see INAC 2012 for an overview of eastern Arctic fisheries). Arctic fishery landings are included in Atlantic landings (Figure 2.1) and are not reported separately by DFO. As ocean temperatures increase, more of the Arctic will be open to fishing for longer periods during the summer and fall.

2.2 Seafood consumption

Canadian fisheries are an important component of food security, providing coastal communities with a significant source of low-cost, high-quality protein (Lowitt 2013). Seafood consumption provides a significant source of protein for many of Canada's coastal communities and continues to be of primary importance to First Nations communities on the West Coast (Mos et al. 2004) and Arctic Inuit communities, where, as of 2008, fish and seafood was the primary source of protein (Government of Quebec 2008). As of 2014, Canadian consumption of fresh, canned and frozen seafood products averaged 8.18 kilograms per capita per annum (DFO 2015b).

As prices increase for export fisheries, the availability of seafood to communities adjacent to local fisheries can decline (Smith et al. 2010). Coastal communities stand to gain from successful fisheries recovery efforts because the continued availability of this food is tightly coupled with ecosystem health and fisheries sustainability. As such, coastal communities could be allies in fisheries recovery efforts.

Seafood is often promoted as a healthier choice than land-produced protein. With increased consumption, further pressure will be placed on wild fish stocks (Jenkins et al. 2009, Kearney 2010). This can also promote the growth of aquaculture (which continues to rely on wild fish and fish products for at least a portion of feed). In addition to seafood consumption, Canadians view our fisheries as having both social and cultural importance (O'Donnell et al. 2014).

2.3 Economic value of Canadian fisheries

2.3.1 Landed value

In contrast to the declining total volume of Canadian seafood, the overall landed value has increased (Figure 2.2). This discrepancy is primarily a result of the higher per unit value of crustaceans, compared to groundfish, as well as the exploitation of highly valuable new fisheries such as glass eels or elvers. To illustrate, lobster typically sells for $3.50-$4.00 per pound, while groundfish (including cod and haddock) ranges from $0.35-$1.00 per pound. In Newfoundland, overall volume declined by 8.7 per cent for all fisheries from 2013 to 2014, but value increased by 8 per cent. The volume of shrimp caught in Newfoundland declined 14.9 per cent from 2013 to 2014; however, values increased by 8.1 per cent (Newfoundland 2015). Similarly, the volume of snow crab caught in Newfoundland declined by 1.9 per cent from 2013 to 2014, while values increased 14.9 per cent (Newfoundland 2015).

Over three-quarters (77 per cent) of Canadian seafood value now comes from its invertebrate fisheries in the Atlantic (Table 2.2, Figure 2.3). Those for lobster, shrimp, crab and scallop are most valuable (Figure 2.3c). Greenland halibut (turbot), which is primarily fished in the Arctic, is Atlantic Canada's most valuable groundfish (Figure 2.3a), but it has only a small fraction of the value of the invertebrate fisheries. Herring dominates both the landings and value of pelagics in the Atlantic (Figure 2.3b).

On the West Coast, Pacific salmon fisheries are the highest-valued fisheries (Figure 2.3b). In comparison to the Atlantic region, the Pacific is much more balanced in terms of the value of its fisheries, with groundfish making up 30.5 per cent; small pelagics, large pelagics and other fish including salmon making up 34.7 per cent; and invertebrates making up 34.8 per cent of the region's total fisheries value (Table 2.2, Figure 2.3). Pacific invertebrate fisheries are a fraction of the value of Atlantic Canada's (Figure 2.3c).

Figure 2.2: Landed value and total volume of Canadian seafood between 1990-2015 Dollar value in $000s in dark blue and volume in metric tonnes in light blue (Source: DFO 2015a).

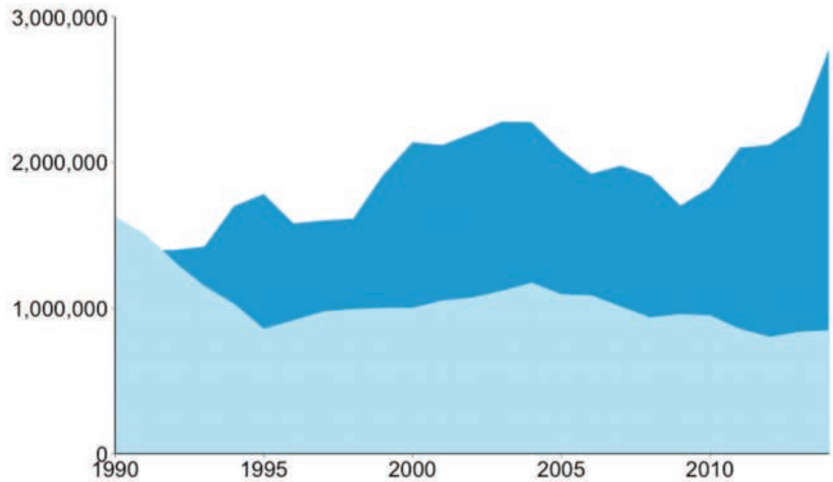


Table 2.2: Value of Canada's Atlantic (including Arctic) and Pacific fisheries in $000s as of 2014 (Source: DFO 2015a). The % Fishery columns show how much the regional fishery for each taxa contributes to the national fishery for that taxa (by weight). The % Total Fishery column shows how much the national fishery for each taxa contributes to the total national fishery (by weight).

	Atlantic ($000)	% Fishery	Pacific ($000)	% Fishery	Canada ($000)	% Total Fishery
Groundfish	182,988	61	119,285	39	302,273	10
Small and large pelagics, other	88,527	39	135,662	61	224,189	8
Invertebrates	2,236,080	94	135,595	6	2,371,674	82
Total fisheries value	**2,507,595**		**390,542**		**2,898,137**	

It should be noted that while this report focuses on Canada's commercial marine fisheries, the value of Canada's recreational fisheries (including inland and non-marine fish) exceeds that of commercial marine fisheries. Recreational fisheries expenditures and investments totalled $5.4 billion in 2013 (DFO 2015c, CESD 2013). Recreational fisheries data, including fishing mortality, are rarely included in fisheries stock assessments or management measures. This results in an underestimation of overall fishing effort on fish stocks that are caught in both commercial and recreational fisheries in Canada (Post et al. 2002). As much as 12 per cent of total catch in Canadian fisheries can be attributed to recreational fisheries (Cooke and Cowx 2004), and conservation measures must be implemented across both recreational and commercial fisheries, particularly for fish populations that are impacted by both sectors (Cooke and Cowx 2006).

Figure 2.3: Value of Canadian seafood in 2014 in $000s, by region (Atlantic Canada and Arctic in blue, British Columbia in green) and species group: a) groundfish, b) small and large pelagics, c) invertebrates (Source: DFO 2015a). Within each plot, all species with a value greater than $2,000,000 (fish) or $10,000,000 (invertebrates) (in the Atlantic and/or in British Columbia) are shown, along with the total for the species group. Note the different y-axis scales.

2.3.2 Seafood exports and imports

Approximately 85 per cent of the value of landed fish in Canada is exported to foreign markets (DFO 2015d). In 2014, 63 per cent of Canada's landed fish, by value, was destined for the United States, at a value of $3.1 billion. The increase in value of the U.S. dollar relative to the Canadian dollar in 2015 and 2016 has effectively increased the value of Canadian seafood by 25-30 per cent over the years when the dollars were on par. China and the European Union are also important export markets: in 2014 these regions accounted for $508 million and $459 million worth of exports respectively, and 19 per cent of total Canadian fish and seafood exports.

Canada exported $4.9 billion of fish and seafood products in 2014 (DFO 2015d), continuing a trend of increasing seafood export values (Figure 2.2). By species, Canada's largest exports are lobster, snow/queen crab, shrimp, and farmed salmon. In 2014, these species represented 63 per cent ($3.1 billion) of the total value and 46 per cent (262 thousand tonnes) of the total volume of fish and seafood exports. Lobster is Canada's most highly valued export species, with $1.5 billion of exports in 2014 and growing markets in China.

Despite the trend of increased seafood exports, Canada has dropped in the global rankings of major seafood exporters. As recently as 1987, Canada was the world's leading exporter; however, by 2012, it had dropped to seventh place (FAO 2014). The reason for this decline is two-fold. One is a result of a reduction in groundfish exports, due to the collapse of North Atlantic stocks in the 1990s from mismanagement and overfishing. The second is the increase in aquaculture production outside of Canada, notably from salmon and shrimp farming, which vaulted countries such as Norway, Thailand and Chile ahead of Canada in total exports. Exports continue to be the largest market for Canadian seafood.

Export rankings also do not reflect the sustainability of fisheries management. In Canada's case, the drop in rankings is partially a result of a failure to manage fish stocks sustainably as well as aquaculture growth in other countries, which proportionally increased their exports.

In statistics for Canada's overall export market, seafood exports are combined with agricultural exports: combined fisheries and agricultural products (including whole and processed products) were the fourth-largest Canadian export category, after vehicles and parts, energy and consumer goods in 2014 (Statistics Canada 2015). Fisheries alone represent only approximately 1 per cent of Canada's total exports (Statistics Canada 2015).

Proportionally, however, fisheries are in the top three exports of each Atlantic Canadian province — Nova Scotia (Nova Scotia 2015), Newfoundland (Newfoundland 2015), New Brunswick (New Brunswick 2013) and Prince Edward Island (Prince Edward Island 2014) — and are the seventh largest export from British Columbia (British Columbia 2014). Canada has a positive trade balance for fisheries, with a net $1.5 billion of exports over imports.

It is difficult to ascertain the amount of fish imported specifically for Canadian consumption, because seafood imports include seafood that is imported for processing and subsequently exported as a final product. Canada's top seafood import products include farmed shrimp, lobster, tuna, scallop and sockeye salmon (DFO 2015c).

2.4 Jobs and the economy

In 2013, the most recent year for which statistics are available, 78,938 people were employed by Canada's seafood industry: 45,904 in direct wild fisheries harvesting, including crew, and an additional 33,034 in processing and packaging for wild fisheries and aquaculture (DFO 2014a). There is some overlap in processing wild fisheries and aquaculture, so the latter employment numbers are not presented separately in national summary statistics. However, direct jobs in aquaculture operations are 6.4 per cent of jobs in direct wild fisheries in Canada.

Harvesting and processing of wild fisheries is the single-largest private-sector employer in Atlantic Canada. More men than women are employed in this sector. Although the proportion varies by region, men make up an average of 66 per cent of the sector's workforce. Of those employed in Canada's direct wild fisheries, 59 per cent are over the age of 40, suggesting that recruitment and succession planning for this sector is challenging (DFO 2006a). The Canadian Council of Professional Fish Harvesters (CCPFH) began a new study in 2014 to identify more recent statistics on the fisheries labour market; results are expected in 2016 (Rick Williams, Praxis Consulting).

How fisheries contribute to Canada's overall economic and labour force success can be further illustrated by reviewing the number of vessels currently in operation and the number of licences held in major fishing provinces.

As of 2013, there are 16,065 fishing licences in Atlantic Canada. Newfoundland has the highest percentage of licences held by independent fishers (i.e., a fisher who owns a vessel and fishes on it), at 84 per cent, with New Brunswick the lowest at 49 per cent (Table 2.3).

Table 2.3: Employment and licences in fishing provinces as of 2013 (Source: DFO 2014a).

Province	Total Employment in Fishing Industry	Total Licences	Licences Held by Independent / Core Fishers (% of total)
Newfoundland and Labrador	19,197	4,095	3,437 (84%)
Nova Scotia*	20,352	5,634	3,346 (60%)
Prince Edward Island	6,975	2,219	1,275 (59%)
New Brunswick*	14,917	2,852	1,372 (49%)
Quebec	4,644	1,265	995 (79%)
British Columbia	9,738	5,400	N/A

*Includes both Gulf Region and Scotia Fundy Region Management Areas

Pacific fisheries are considerably different than those in the Atlantic, primarily because there is not a similar policy framework with a goal of maintaining the independent inshore fleet. As a result, the number of fishing licences declined from more than 15,000 in the late 1980s to only 5,400 in 2013 (Table 2.3, DFO 2014a).

3. HOW WELL ARE CANADA'S FISHERIES BEING MANAGED?

3.1 The legal and policy framework for fisheries management

It is generally accepted that Canada's existing fisheries and oceans law and policy are not the most significant barrier to improved fisheries outcomes (Hutchings et al. 2012, Bailey et al. 2016). Rather, it is the long-standing lack of political will to implement these management tools that is largely responsible for inhibiting recovery of Canada's fisheries.

This section will outline the broad legal and policy framework for the protection and sustainability of Canada's fisheries and marine environment. We will review Canada's international commitments, through binding and soft-law instruments within Canadian waters and on the high seas. We will identify gaps in this framework, particularly regarding legally binding targets and timelines for rebuilding depleted fish populations. We will also explore how Canada's *Fisheries Act* lacks important aspects of modern fisheries management that are included in international fisheries law, as well as comparable legal frameworks to those of highly developed fishing nations (Hutchings 2012, Hutchings et al. 2016, WCEL 2016). We will then make recommendations for improving Canada's legal and policy framework to enable fisheries recovery.

3.1.1 National legal and policy framework for fisheries management

Canada's legislative framework for sustainably managing its fisheries and marine ecosystem includes the *Coastal Fisheries Protection Act* (1985), the *Fisheries Act* (1985, updated), the *Oceans Act* (1996), the *Species at Risk Act* (2002), and related policies (Table 3.1).

Of these Acts, the *Fisheries Act* is the most significant because it directly provides for the allocation and conservation of fisheries resources. The *Coastal Fisheries Protection Act* was developed primarily to provide a legal framework for managing Canada's extended territorial sea, following the establishment of the 200-mile limit in 1977. The *Oceans Act* is one of the more ambitious pieces of legislation in Canada, but it is also one of the least implemented (Vanderzwaag and Hutchings 2005). With respect to fisheries recovery, the *Oceans Act* does allow for the establishment of Marine Protected Areas (MPAs), which could aid in the recovery of depleted marine populations.

The *Species at Risk Act* (SARA) includes legal requirements for recovery of species that are threatened or endangered. However, these requirements only apply once a species is officially listed under the Act upon recommendation of the Minister of Environment and Climate Change. In the case of aquatic species, including marine fish, the Minister of Fisheries, Oceans and the Canadian Coast Guard makes the recommendation to the Minister of Environment and Climate Change. However, the application of SARA to marine species, particularly those that are commercially fished, is inadequate (Mooers et al. 2007, Findlay et al. 2009, Hutchings and Festa-Bianchet 2009, Schultz et al. 2013).

Fisheries Act

The *Fisheries Act* was established to manage fisheries as a public resource, protect fish from human impacts other than fishing, and provide a way to allocate fisheries resources. The Act has long been considered one of the country's most important environmental acts, particularly for freshwater ecosystems, with a long history of case law around habitat protection for impacts on fish and fish habitat (Hutchings and Post 2013).

Table 3.1: National and international legal and policy instruments in place for fisheries recovery in Canada

National Legal Instruments	Policy Instruments
Fisheries Act (1985)	Aboriginal Fisheries Strategy (1992) Atlantic Fisheries Policy Review – A Framework for the Management of Fisheries on Canada's Atlantic Coast (1995) Canadian Code of Conduct for Responsible Fishing Operations (1998) New Emerging Fisheries Policy (2001, revised 2008) Integrated Aboriginal Policy Framework (2005) Canada's Policy for Conservation of Wild Pacific Salmon (2005) Sustainable Fisheries Framework Policy Suite: A Fishery Decision-Making Framework Incorporating the Precautionary Approach (April 2009) Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas (April 2009) Policy on New Fisheries for Forage Species (April 2009) Guidance for the Development of Rebuilding Plans under the Precautionary Approach Framework: Growing Stocks out of the Critical Zone (April 2013) Ecological Risk Assessment Framework (ERAF) for Coldwater Corals and Sponge Dominated Communities (April 2013) Policy on Managing Bycatch (April 2013) Guidance on Implementation of the Policy on Managing Bycatch (April 2013)
Coastal Fisheries Protection Act (1985)	
Oceans Act (1996)	
Species at Risk Act (2002)	

International Legal Instruments	Policy Instruments
Convention on Biological Diversity (1993)	Aichi Target 6,11,12 (2011)
United Nations Fish Stocks Agreement (2002)	

Despite its importance – particularly for Canada's coastal provinces – the *Fisheries Act* does not have a stated purpose. Nor has it been updated to include modern management principles such as the precautionary or ecosystem-based fisheries management approaches or science-based, transparent decision-making (Hutchings et al. 2016). Efforts to address these deficiencies have been problematic and unsuccessful in the past. Proposed amendments to Bills C-36 and C-45 attempted to include modern principles of fisheries management, but both bills ended up dying on the order bill in 2006 and 2008, respectively.

In 2012, the federal government was successful in negatively altering the *Fisheries Act* through a budget omnibus bill, demonstrating that when there is political will, the *Fisheries Act* can be amended in short order. The 2012 amendments significantly reduced protections for fish habitat, outlined in Section 35 of the *Fisheries Act* (Hutchings and Post 2013).

The changes came into force in November 2013 (DFO 2013a), effectively reducing the number of species eligible for habitat protection by narrowing the focus of these provisions to only those species that are subject to, or that are deemed to support, commercial, recreational, and aboriginal fisheries. Fish species are now categorized into those that are valued (i.e., fishery-related) and those that are not. This approach would seem to fail to account for a species' inherent value, ecosystem services, future potential use, and ecosystem support from non-targeted species (i.e., prey) (Hutchings and Post 2013); it is yet to be tested in Canadian court.

The *Fisheries Act* does allow for fisheries closures that can be enacted to protect various life history stages of fish (e.g., spawning closures) or marine ecosystem components (e.g., sponge and coral closures). Such closures could be instrumental in fisheries recovery, especially since Canada still has very few MPAs. They have proven useful in other countries. On the U.S. side of the Gulf of Maine, for example, large areas were closed to all fishing gear in 1994, and re-opened to scallop fishing in 1999. The benefits to stock recovery, particularly for scallops, were very clear (Murawski et al. 2000, Myers et al. 2000, National Fisheries Conservation Centre 2011).

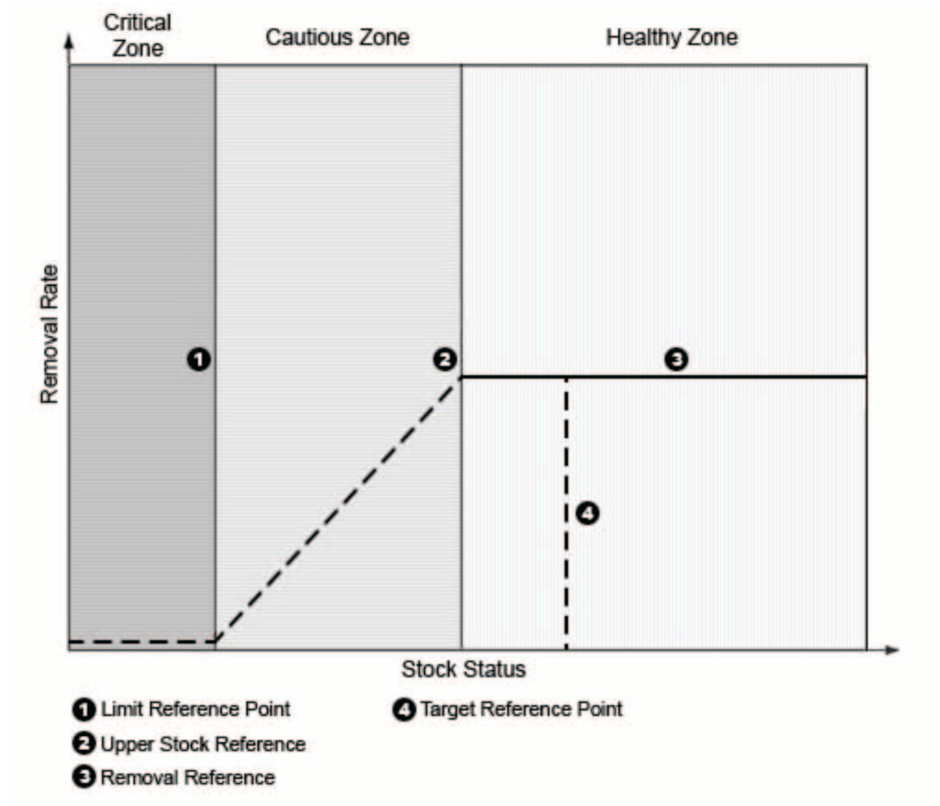
Recently, new international best practices and standards in fisheries management have been adopted through international soft law such as the United Nations General Assembly Sustainable Fisheries Resolution, International Programmes of Action on Illegal, Unregulated and Unreported Fishing (IUU), Sharks, Seabirds and fisheries technical guidelines articulated by the United Nations' Food and Agriculture Organization (FAO). Canada has attempted to stay current by building a soft law Sustainable Fisheries Framework (SFF). Aspects of this framework, which have been adopted since 2009 (Table 3.1), provide important policy direction on the precautionary approach, bycatch, managing impacts of fisheries on sensitive benthic areas, and new forage fisheries.

Canada has also updated its Integrated Fisheries Management Plan (IFMP) template, which guides conservation and sustainable use for marine resources (DFO 2010a), to include elements of the Sustainable Fisheries Framework policy suite. DFO has also provided guidance in Integrated Fisheries Management Plan development, to direct fisheries managers in establishing management actions for specific fisheries (DFO 2013b).

The most important aspects of the Sustainable Fisheries Framework policy suite from the perspective of stock rebuilding and recovery are the Precautionary Approach Framework and associated Guidance for the Development of Rebuilding Plans (Table 3.1). Unlike the United States, Canada does not use "overfished" and "overfishing" as formal designations to refer to depleted populations and excessive fishing mortality. Instead, the Precautionary Approach Framework identifies critical, cautious and healthy zones for individual fish populations, as determined by specific reference points (Figure 3.1). Based on these designations, stocks are then meant to be matched with appropriate management measures. This includes establishing reference points and harvest control rules, which are particularly important for rebuilding populations that are in the "critical zone." Canada also refers to stocks as at or above the limit reference point (LRP) or upper stock reference point (USR) (DFO 2009a, Figure 3.1).

The Precautionary Approach Framework serves to bring Canadian policy in line with the United Nations Fish Stocks Agreement (UNFSA) relating to sustainable development of fisheries resources (Shelton and Sinclair 2008). As of 2016, however, there has only been one rebuilding plan approved under the Sustainable Fisheries Framework: the Conservation Plan and Rebuilding Strategy (CPRS) for 3Ps cod in Newfoundland. Despite the ministerial approval of this plan in 2014, DFO has stated that the plan cannot be measured or quantified in terms of its potential success (DFO 2012a). The value of these frameworks – which will depend upon the degree to which they are implemented and adhered to with clear targets and timelines – remains to be seen.

Figure 3.1: DFO's Precautionary Approach Framework establishes critical, cautious and healthy zones, determined by the Limit Reference Point (LRP), Upper Stock Reference Point (USR), Removal Reference Point (F) and Target Reference Point (TRP) (Source: DFO 2009a).



Coastal Fisheries Protection Act

The *Coastal Fisheries Protection Act* primarily pertains to managing fish stocks that were fished by foreign fishing vessels prior to the establishment of the national 200-mile fishing jurisdictional limit. The Act clearly identifies that the stocks on the Newfoundland Grand Banks are a renewable world food source that have provided a livelihood for fishers for centuries (Section 5.1.a) and also recognizes that the stocks are threatened with extinction (Section 5.1.b) (Government of Canada 1985). Interestingly, the stated purpose of the Act is "to enable Canada to take urgent action necessary to prevent further destruction of those stocks and to permit their rebuilding" (Section 5.2). The *Coastal Fisheries Protection Act* is, however, rarely used as a basis for establishing management measures for depleted stocks. Moreover, given that this act recognizes extinction risk, its ability to incent improved management measures and be linked to the *Species at Risk Act* may be underutilized.

Oceans Act

The *Oceans Act* effectively enshrines the concept of sustainable development and the precautionary approach into Canadian law. The most relevant aspects of the *Oceans Act* to fisheries recovery are Sections 25, 30 and 35, which outline respectively: the goals for establishment of MPAs, principles for oceans management, and the basis for an oceans management strategy. Section 25 (a-e) clearly outlines the goals of protecting areas within the Exclusive Economic Zone (EEZ) from human activity. This protection includes conservation and protection of commercial and non-commercial resources and their habitats, endangered or threatened marine species and their habitats, unique habitats, areas of high biodiversity value or productivity, and any other resource or habitat as determined by the Minister. Section 30a-c includes the principles of sustainable development (meeting the needs of the present generation without comprising the ability of future generations to do the same), integrated management of marine activities and the precautionary approach, all of which are critical to the recovery of fisheries resources.

All three sections of the Act could be invoked for the recovery of depleted marine fish populations. However, they are rarely leveraged as part of the fisheries management process. Additionally, there is significant pressure from the fishing industry to ensure that Canadian MPAs allow for fishing within the MPA boundary. As of 2016, only 1.3 per cent of Canada's oceans are protected through MPAs, and few of them are no take, meaning that fishing and other extractive activities can continue within the MPA (CPAWS 2015). Consequently, in their 2015 report, CPAWS charged that there remains little difference between the activities that take place inside and outside of Canada's MPAs.

Species at Risk Act

Canada's *Species at Risk Act* (SARA) has been in force since 2003 and provides legal protection for species considered at risk of extinction. The status of a species is first determined by the Committee on Endangered Wildlife in Canada (COSEWIC), which conducts independent wildlife assessments, thus providing the scientific basis for a recommendation for listing under SARA. Following assessment, the government has three choices: to list the species on SARA, to not list the species on SARA, or to return the assessment to COSEWIC for reconsideration based on scientific information. By not returning the assessment, the government has implicitly accepted the scientific assessment.

If a species is listed as threatened or endangered under SARA, there is a legal requirement to develop a recovery strategy and action plan, with the goal of reducing threats and improving population status (McDevitt-Irwin et al. 2015). Those species listed as special concern require a management plan.

Implementation of SARA has not been effective for marine fish because they tend to not be listed due to socio-economic reasons (Schultz et al. 2013). Since SARA was established, only 12 species of marine or anadromous fish have been listed, five on the Atlantic coast and seven on the Pacific coast (Table 3.2). Only one of the fish species listed was previously targeted as a commercial species (Atlantic salmon), while the others have been, and continue to be, caught as bycatch in commercial fisheries. Fishing remains the greatest threat to the recovery of these species. To date, not a single recovery action plan has been developed for Canada's SARA-listed marine or anadromous fish species (McDevitt-Irwin et al. 2015).

As of 2016, 28 marine fish species (comprised of multiple populations in some cases) have been assessed by COSEWIC as endangered, threatened, or special concern but not listed under SARA (Tables 3.3, 3.4). These species either have been denied SARA listing (e.g., Atlantic cod in 2006) or still remain in the listing process without a decision (it has been a decade since shortfin mako shark was assessed by COSEWIC and it still has not received a SARA listing decision). Seventeen of these species are on Canada's Atlantic coast (Table 3.3), including gadoids, sharks and skates, and 11 are on the Pacific coast (Table 3.4), including rockfish, elasmobranchs and salmon.

To address the tendency to not list marine fish under SARA, DFO adopted a Default Listing Policy in 2014, whereby the default decision should be to list marine species under SARA unless there is a compelling reason not to do so (DFO 2014b). In this case, DFO must develop a work plan to identify a clear path and specific actions to achieve population recovery (DFO 2014b). The usefulness of this policy has, however, not been tested because no decisions about listing marine species under SARA have been made since 2013.

Table 3.2: Fish species listed under SARA as of March 2016

(SC=Special Concern, TR=Threatened, EN= Endangered) (Source: SARA 2016). Taxonomic codes: G=Groundfish, O=Other, R=Redfish/rockfish, SS=Sharks and skates

Common Name	Scientific Name	Population	Taxa	Status	Year Listed
Atlantic wolfish	*Anarhichas lupus*	Atlantic	G	SC	2002
Northern wolfish	*Anarhichas denticulatus*	Atlantic	G	TR	2002
Spotted wolfish	*Anarhichas minor*	Atlantic	G	TR	2002
Longspine thornyhead	*Sebastolobus altivelis*	Pacific	R	SC	2009
Rougheye rockfish Type I	*Sebastes sp. Type I*	Pacific	R	SC	2009
Rougheye rockfish Type II	*Sebastes sp. Type II*	Pacific	R	TR	2009
Yelloweye rockfish	*Sebastes ruberrimus*	Pacific outside and inside waters populations	R	SC	2011
Basking shark	*Cetorhinus maximus*	Pacific	SS	EN	2010
Bluntnose sixgill shark	*Hexanchus griseus*	Pacific	SS	SC	2009
Tope shark	*Galeorhinus galeus*	Pacific	SS	SC	2009
White shark	*Carcharodon carcharias*	Atlantic	SS	EN	2006
Atlantic salmon*	*Salmon salar*	Inner Bay of Fundy	O	EN	2012

*Note: Salmon are not included in this report.

Table 3.3: Atlantic fish species assessed by COSEWIC but not listed under SARA as of March 2016
(SC=Special Concern, TR=Threatened, EN=Endangered, DD=Data Deficient) (Source: COSEWIC 2016). Taxonomic codes: F=Flatfish, G=Groundfish, R=Redfish/rockfish, SS=Sharks and skates, TS=Tuna and swordfish. Year denotes the year of the most recent COSEWIC assessment.

Common Name	Scientific Name	Population	Taxa	COSEWIC Status	Year Assessed
American plaice	*Hippoglossoides platessoides*	Maritime population, Newfoundland and Labrador population, Arctic population	F	TR, TR, DD	2009
Atlantic cod	*Gadus morhua*	Newfoundland and Labrador population, Laurentian North	G	EN	2010 (Denied listing 2006)
Cusk	*Brosme brosme*	Atlantic	G	EN	2014 (Denied listing 2013)
Roughhead grenadier	*Macrourus berglax*	Atlantic Ocean	G	SC	2007
Roundnose grenadier	*Coryphaenoides rupestris*	Arctic Ocean, Atlantic Ocean	G	EN	2008
White hake	*Urophycis tenuis*	Atlantic, Northern and Southern Gulf of St. Lawrence	G	EN, SC	2013
Acadian redfish	*Sebastes faciatus*	Atlantic population, Bonne Bay population	R	TR, SC	2010
Deepwater redfish	*Sebastes mentella*	Laurentian Channel population, Northern population	R	EN, TR	2010
Basking shark	*Cetorhinus maximus*	Atlantic	SS	SC	2009
Blue shark	*Prionace glauca*	Atlantic, Pacific population	SS	SC, DD	2006
Porbeagle shark	*Lamna nasus*	Atlantic	SS	EN	2014 (Denied listing 2006)
Shortfin mako	*Isurus oxyrhinchus*	Atlantic population	SS	TR	2006
Smooth skate	*Malacoraja senta*	Laurentian-Scotian, Funk Island Deep, Hope Dale Channel, Nose of Grand Bank	SS	SC, EN, DD, DD	2012
Spiny dogfish	*Squalus acanthias*	Atlantic	SS	SC	2011
Thorny skate	*Amblyraja radiata*	Atlantic	SS	SC	2012
Winter skate	*Leucoraja ocellata*	Southern Gulf of St. Lawrence, Eastern Scotian Shelf, Georges Bank-Western Scotian Shelf-Bay of Fundy	SS	EN, TR, SC	2015
Atlantic bluefin tuna	*Thunnus thynnus*	Atlantic population	TS	EN	2011

Table 3.4: Pacific fish species assessed by COSEWIC but not listed under SARA as of March 2016
(SC=Special Concern, TR=Threatened, EN=Endangered) (Source: COSEWIC 2016). Taxonomic codes: FF=Forage fish, O=Other, R=Redfish/rockfish, SS=Sharks and skates. Year denotes the year of the most recent COSEWIC assessment.

Common Name	Scientific Name	Population	Taxa	COSEWIC Status	Year Assessed
Eulachon	*Thaleichthys pacificus*	Fraser River, Central Pacific Coast, Nass/Skeena Rivers	FF	EN, EN, SC	2011, 2013 (Nass/Skeena)
Bocaccio	*Sebastes paucispinis*	Pacific	R	EN	2013 (Denied listing 2011)
Canary rockfish	*Sebastes pinniger*	Pacific	R	TR	2007 (Denied listing 2011)
Darkblotched rockfish	*Sebastes crameri*	Pacific	R	SC	2009
Quillback rockfish	*Sebastes maliger*	Pacific	R	TR	2009
Yellowmouth rockfish	*Sebastes reedi*	Pacific	R	TR	2010
North Pacific spiny dogfish	*Squalus suckleyi*	Pacific	SS SS	SC	2011
Tope shark	*Galeorhinus galeus*	Pacific	SS	SC	2009
Chinook salmon*	*Oncorhynchus tshawytscha*	Okanagan	O	TR	2006
Coho salmon*	*Oncorhynchus kisutch*	Interior Fraser	O	EN	2002
Sockeye salmon*	*Oncorhynchus nerka*	Sakinaw, Cultus	O	EN	2003

*Note: Salmon are not included in this report.

First Nations fisheries management agreements

Primarily as a result of case law, precedents have been set for First Nations to have access to fisheries for food, ceremonial and social purposes and to take part in commercial fisheries (R. *v*. Sparrow 1990, R. *v*. Marshall, 1999). This directly resulted in the development of the Aboriginal Fisheries Strategy (AFS) in 1992 (Table 3.1), which established a policy basis for co-management agreements for fisheries in British Columbia (DFO 2003). From this, the Atlantic Integrated Commercial Fisheries Initiative (AICFI) was developed to provide Mi'kmaq and Maliseet First Nations in Atlantic Canada with a means to develop governance and management skills and capacity for commercial fisheries operations (DFO 2007a, Box 3.1).

On the West Coast, the Pacific Integrated Commercial Fisheries Initiative (PICFI) served to create an effective framework for First Nations fisheries co-management, as well as to establish an effective voice in fisheries co-management (Box 3.1).

The 2015 Mandate Letter from Prime Minister Trudeau to the Minister of Fisheries, Oceans, and the Canadian Coast Guard includes, as for all ministers, a commitment to a renewed nation-to-nation relationship between the federal government and Canada's First Nations and Inuit (Trudeau 2015). Because of the importance of fishing resources for food and trade in First Nations communities, recovery of depleted fish stocks will require a shared interest and a commitment to similar outcomes among DFO, non-First Nations fisheries and First Nations and Inuit peoples.

Box 3.1: Aboriginal Fisheries Policy Objectives and Principles in Canada

The Atlantic Integrated Commercial Fisheries Initiative (AICFI) identifies objectives for Aboriginal fisheries and states that First Nations will:

- Better use their existing access and enhance economic returns for the benefit of their communities;
- Increase their knowledge and skills required to manage their fisheries enterprises;
- Have the training to fish safely and effectively operate their vessels; and
- Help build the capacity needed to meet their future requirements for commercial fisheries operations, co-management and training independently.

The Pacific Integrated Commercial Fisheries Initiative (PICFI) Principles for Co-Management include:

- Shared Responsibility: All fishery groups (First Nations, commercial, recreational, environmental) and government bring their knowledge and expertise to the table to seek mutually beneficial outcomes.
- Accountability: Representatives in multi-lateral processes must be accountable to their constituents and lend their support to agreed outcomes.
- Inclusiveness: Groups with a direct interest in the fisheries resource should have an opportunity to contribute to decision-making processes.
- Transparency: Co-management participants must clearly identify their fishery interests and work to develop a foundation of mutual trust and respect.

Source: DFO 2007a, DFO 2008a

3.1.2 Canada's international commitments to sustainable fisheries

In addition to national governance mechanisms, Canada also has contributed to the development of, and is a signatory or party to, several international agreements on sustainable fisheries and biodiversity conservation (Table 3.1). Evolving paradigms in fisheries science and management include stock assessment modelling, the application of the precautionary approach and related reference points, harvest control rules and the ecosystem approach, all of which are critical to scientific advice and management decisions that can lead to fisheries recovery.

United Nations Fish Stocks Agreement

Canada was instrumental in calling for and negotiating the *United Nations Fish Stocks Agreement* (UNFSA), following a call for a governance regime to manage high-seas fisheries after the 1992 Earth Summit in Rio and in response to conflicts with foreign fishing fleets (de Fontaubert 1995). UNFSA established important fisheries management principles in law, including the ecosystem approach (Article 5), the precautionary approach (Article 6) and transparency (Article 12), as well as the term Maximum Sustainable Yield (MSY) and related reference points (Annex II), all of which have served to influence Canadian fisheries law and policy. UNFSA also requires using compatible management measures for stocks that straddle jurisdictional boundaries between national and international waters (Article 7). As countries collaborate on managing high-seas fisheries for these "straddling stocks" and highly migratory stocks through Regional Fisheries Management Organizations (RFMOs), there has been uptake of the precautionary approach, ecosystem approach and establishment of MSY-based reference points for the majority of targeted fish stocks (Meltzer and Fuller 2009). International fisheries management is certainly not perfect, but implementation of UNFSA by all signatories to the agreement is reviewed every five years at the United Nations, which helps to provide incentive for continuous improvement. Notably, Canada is a signatory to UNFSA and the next review of UNFSA, implementation will take place in June 2016.

Canada is also a contracting party and member of several RFMOs that manage straddling and highly migratory stocks adjacent to Canada's EEZ. These RFMOs include the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tuna (ICCAT), the North Atlantic Fisheries Organization (NAFO) and the North Pacific Fisheries Commission (NPFC). In some cases, stock assessments for fisheries taking place in Canadian waters are done through the scientific councils and committees of these RFMOs, particularly for ICCAT and NAFO. Thus, stock recovery in Canada can be influenced by decisions made internationally. North Atlantic swordfish is one example of this: a rebuilding plan for the stock was adopted at ICCAT in 1998 and came into force in 1999. It has been largely successful in rebuilding the stock, although the level to which it has been rebuilt remains significantly lower than its pre-exploitation biomass (Appendix A).

Convention on Biological Diversity

Canada is also a signatory to the Convention on Biological Diversity (CBD) and is therefore committed to meeting Aichi targets agreed upon in 2011 (CBD 2011). Specifically, Target 6 and Target 11 identify commitments to protect marine diversity, including fish stocks, through management and protected areas, while Target 12 links directly to the implementation of Canada's *Species at Risk Act*:

> **Target 6:** By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem-based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.
>
> **Target 11:** By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 12: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Canada's legal and policy framework for fisheries and oceans management should be able to deliver on the targets for 2020. Meeting these targets will, however, require a concerted effort to achieve conservation objectives for species protection and recovery with fisheries management decisions.

3.1.3 Gaps in Canada's legal and policy framework for fisheries management

As noted above, Canada's *Fisheries Act* has not been updated to be compatible with the United Nations Fish Stocks Agreement (UNFSA). Notably absent from the *Fisheries Act* is a legal requirement for targets and timelines for stock rebuilding, along with provisions to prevent overfishing or to react accordingly when overfishing is determined to be occurring. Clear management actions for stock rebuilding, following the identification of overfishing, have proven to be important in the United States, where they are included in the *Magnuson-Stevens Act* (see Box 3.2 for specific provisions relating to stock rebuilding).

Box 3.2 United States Magnuson-Stevens Act: Relevant provisions for stock rebuilding

Section 301: National Standards for Fishery Conservation and Management: Outlines national standards, including consistency with conservation and management measures that "shall prevent overfishing," while achieving optimum yield, and be based upon the best scientific advice.

Section 303: Contents of Fishery Management Plans: Subsection 1(A), further details the requirements of fisheries management plans to include conservation and management measures to prevent overfishing and rebuild overfished stocks, as well as protect, restore and promote the long-term health of the fishery. Subsection 10 requires specific objectives and measureable criteria to apply when the fishery is determined to be overfished, including measures to be put in place to prevent such overfishing and rebuild. Subsection 15 requires that the management plans establish a mechanism for specifying annual catch limits (including a multi-year plan), implementing regulations or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability.

Section 304: Action by the Secretary: With regards to rebuilding fisheries, Section (E) includes provisions for accountability with reports required to Congress (equivalent to the Canadian Parliament) on the status of fisheries that are overfished or approaching overfishing within two years. If a fishery is determined to be overfished, Section 304.2 requires action to be taken to end overfishing, with the Secretary (equivalent to Canada's Minister of Fisheries, Oceans and the Canadian Coast Guard) notifying the appropriate management Council (equivalent to DFO Regions) requesting that action be taken to end overfishing and that conservation and management measures be implemented to rebuild affected stocks. All such notices are to be made public, through publication in the Federal Register (equivalent to the Canadian Gazette). This action (subsection 304.3) must include, within two years, a management plan or plan amendment that will (a) end overfishing immediately and rebuild affected fish stocks or (b) prevent overfishing from occurring. Subsection 304.4 requires that the fisheries management plans specify a time period for rebuilding that shall be as short as possible, but taking into account the life history of overfished stocks and the needs of fishing communities, among other considerations, and not exceed 10 years.

Source: http://www.nmfs.noaa.gov/sfa/magact/

While the Sustainable Fisheries Framework has added some important new policy directives to Canadian fisheries management, there are clear gaps in fully incorporating clear policy direction on all aspects of modern fisheries management, including:

- **Catch monitoring:** DFO has recognised the need for clarity on catch monitoring and is in the process of compiling existing tools for catch monitoring that are being used in the various management regions for Canadian fisheries. Catch data are important for use in stock assessments, and the adoption of the Bycatch Policy has created a need for direction on what data are needed and how they might be collected. Although the Pacific Region has developed its own framework for fishery monitoring and catch reporting (DFO 2012b), there is no national policy framework. According to DFO, a catch monitoring policy is in development and is expected to be completed within two years, as of March 31, 2016 (Marc Clemens, DFO pers. comm.).

- **Ecosystem approach:** Canada has no overarching policy direction or guidance on implementing an ecosystem approach to fisheries management, even though it could be argued that the Bycatch, Sensitive Benthic Areas and New Forage Species Policies were all created with the intention of taking other elements of the ecosystem into account. Such a policy would be useful from a Canadian fisheries perspective given the importance of, and progress toward, this approach in other jurisdictions and the establishment of Food and Agriculture Organization (FAO) guidelines on the ecosystem approach to fisheries more than 10 years ago (FAO 2003).

  Such a policy could provide overall guidance on managing multi-species fisheries, take ecosystem considerations into account in decision-making and help to avoid creating rebuilding plans for fisheries that cannot exist sustainably and simultaneously, such as northern shrimp and northern cod (Worm and Myers 2003) or small pelagics and groundfish (Frank et al. 2005). This guidance could also incorporate aspects of fisheries that target forage species, particularly existing fisheries for forage species, which are not currently addressed in the Policy for New Fisheries for Forage Species. The omission of existing forage fisheries for herring, mackerel, capelin, shrimp and krill means that these fisheries continue to be managed by conventional methodologies rather than considering their ecosystem role when developing advice for fisheries allocations.

- **Recovery of depleted species:** There are also gaps in the Sustainable Fisheries Framework for the protection of depleted species, in particular those COSEWIC-assessed species that have yet to be listed, and legally protected, under SARA. The "Guidance on Development of Rebuilding Plans" (DFO 2013c) does not specifically refer to marine fish species that are also assessed by COSEWIC. Marine fish species tend to spend three to five years waiting for a listing decision after being assessed and then are generally denied listing under SARA for socio-economic reasons (Schultz et al. 2013, McDevitt-Irwin et al. 2015). When denied listing, *Fisheries Act* measures should then be used to rebuild the populations in question. However, the failure to include COSEWIC-assessed species in the Guidance on the Development of Rebuilding Plans means that there is no specific measure identified for non-listed species.

  The Policy for Managing Bycatch refers to species that are listed under SARA but makes no provisions for those species that have been assessed by COSEWIC and are either still awaiting a SARA listing decision or have been denied a SARA listing. This becomes problematic for achieving marine fish recovery, because there is no requirement that additional measures be implemented for species that are clearly in decline or have experienced severe declines. Given the number of marine fish species that have been assessed by COSEWIC that are either the target of or implicated as bycatch in Canadian fisheries, this omission makes it difficult to gain agreement on bycatch reduction measures for many species.

- **Implementation of management measures:** Integrated Fishery Management Plans are the ideal vehicle for unifying Canada's Sustainable Fisheries Framework policy suite; however there is little accountability regarding the implementation and relative success of these policies. McDevitt-Irwin et al. (2015) assessed the inclusion of the Precautionary Approach Framework, Bycatch Policy and Sensitive Benthic Areas Policy in Integrated Fisheries Management Plans with specific relevance to measures in place for marine fish species that have been assessed by COSEWIC but not listed under the *Species at Risk Act*. They found that 52 per cent of Integrated

Fisheries Management Plans in the Atlantic and 54 per cent of those in the Pacific contained measures under the Sustainable Fisheries Framework that could offer protection for threatened and endangered species (McDevitt-Irwin et al. 2015). Yet, McDevitt-Irwin et al.'s 2015 analysis did not evaluate the extent to which the policies were implemented (only if they had been included) or their efficacy. Thus, their numbers, low as they are, still present an overly optimistic portrayal of Canada's fisheries management.

The bias against listing marine fish species under SARA, and the recent establishment of the Default Listing Policy for marine fish, offers potential for cooperation between DFO fisheries management staff and Species at Risk staff aimed at recovering marine fish. However, a decision to not list has to be made in order to trigger the development of required work plans. A more proactive approach would be to begin to develop a recovery strategy as soon as a population is assessed by COSEWIC, rather than waiting for a SARA listing decision (McDevitt-Irwin et al. 2015).

- **Ministerial discretion:** Perhaps one of the most important aspects of the *Fisheries Act* relating to management decisions is the level of discretion that the Act allows the Minister. This discretion impacts most decisions related to implementing policy, setting fisheries quotas and determining allocations. As such, a commitment to science-based decision-making should be accompanied by a reduction in Ministerial discretion within the Act.

3.1.4 Recommendations to improve Canada's legal and policy framework and enable fisheries recovery

Canada's legal and policy framework needs to be modernized and aligned with international fisheries law and related laws in other developed fishing nations. The following six recommendations will facilitate and enable fisheries recovery and stock rebuilding in Canada:

1. Modernize the *Fisheries Act*. Canada's *Fisheries Act* should be amended to include principles of modern fisheries management, such as the precautionary and ecosystem approaches and science-based and transparent decision-making. The *Fisheries Act* should include a legal obligation to prevent overfishing and to rebuild fish stocks within clearly defined timelines and with pre-identified recovery targets (Hutchings et al. 2012, 2016).

2. Prioritize rebuilding depleted fish populations. In its current state, the *Fisheries Act* fails to protect and rebuild commercially exploited species that have been assigned a status by COSEWIC but not listed under SARA. To address that failure, any marine fish species assessed by COSEWIC as threatened or endangered should be immediately considered to be in the critical zone of the Precautionary Approach Framework, with associated management measures implemented as a matter of urgency.

3. Develop policy and guidance on the ecosystem approach as part of the Sustainable Fisheries Framework. DFO should make it a priority to ensure a policy on the application of the ecosystem approach is developed and applied to address impacts of the ecosystem on fisheries, including climate change, forage species and trophic interactions.

4. Increase the availability and accountability of Integrated Fisheries Management Plans. All IFMPs should be publicly available and should be updated annually to include progress towards implementation of DFO's Sustainable Fisheries Framework.

5. Include recovery of depleted species in spatial protection measures. Ensure that recovering depleted marine species, including those that are the subject of ongoing fisheries, is an objective of spatial protection initiatives (DFO 2011a), as MPAs are established in the lead-up to achieving the 2020 commitment to the *Convention on Biological Diversity* (CBD).

6. Develop a work plan with the goal of achieving Convention of Biological Diversity Aichi Target 6. Canada should assess its fisheries in terms of their level of achievement of the recommended milestones outlined by the CBD to achieve Target 6 of the Aichi Targets. Aichi Target 6 should be integrated into fisheries management plans, with annual reporting mechanisms established.

3.2 Additional mechanisms for fisheries science and management

Because DFO is simultaneously the science advisory body and the regulatory body for fisheries in Canada, advocating for recovery through science-based advice for management decisions is likely the most effective way to achieve better outcomes for Canadian fisheries. However, there is a suite of additional mechanisms that could influence management decisions, contribute to science advice and, in some cases, replace management solely by the Canadian government. These additional mechanisms include co-management agreements between fishing communities or entities and DFO, collaborative research networks and market-based approaches. Here, we briefly review each of these mechanisms within the Canadian context.

3.2.1 Co-management of fisheries

Advances in conservation-based practices, including stock recovery, can be achieved by engaging the fishing industry in proactive research, data-sharing and management decision-making. The concept of co-management arose primarily through a need to improve the success of fisheries management as stocks became depleted and new sources of knowledge, cooperation, compliance and enforcement were deemed necessary (Sen and Nielson 1996). The goal of co-management is that fishers and government take joint management responsibility. Success is based on the idea that if fishers and their community fully understand the state of the resource and the need for reduced fishing effort or conservation-based practices, then they will be more willing to comply with management measures and can also be involved in developing them.

Canada does not have a comprehensive listing of fisheries that are co-managed and does not appear to be tracking their outcomes, although academic research has been done in the past on specific fisheries including Atlantic herring in the Bay of Fundy (Lane and Stephenson 1998) and shrimp in British Columbia (Harbor et al. 1999). Co-management in Canada has been met with varying degrees of success, although defining success has largely been done from the perspective of social science indicators (Evans et al. 2011, Pinkerton 2011) rather than from the perspective of fisheries recovery. A global analysis of 130 co-managed fisheries found that the state of fisheries was positively correlated with community leadership, the existence of individual or community quotas and the existence of protected areas, with several other factors also contributing to fishery health (Gutiérrez et al. 2011).

Co-management in Canadian fisheries, either in partnership with fishing associations, specific quota holders or First Nations, has the potential to influence stock recovery. However, recovery needs to be a primary outcome of the co-management agreement and should be aligned with implementation of key aspects of the Sustainable Fisheries Framework.

3.2.2 Research partnerships and collaborations

Traditionally, DFO, Canadian Geological Service and Canadian Hydrographic Service have collected critical information needed for fisheries management, including conducting research surveys, collecting oceanographic data such as temperature and salinity, and undertaking long-term monitoring of important ecosystem components such as plankton and zooplankton. This collection of basic data has allowed for tracking of important trends in ecosystem health, climate change and relative stock abundance.

Publicly funded science has also examined basic marine ecological functions, ecosystem impacts of fishing and impacts of climate change on the marine environment. Cuts over the last decade to science capacity in Canada, as well as a move to more applied science funding through government research funds such as the Natural Sciences and Engineering Research Council (NSERC) and Natural Resources Canada (NRCAN), have reduced the capacity of government scientists to explore some of the more important aspects of ecosystem science (Treasury Board of Canada Secretariat 2016).

One of the outcomes of these funding cuts has been the development of collaborative research networks, which bring together government scientists and academics and, in some cases, the fishing industry as well as non-government organizations. In addition to collaborative research, there are also projects attempting to bring together social science and natural science in response to the complexities that are inherent in fisheries science and management decisions (Table 3.5).

The research networks covered in Table 3.5 are either just completing a round of funding or are in the first year or two of new funding, but it is likely that both the collaborative process and research emerging from this work will begin to impact fisheries science and management decisions in the years to come.

Table 3.5: Canadian research networks working to advance scientific and social science research relevant to achieving healthy fisheries

Research Network	Mandate	Partners
ArcticNET www.arcticnet.ulaval.ca Funded by NSERC	Study the impact of climate change and modernization in the coastal Canadian Arctic.	Network of Centres of Excellence of Canada: 150 natural, human health and social scientists with their partners from Inuit organizations, northern communities, federal and provincial agencies and the private sector; 1,000 graduate students, postdoctoral fellows, research associates, technicians and other specialists from 34 Canadian universities; and 20 federal and provincial agencies and departments collaborate with more than 150 partner organizations in 14 countries.
Canadian Fisheries Research Network (CFRN) http://www.cfrn-rcrp.ca Funded by NSERC 2010-2015	Focus on issues of direct relevance to the fishing industry, aimed at increasing knowledge that will enhance ecological sustainability, socio-economic viability and management of Canadian fisheries. The research objectives of the network are to: 1. Overcome information gaps for important commercial fisheries and improve the use of industry information in assessment and management; 2. Enhance ecological sustainability while achieving operational efficiency; and 3. Improve the basis for the ecosystem approach to fisheries management.	Collaboration of academic researchers, the fishing industry, and government researchers and managers from across Canada. Includes more than 30 academics from 15 universities working with representatives of DFO and fishing fleets from Canada's Atlantic, Pacific and freshwater fisheries. Industry-driven and built around projects that involve the active collaboration of each sector.
Canada Healthy Oceans Network (CHONe) http://chone.marinebiodiversity.ca/ Funded by NSERC 2008-2013, 2015-2020	Provide outcomes that are useful to the formation of conservation policy for Canadian oceans. This includes developing new tools, models and decision frameworks, as well as new discoveries and the delivery of advisory reports, presentations and other public awareness products.	150 researchers from DFO, seven government laboratories and 14 universities across Canada carrying out 35 collaborative research projects in three interrelated research themes: Marine biodiversity, population connectivity and ecosystem function in Atlantic, Pacific and the Arctic oceans from the intertidal to the deep ocean.
Fish-WIKS http://fishwiks.ca/ Funded by SSHRC 2012-2017	Identify the commonalities and differences in Indigenous knowledge systems across the Pacific, Arctic, Inland and Atlantic regions and in four distinct coastal communities in Canada (Tla-o-qui-aht, British Columbia; Repulse Bay, Nunavut; Nipissing, Ontario; and Eskasoni, Nova Scotia). Understand western and Indigenous knowledge systems and explore how the different processes by which knowledge is acquired, transmitted and used can be harnessed to enhance Canadian fisheries policy.	Assembly of First Nations, British Columbia First Nations Fisheries Council, Unama'ki Institute for Natural Resources and the Government of Nunavut and indigenous and non-indigenous scholars with complementary expertise in aboriginal scholarship and fisheries governance from Dalhousie University, University of Guelph, University of Toronto and Vancouver Island University.
OceanCanada http://oceancanada.org/ Funded by SSHRC, 2014-2020	Build resilient and sustainable oceans on all Canadian coasts and to support coastal communities as they respond to rapid and uncertain environmental changes; to take stock of what we know about Canada's three oceans, build scenarios for possible futures that await coastal-ocean regions and create a national dialogue and shared vision for Canada's oceans; and to synthesize social, cultural, economic and environmental knowledge about oceans and coasts nationally.	15 formal research partners, including universities from coast to coast, community organizations and DFO.
Too Big To Ignore http://toobigtoignore.net/ Funding from various partners, SSHRC in Canada 2011-present	Elevate the profile of small-scale fisheries, argue against their marginalization in national and international policies and develop research and governance capacity to address the challenges of global fisheries.	15 partners and 62 researchers from 27 countries, conducting activities around the world.

3.2.3 Market-based approaches in sustainable seafood

This past decade in Canada has seen significant growth in market-based approaches that provide an incentive for improved sustainability or use purchasing power to influence changes in fisheries. This can include eco-certifications, business commitments to sustainable seafood purchasing through corporate social and environmental sustainability efforts, and consumer-based programs that provide recommendations on sustainable seafood.

Programs such as Ocean Wise (www.oceanwise.ca), SeaChoice (www.seachoice.org), Sustainable Fisheries Partnerships (www.sustainablefish.org) and WWF (www.wwf.ca) all work with a retailer, restaurant, food service or supplier to provide information on the sustainability of seafood with the goal of increasing the volume of sustainable seafood purchased over time. This work builds on the market approaches taken in other commodities, including forestry products, palm oil and the emerging markets for carbon and greenhouse gas reduction commitments (www.supply-change.org) and expands on fisheries-based initiatives such as dolphin-free tuna, all of which are based on the principle that human consumption should not have to come at the cost of environmental destruction and biodiversity loss.

The Canadian fishing industry now views certification as important to accessing export markets, which has incentivized improved fisheries practices. As of March 2016, 40 Canadian fisheries have been certified under the Marine Stewardship Council (MSC), with six fisheries still in assessment (see Table 3.6). This represents approximately 80 per cent of Canadian fisheries by value (MSC 2015) and approximately 65 per cent of Canadian fisheries by volume (Govender et al. 2016).

The value of MSC in driving change on the water, improving practices and rebuilding fisheries has been questioned (Ward 2008, Christian et al. 2013 as examples), but there is some evidence that engaging fisheries in the certification process is beneficial and can achieve sustainability objectives (Martin et al. 2012). Within the Canadian context, a serious shortcoming of the MSC process is that it overlooks many at-risk species: species that have been assessed as at-risk by COSEWIC but not listed under SARA are not considered within their “Endangered-Threatened-Protected (ETP)” definition and hence do not receive conservation measures (McDevitt-Irwin et al. 2015). Given the propensity not to list marine fish under SARA, this is a serious loophole that MSC has exploited within Canada.

The vast majority of MSC certifications include conditions that have to be met at various milestones over a five-year period, so assessing change at the population level as a result of certification will take some time. Where certified fisheries are seen as depleted, there is an opportunity to track progress on meeting related conditions and ensure that fisheries are compliant with DFO’s Precautionary Approach Framework, that they have meaningful reference points and harvest control rules and that recovery is evident through the certification action plans.

3.3 Transparency in Canadian fisheries science and management

3.3.1 The lack of transparency

To achieve stock recovery and ensure management accountability, it is imperative that basic data on the state of Canada’s fisheries be made public and that information regarding management processes and decision-making is available and open to all stakeholders. The concept of transparency in fisheries management decisions is embedded in international law as part of the United Nations Fish Stock Agreement (Article 12), and Regional Fisheries Management Organizations have been reviewed on their actions to promote transparency (Clark et al. 2015). In Canada, there is no similar requirement that the government be transparent about decision-making regarding a shared public resource. However, the 2015 federal Mandate Letter to the Minister of Fisheries, Oceans and the Canadian Coast Guard does call for increased transparency and science-based decision-making (Trudeau 2015).

Table 3.6: Canadian fisheries certified by the Marine Stewardship Council as of March 2016 (Source: MSC 2016)

Fishery*	Year Certified
Atlantic	
Gulf of St. Lawrence shrimp	2008, recertified in 2014
Scotian Shelf northern prawn trawl	2008, recertified in 2014
Eastern Canada offshore lobster	2010, recertified in 2015
Eastern Canada offshore scallop	2010, recertified in 2015
Northwest Atlantic Canada harpoon swordfish	2010 (5th surveillance report Feb 2016)
Haddock	2010, recertified in 2016
Yellowtail flounder	2010, recertified in 2015
Canada northern and striped shrimp Area 1	2011
Canada northern and striped shrimp Area 2, 3, 4, 5, 6	2011
Canada northern and striped shrimp Area 7	2011
Clearwater Seafoods Grand Bank Arctic surfclam	2012
Gulf of St. Lawrence snow crab	2012
Scotian Shelf snow crab	2012
Northwest Atlantic Canada swordfish longline	2012
Atlantic Canada halibut	2013
FBSA Canada Full Bay scallop	2013
Iles-de-la Madeline lobster trap	2013
Newfoundland and Labrador snow crab	2013
Gulf of St. Lawrence fall herring gillnet	2014
NAFO division 4R Atlantic herring purse seine	2014
Prince Edward Island lobster trap	2014
Bay of Fundy-Scotian Shelf and Southern Gulf of St. Lawrence lobster trap	2015
Gaspesie lobster trap	2015
3Ps Atlantic cod	2016
Pacific	
Pacific halibut	2009, recertified in 2015
Whiting	2009
Albacore tuna	2010, recertified in 2015
British Columbia pink salmon	2011
British Columbia spiny dogfish	2011
British Columbia chum salmon	2013
British Columbia sockeye salmon	2013

*Note: Two inland Canadian fisheries (Waterdhen Lake walleye and Waterdhen Lake northern pike) also were certified in 2014. Salmon are not included in the stock assessment aspect of this report.

DFO has adopted transparency around proactive disclosure, access to information — generally through the federal government Access to Information Process (ATIP) — and corporate management and reporting (DFO 2016a). There is, however, no reference to the transparency of international fisheries management meetings and procedures called for by UNFSA. There are examples of DFO engaging openly with non-government organizations, but there is no provision for encouraging participation in fisheries management meetings.

It is important to note that between 2006 and 2015, DFO scientists, along with other government scientists, were not encouraged and in some cases not permitted to speak to the media or the public about their work and their scientific discoveries.

Data and information availability

DFO is often perceived to lack transparency in its data sharing. We encountered several challenges during data collection for this report, which pertain (in various cases) to a lack of transparency on the part of the federal government, a lack of organization in how data are presented on DFO websites, inaccessibility of data, or a lack of scientific capacity within DFO. The major challenges we faced were:

- **There is no publicly available comprehensive list of Canadian fisheries or fished stocks.** For example, Environment and Climate Change Canada (ECCC) recently published a report, *Canadian Environmental Sustainability Indicators: Status of Major Fish Stocks* (ECCC 2016), in which they assessed the status of 155 major fish stocks assessed up to the year 2014. While this is an admirable undertaking, the report is not transparent since it does not present the list of individual fish stocks assessed. Environment and Climate Change Canada was unwilling to make the list publicly available or to share it with us. Consequently, there is no way of knowing which stocks were included or the status of any individual stock and thus no way to directly compare their results with ours.

- **There is no central database from which fisheries data can be easily obtained.** Data may be accessed through specific requests to DFO scientists, and some data-sharing agreements exist between DFO and academic institutions. Information on stock status and recovery potential assessments generally exists: the Canadian Science Advisory Secretariat (CSAS) (DFO 2016b) maintains a website with all documents produced through the CSAS processes, but the reports are woefully late, often released more than a year after the data were used for management decisions. Missing from this information is an easily accessible overview of measures in place to achieve conservation objectives (e.g., limit and target references points, harvest control rules, current quota, bycatch measures, habitat protection measures, etc.).

- **There is no single public source of information for each Canadian fish stock.** Information for each stock is scattered across many different parts of the DFO website and relevant information is found in many different types of reports, each in its own location. Research Documents containing stock assessment data were not always called "assessments," making it difficult to ensure that all stock assessment data have been located. As a result of these limitations, it is difficult to ensure that all available information for a stock has been accessed.

- **Stock assessments are sometimes inaccessible, and Research Documents are not always being produced for new stock assessments.** Stock assessment data are held by the individual assessment authors and often no contact email for the primary authors was listed on the Research Document. On some occasions, the only contact information listed was for the central DFO advisory contact (csas-sccs@dfo-mpo.gc.ca), who then had to direct us to the individual authors. We also encountered variability in the ease of obtaining stock assessment data from the assessment authors. While some authors were happy to provide us with the requested data when asked, others required formal data requests to be processed, and a few either refused to provide the requested data or never responded. Additionally, we found several cases where the most recent stock assessment information was only presented in a short Science Advisory Report with no equivalent Research Document. This practice appears to have become increasingly frequent. Science Advisory Reports contained only summary figures and either no time series data or time series data for only a few of the most recent years. This increases the difficulty of determining the most recent stock assessment information.

- **There is a lack of transparency within stock assessment Research Documents.** Stock assessment results are often output only in figures, not tables, such that the exact numbers are unavailable. Reference points were often referred to in stock assessments without the actual value being reported. To illustrate, the 2013 assessment of 4VWX Atlantic Herring (Singh et al. 2014) refers to a lower limit reference point throughout the document and states that the limit was identified as "the 2005-2010 average acoustic survey biomass," but the actual value is never reported. Consequently, it is difficult to tell if management decisions are effective or if science advice is being followed. In some cases, stocks are now assessed in slightly different areas than they were in the past, because assessment areas have been either merged or renamed. This makes it difficult to determine how new areas align with previous assessment areas (e.g., Northern shrimp in the Western Assessment Zone, Eastern Assessment Zone/ SFA 2 and 3), especially when searching for assessments.

Transparency in management decisions

Information relating to fisheries decisions is not readily available. This is largely a result of DFO's history of not adhering to science advice and making management decisions based on competing priorities, as is the contentious nature of some fisheries management decisions. Importantly:

- **DFO management decisions are not all publicly available.** A DFO webpage with management decisions for stocks in Atlantic Canada, Quebec and the Arctic is available, listing species and decisions for some stocks by year (DFO 2015e). Of the species listed on the Management Decisions webpage, only 21 per cent had a management decision for 2015 posted for at least one stock. (In comparison, 25 per cent had a management decision for 2014, 29 per cent for 2013, 56 per cent for 2012, and 67 per cent for 2011.) At no point was there a corresponding webpage for Canada's Pacific stocks, and to our knowledge no management decisions for these stocks are publicly available.

  Because management advisory committees and related reports or meeting results are difficult to access, it is also difficult to track how and why fisheries management decisions are made. A recent case in point is the setting of the Atlantic mackerel quota in 2014-2015 at 8,000 tonnes when the scientific advice was to set the quota at 800 tonnes (DFO 2015f, Box 3.3).

  When decisions clearly go against scientific advice, it is very difficult to find the substantiated reasons for these decisions or information in fisheries management advisory bodies. For example, no information regarding management advisory councils is available online, and references to meetings or meeting minutes are found only on member association meeting websites. This is in stark contrast to the United States National Oceanic and Atmospheric Association (NOAA), which posts all management advisory councils on its website, as well as posting past and future meeting dates (NOAA 2015a).

- **The Minister has discretionary power.** Management decision-making processes for marine species can be circumvented by direct communication with the Minister's office or regional fisheries directors, largely as a result of discretionary powers of the Minister, inherent in the *Fisheries Act*.

Identifying barriers to transparency

In some cases, the lack of transparency in data availability and fisheries management decision-making can be attributed to passive non-transparency, where there may be no intention to obfuscate but no systems are in place to ensure that transparency occurs. There are also examples of active non-transparency, in which fisheries information is not made available and the only recourse is to use the ATIP process (Table 3.7). Improving transparency within DFO will require a substantive shift in culture as well as a commitment to specific initiatives and earmarking of resources.

3.3.2 Recommendations to improve transparency

Improve and enhance data availability

- DFO should produce a list of commercially fished Canadian fish and invertebrate stocks and make it easily accessible on their website, as per the Policy for Scientific Data (http://www.dfo-mpo.gc.ca/science/data-donnees/policy-politique-eng.htm).

Box 3.3: Atlantic mackerel: When science and management advice part ways

The total allowable catch (TAC) for the Northwest Atlantic Mackerel was set at 200,000 tonnes per year between 1987 and 2000. Between 2000 and 2006, mackerel landings increased by nearly 400 per cent due to an exceptional year-class in 1999 and a significant increase in fishing effort (DFO 2008b).

Low biomass estimates in the late 1990s and early 2000s led to the TACs being lowered in Canada to 150,000 tonnes per year between 2001 and 2009. In 2005, the U.S. proposed a TAC of more than 200,000 tonnes for the 2006–2008 period (note that the U.S. provides two numbers, the allowable or acceptable biological catch of 335,000 tonnes and a quota of 115,000 tonnes). The TAC was lowered to 80,000 tonnes following the 2009–2010 joint Canada-U.S. assessment and further lowered to 60,000 tonnes following the 2010 Canadian Advisory Committee meeting.

In 2012, scientific advice recognized that stock abundance would not increase in the short term and that the fishing mortality rate should be lowered over the next few years compared to that of 2011. Thus, recommended average catches in 2012 and 2013 were 9,000 tonnes (to match sustainable catch levels achieved from 1968 to 1992, DFO 2012c). However, following the 2012 Canadian Advisory Committee meeting, the TAC for subareas 3 and 4 was set at 36,000 tonnes to equal the U.S. TAC: four times the recommended limit.

In 2014, scientific advice for mackerel was that annual catches in 2014 and 2015 should not exceed 800 tonnes (DFO 2014c). ***Despite this, the mackerel TAC for 2014 was set at 8,000 tonnes, a reduction of 26,000 tonnes compared to 2013 but still more than 10 times the recommended quota (DFO 2015f).***

- DFO should organize their website such that all relevant information for a stock, including stock assessments, other scientific reports and management decisions, can be accessed in a single place, potentially as depicted below (Figure 3.2). Adopting a similar web-based information system, such as that of NOAA's FishWatch (http://www.fishwatch.gov), would ensure that the same data for each fishery is submitted and displayed in the same format for all fisheries across the country, perhaps using DFO's Sustainable Fisheries Checklist as the baseline for this information.

- Scientific capacity within DFO must be restored to the extent that scientists are able to produce Research Documents in a timely manner for new stock assessments. These Research Documents should be readily accessible to the public.

- Research Documents should clearly present the details of the stock assessments. Thus, each stock assessment Research Document should begin with a standardized output page that includes the most important assessment results (e.g., time series of catch and spawning stock biomass, as well as reference points and stock status in relation to reference points), akin to the stock assessment reports produced by the International Council for the Exploration of the Sea (ICES; www.ices.dk). Stock assessments should also clarify how new management areas relate to previously assessed areas.

- DFO data should be fully integrated into the Government of Canada's Open Data Pilot Project.

Table 3.7: Examples of passive and active non-transparency within DFO fisheries science (FS) and fisheries management (FM)

Passive non-transparency	Active non-transparency
Many documents, including Research Documents that support stock assessments, integrated fisheries management plans and conservation harvesting plans, are not available online because of translation requirements (FS, FM).	As the fishing industry assumes an increasing responsibility for data collection, data become less available and can be considered proprietary (FS).
Fisheries management advisory committee minutes are not publicly available (FM).	Posting of science reports can be influenced by political processes (FS).
The lack of an overall data-storage system and mechanism for information and data sharing results in non-transparency for data and information relating to fisheries stock assessments, management decisions and management actions (FS, FM).	The perception that data are owned by individual scientists, rather than by the Canadian public, is part of past culture and perhaps some existing culture, in some DFO regions (FS).
Stock Assessment Reports (SARs) are often written by committee and influenced by strong and vocal fishing industry players. In some cases the fishing industry defines reference points and develops harvest control rules. This is not clear in the final documents (FS).	Historically, a fear existed that making data publicly available will be used against DFO. While scientists are now permitted to speak openly, some fisheries managers have not had a culture of openness. This varies by DFO region (FS, FM).

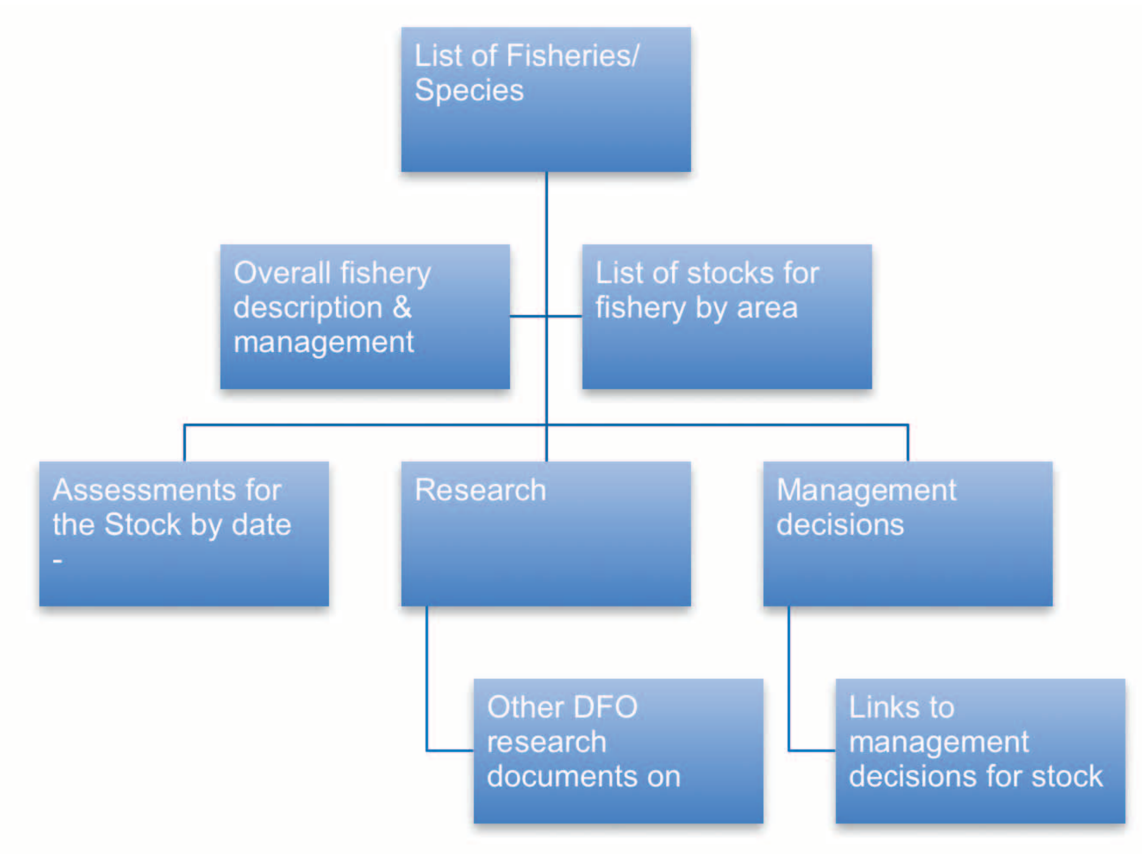
Ensure transparency in management processes and decisions

- DFO should publish a list of all management advisory committees, the dates and locations of meetings, and their post-meeting minutes.

- DFO should develop a national standardized reporting system for management decisions, similar to the CSAS website, and ensure that management decisions for all active fisheries are posted in a timely manner.

- DFO should publish all quotas for all fisheries in a clear and transparent manner and include them in the above-mentioned database or portal.

Figure 3.2: A flowchart depicting how information on Canadian fisheries, stock assessments and management decisions could be better presented for public information and access



Promote a culture of transparency

- DFO should ensure that the culture of open data permeates all government regions and all aspects of fisheries science and management.
- DFO should reinstate a vigorous peer review process of stock assessments, so that there is external input and oversight to science reports and processes.
- DFO should continue to support scientists publishing research in peer-reviewed journals and active engagement with public reporting of such research, including through traditional and social media.

4. WHAT IS THE STATUS OF CANADA'S FISH STOCKS?

The following analysis covers Canada's major active marine fisheries, as well as those species that have been designated as a conservation concern by COSEWIC. We review the availability and quality of stock status information for 165 Canadian marine fish and invertebrate stocks that are commercially harvested either as targets or bycatch. Note that this report does not encompass any of Canada's salmon stocks. Emerging Canadian fisheries, such as those for whelks, sea cucumbers and elvers, were excluded from this analysis primarily because there are no assessments available for these stocks.

Data from recent assessments were available for 125 managed stocks. Of these stocks, 82 are found on Canada's East Coast (n=28 species total) and 43 are on Canada's West Coast (n=18 species total) (Appendix B, Table B1). We first examine the frequency of stock assessments and types of data that are available for each of the 125 stocks. Next, we assess their status, including the state of their stock size and exploitation levels relative to reference points, where available (Appendix B, C). We then examine biomass and exploitation trends of these stocks together to assess the overall status of Canada's fisheries. We also note the status of each stock according to the DFO Precautionary Approach Framework (Figure 3.1), using information from each assessment, and we compare these designations to those from a recent government report on the status of Canada's fisheries (ECCC 2016). Finally, we provide an overview of the conservation status of Canadian stocks by denoting the COSEWIC and SARA status of each stock and noting which stocks have IFMPs.

4.1 Methods

To determine the overall state of Canada's fisheries, we first developed a list of marine fish and invertebrate stocks that are subject to targeted or incidental commercial fishing pressure within Canada and are managed. In total, this list consisted of 165 stocks. Herein, we assess the 125 stocks for which a recent stock assessment had been conducted within the past five years and at least some of the required data were available (Table B1).

The remaining 40 stocks did have stock assessments but were not included in our analyses, either because we were unable to obtain the required data (n=15), the data were deemed unreliable (n=5) or the stock assessments were outdated (n=20) (Table 4.1). For some species, including thorny and winter skate, there are COSEWIC assessments but no recent DFO stock assessments.

For each of the 125 stocks we analyzed, we reviewed their most recent stock assessment and compiled the relevant data following the protocol of the RAM Legacy Stock Assessment Database (RAM database; www.ramlegacy.org), the only open-access global compilation of stock assessments. We first examined if the 125 stocks were already present in the RAM database, and if so, the years for which data were available. We then searched the government's Canadian Science Advisory Secretariat (CSAS) website by each stock name for stock assessment Research Documents published since the last year available within the RAM database.

For 23 Canadian stocks, the data already present in the RAM database were from the most recent stock assessment. For the remaining 102 stocks (82 per cent), we provided updated stock assessment data or additions of new stocks to the database. This represented 76 per cent of all Atlantic stocks (n=62) and 93 per cent of all Pacific stocks (n=40). To do this, we reviewed new assessment documents and determined which data were available for entry. In cases where the information was presented in a figure, but not listed in tables, we contacted stock assessment report authors and lead scientists to request the time-series data (e.g., estimated total biomass or spawning stock biomass). We also searched the Canadian Science Advisory Secretariat's schedule to determine previous and upcoming assessment dates for all 125 stocks.

In addition, we searched the Canadian Science Advisory Secretariat's website by stock to determine if any Science Advisory Report (SARs) had been published since the most recent stock assessment Research Document (DFO 2016b). In some cases, these Science Advisory Reports referred to an updated stock assessment conducted for a stock for which there was no corresponding Research Document for the full assessment. This appears to have resulted from a lack of capacity within DFO to produce Research Documents following the completion of a new stock assessment, presumably as a result of the large budget and staff cuts to DFO over the past decade. In these cases, we emailed contacts listed on the Science Advisory Reports to request the data from figures presented in SARs.

For each stock, we also compiled the current COSEWIC and SARA designations, the year of the most recent recovery potential assessment (RPA) and information from the Integrated Fisheries Management Plans.

In the following analyses, we examine stocks by coast (Atlantic vs. Pacific) as well as by broad taxonomic groups (flatfish, forage fish, groundfish, invertebrates, redfish or rockfish, sharks and skates, and tuna and swordfish). Note that "groundfish" is not a taxonomic grouping: rather, it includes fishes from many different families that are unified by their use of benthic habitat.

Table 4.1: Managed and assessed Canadian marine fish and invertebrate stocks that were excluded from this analysis
Taxonomic codes: F=Flatfish, FF=Forage fish, G=Groundfish, I=Invertebrate, O=Other, R=Redfish/rockfish, SS=Sharks and skates. Reasons for not including stocks: (1) required data or related research documents were not available online or supplied by the stock assessment author; (2) stock assessment author(s) deemed the data to be unreliable; (3) no new stock assessment had been conducted in the past five years.

Species	Scientific name	Region	Taxa	Reason
ATLANTIC COAST				
Atlantic halibut	*Hippoglossus hippoglossus*	Gulf of St. Lawrence	F	1
Witch flounder	*Glyptocephalus cynoglossus*	Northern Newfoundland and Labrador	F	3
Capelin	*Mallotus villosus*	Newfoundland and Labrador	FF	1
Atlantic cod	*Gadus morhua*	Scotian Shelf	G	1
Atlantic wolffish	*Anarhichas lupus*	Atlantic Coast	G	2
Cusk	*Brosme brosme*	Maritimes	G	1
Haddock	*Melanogrammus aeglefinus*	Scotian Shelf	G	1
		St. Pierre Banks	G	3
Northern wolffish	*A. denticulatus*	Atlantic Coast	G	2
Spotted wolffish	*A. minor*	Atlantic Coast	G	2
Roughhead grenadier	*Macrourus berglax*	Atlantic Coast	G	3
Roundnose grenadier	*Coryphaenoides rupestris*	Atlantic Coast	G	3
White hake	*Urophycis tenuis*	Maritimes NAFO 4VWX5	G	1
Sea scallops	*Placopecten magellanicus*	Scallop Fishing Area 29	I	1
		Scallop Production Area 1-6	I	1
		Georges Bank	I	1

Species	Scientific name	Region	Taxa	Reason
		Browns Bank	I	1
Snow crab	*Chionoecetes opilio*	Scotian Shelf	I	1
Monkfish	*Lophius americanus*	Newfoundland and Labrador	O	3
Blue shark	*Prionace glauca*	Atlantic	SS	1
Basking shark	*Cetorhinus maximus*	Atlantic	SS	3
Shortfin mako	*Isurus oxyrinchus*	Atlantic	SS	3
Smooth skate	*Malacoraja senta*	Maritimes	SS	3
Thorny skate	*Amblyraja radiata*	Maritimes	SS	3
Winter skate	*Leucoraja ocellata*	Maritimes NAFO 4TVWX	SS	3
White shark	*Carcharodon carcharias*	Atlantic	SS	3
PACIFIC COAST				
English sole	*Parophrys vetulus*	West coast Vancouver Island and Queen Charlotte Sound	FF	3
		Hecate Strait	FF	3
Pacific herring	*Clupea pallasii*	Area 2W	FF	2
	Clupea pallasii	Area 27	FF	2
Sablefish	*Anoplopoma fimbria*	British Columbia	O	1
Darkblotched rockfish	*Sebastes crameri*	British Columbia	R	3
Lingcod	*Ophiodon elongatus*	Outside Strait of Georgia	R	3
Longspine thornyhead	*Sebastolobus altivelis*	British Columbia	R	3
Rougheye rockfish	*Sebastes aleutianus*	British Columbia	R	3
Shortspine thornyhead	*Sebastolobus alascanus*	British Columbia	R	1
Yellowmouth	*Sebastes reedi*	British Columbia	R	1
Basking shark	*Cetorhinus maximus*	British Columbia	SS	3
North Pacific spiny dogfish	*Squalus suckleyi*	Inside Strait of Georgia	SS	3
		Outside Strait of Georgia	SS	3

4.2 Results

4.2.1 Frequency of stock assessments

Assessments are rarely conducted on an annual basis for Canadian stocks, whether they are for Atlantic fish (Figure 4.1), Atlantic invertebrates (Figure 4.2) or Pacific species (Figure 4.3). A few marine fish stocks were assessed in 2015 and have assessments scheduled for 2016, including Atlantic halibut, Southern Gulf of St. Lawrence cod (COD4TVn) and herring (HERR4TFA and SP), but prior to 2015 they had not been assessed for the previous three to seven years (Figure 4.1). For the time period examined, only two of the 125 stocks, northern shrimp (PANDALSFA2-3; Figure 4.2) and Pacific hake (PHAKEPCOAST; Figure 4.3), have had stock assessments conducted (or planned) for three consecutive years.

Federal budget cuts to DFO over the past decade (Treasury Board of Canada 2016) eroded the department's capacity to conduct annual stock assessments for stocks on Canada's Atlantic or Pacific coasts. In Atlantic Canada, the result is a gap of up to five years in stock assessment information and data for some stocks, including for the three Acadian redfish and two deepwater redfish stocks (Figure 4.1). Many other stocks have gaps of three to four years between assessments, including most northern shrimp and snow crab stocks (which are scheduled to be assessed this year after their last assessments in 2013; Figure 4.2). On Canada's West Coast, assessment frequency was varied and patchy across species. Three stocks have had new assessments conducted and Research Documents produced in 2016 (Pacific hake and two rock sole species) (Figure 4.3). Ten stocks, including big skate, longnose skate and Pacific cod stocks, had new assessments and Research Documents produced in 2015 (Figure 4.3). Additionally, although stock assessments were conducted in 2015 for eulachon, herring, lingcod and yelloweye rockfish stocks, Research Documents were not produced for any of these assessments. Rather, only summary Science Advisory Reports were produced (Figure 4.3). The eulachon, herring and yelloweye rockfish stocks had previously been assessed in either 2011 or 2012 (Figure 4.3). However, lingcod and many other Pacific stocks have not had assessments with accompanying Research Documents published since 2010 or before (Figure 4.3).

Several stocks are assessed by management bodies other than DFO, including swordfish by ICCAT (Figure 4.1) and Pacific halibut by IPHC (Figure 4.3). Consequently, scheduling these assessments is beyond DFO's control and subject to the constraints of those organizations. In the Northwest Atlantic, for example, the NAFO Scientific Council conducts assessment for straddling stocks. While Canada is very involved in these assessments, they are requested by the NAFO Fisheries Commission, with input from contracting parties.

With respect to future assessments, we note that the year of the next planned assessment was only available for 18 of 54 Atlantic fish stocks (Figure 4.1) and 11 of 28 Atlantic invertebrate stocks (Figure 4.2). Only one out of 43 stocks on the West Coast, Pacific hake, had a published date for its next assessment (2017).

The infrequency with which assessments are conducted and the recent trend of Research Documents not being produced to describe those that have been conducted should be regarded as significant impediments to sound fisheries management and fisheries recovery in Canada.

Temporal gaps in knowledge about the state of stocks, ranging in many cases between three to five years, inhibit scientists' and managers' ability to respond quickly to population declines, one of the critical elements of successful fisheries recovery (Neubauer et al. 2013). These knowledge gaps also present problems for Marine Stewardship Council (MSC) audits and are problematic in light of climate change, which will demand responsive and adaptive action.

Figure 4.1: Assessment frequency of each of the Atlantic marine fish stocks.

Points note the year of the most recent stock assessment Research Document (pink), the year of the most recent stock assessment summary (Science Advisory Document; green), the year of the previous stock assessment Research Document (purple) and the year of the next planned stock assessment, if available (blue). Stocks are denoted and ordered on the y-axis by their stock code (as in Table B1).

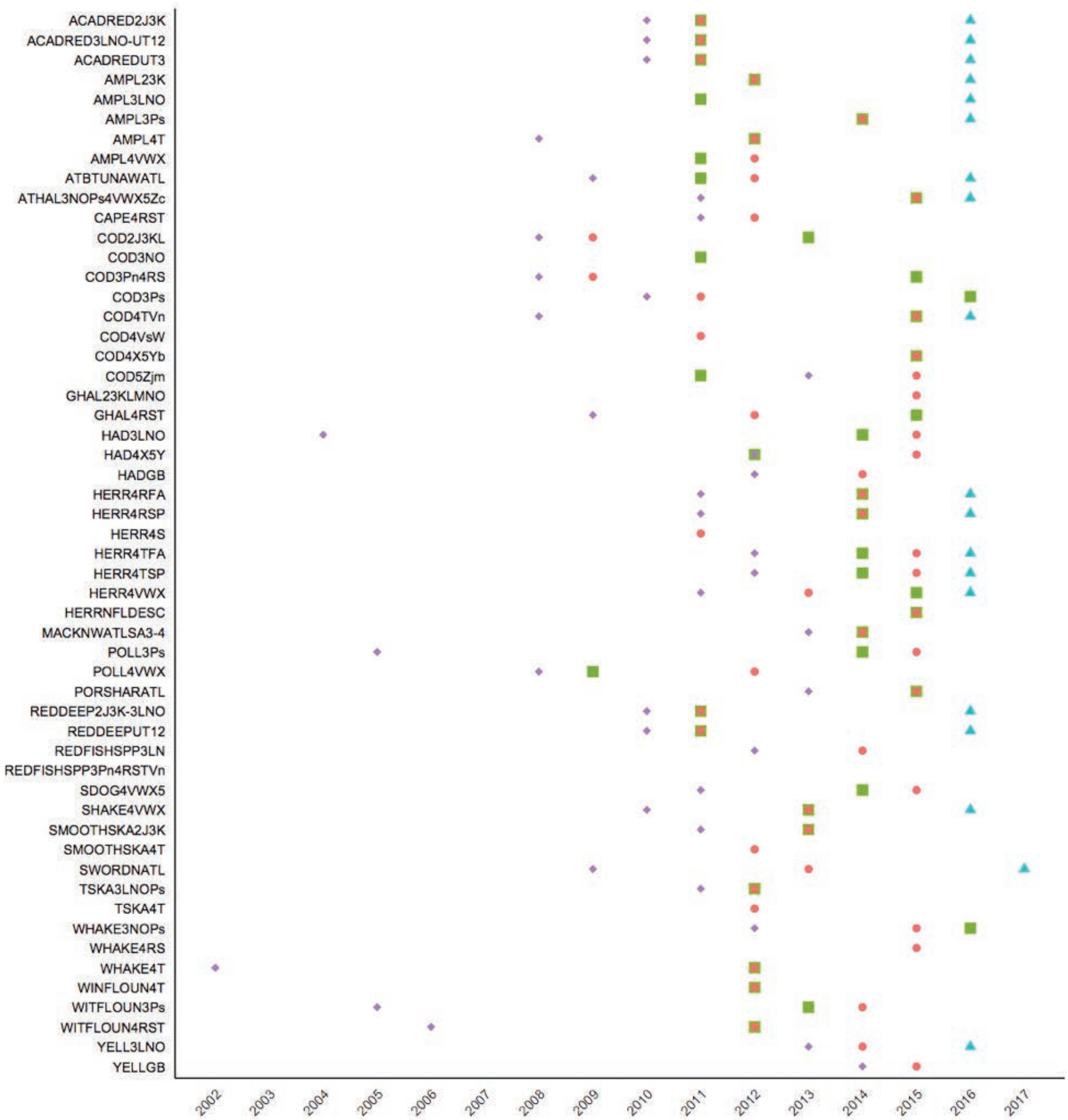


Figure 4.2: Assessment frequency of each of the Atlantic invertebrate stocks.
Points note the year of the most recent stock assessment Research Document (pink), the year of the most recent stock assessment summary (Science Advisory Document; green), the year of the previous stock assessment Research Document (purple) and the year of the next planned stock assessment, if available (blue). Stocks are denoted and ordered on the y-axis by their stock code (as in Table B1). Note that SCALL4T had not previously been assessed since 1989.

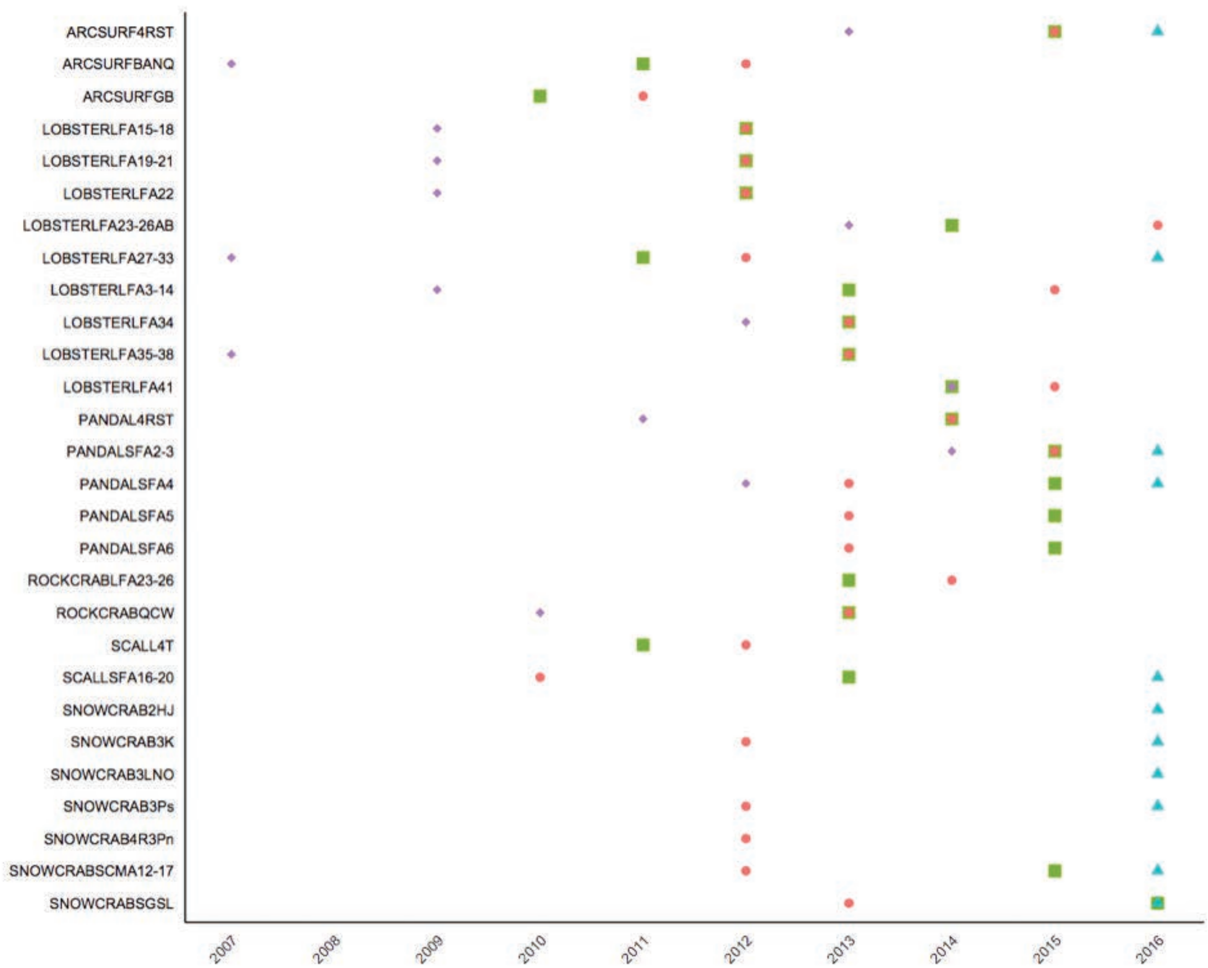
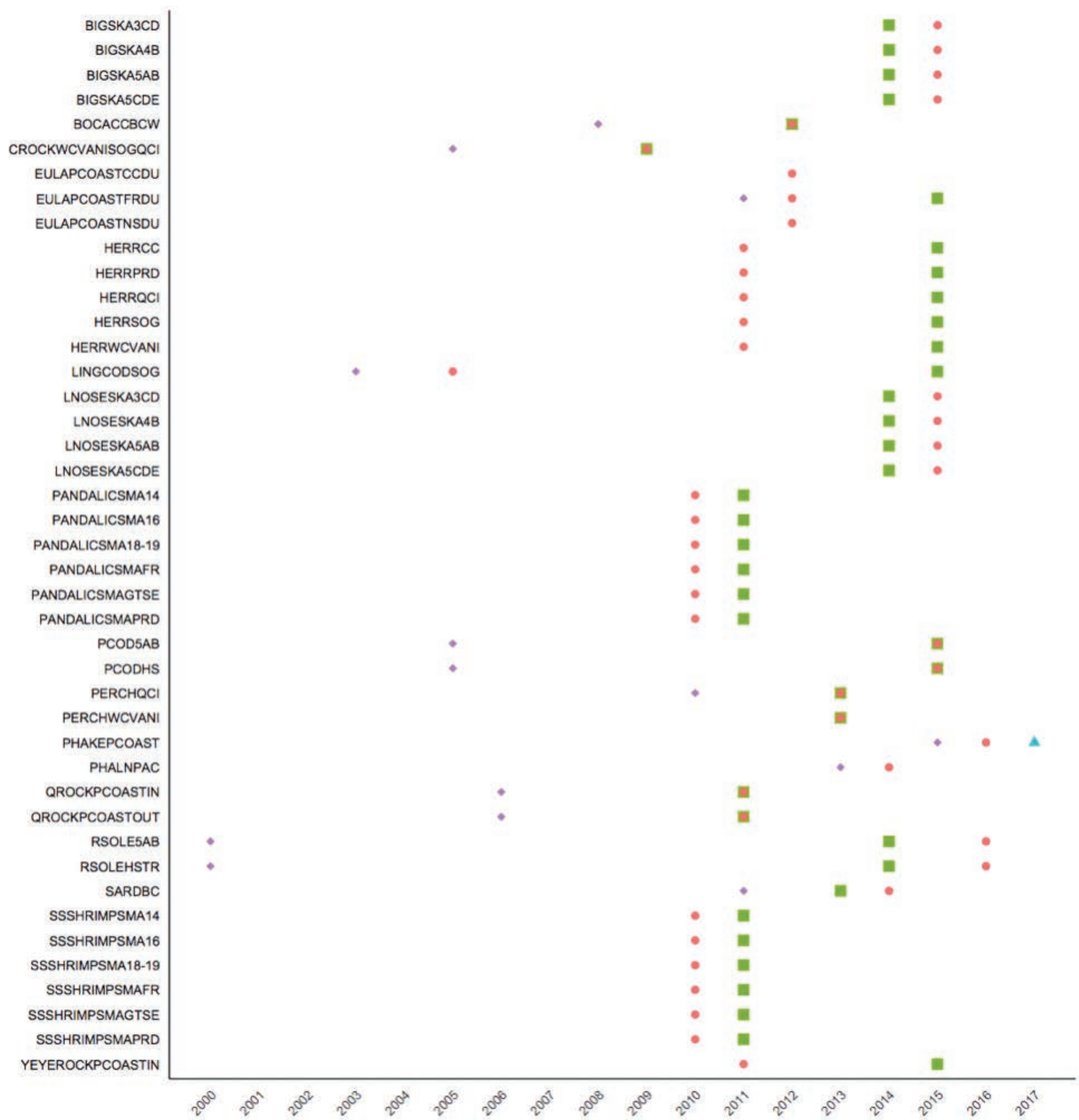


Figure 4.3: Assessment frequency of each of the Pacific stocks.

Points note the year of the most recent stock assessment Research Document (pink), the year of the most recent stock assessment summary (Science Advisory Document or Science Response Document [for Pacific Herring stocks] green), the year of the previous stock assessment Research Document (purple), and the year of the next planned stock assessment, if available (blue). Stocks are denoted and ordered on the y-axis by their stock code (as in Table B1).



4.2.2 Stock assessment types and data availability

Beyond the infrequency of stock assessments, there also is variability in the quantity and quality of data with which to conduct them, and in how comprehensive they are.

Framework assessments are the most comprehensive type of stock assessment conducted by DFO and represent the best practice. They review all available data for a stock to examine the biology, stock structure, the fishery, abundance indices, current assessment methodology and approaches for determining acceptable harvest limits (Stone and Hansen 2015). Framework assessments provide an opportunity for DFO scientists to critically evaluate the assessment approach for a given stock and, if necessary, develop new modelling approaches. They may also be independently peer-reviewed (T. Worcester pers. comm. 21 March 2016). Some framework assessments have been undertaken for Atlantic stocks, and although none have been conducted for Pacific stocks, the region is interested in doing so.

Framework assessments have been recently undertaken for Scotian Shelf silver hake (*Merluccius bilinearis*; Stone et al. 2013), western Scotian Shelf and Gulf of Maine (4X5Y) haddock (*Melanogrammus aeglefinus*; Stone and Hansen 2015) and Scotian Shelf and Southern Grand Banks Atlantic halibut (*Hippoglossus hippoglossus*; DFO 2015g). For Scotian Shelf silver hake, the framework process led to adopting a logistic biomass dynamic model as the basis for estimating population biomass (for 1993 to 2014), the estimation of Maximum Sustainable Yield (MSY)-based reference points from the model outputs, and the evaluation of consequences and risk to productivity of the stock under different harvest options (Cook 2013, DFO 2015h, Stone et al. 2013).

In the case of 4X5Y haddock, the framework assessment was motivated by a need to carefully examine a strong retrospective pattern in model results from the previous assessments (i.e., a tendency to overestimate the spawner stock biomass when additional years of data were added) and a mismatch between survey and catch information (Stone and Hansen 2015). The assessment was conducted in two parts over the course of a year and allowed for detailed examination of data inputs as well as assessment models (Stone and Hansen 2015).

Similarly, for the Atlantic halibut stock, a framework assessment science advisory meeting reviewed the data inputs and models. A second meeting focused on the stock assessment model performance and evaluated the stock status relative to its reference points, generated forecasting advice and reported on bycatch of non-target species in the fishery (DFO 2015g). The latter meeting led to the development of a new statistical catch at length (SCAL) assessment model, which estimates spawner stock biomass between 1970 and 2013 (DFO 2015i). For this stock, it was recommended that fishery framework and stock assessment meetings occur five years apart, with annual interim assessments (DFO 2015g). A safety net exists for the stock such that if, during the interim period there are three years in which the research survey index for Atlantic halibut falls below the long-term mean, a new framework assessment can be triggered (DFO 2015i, Appendix C).

The framework assessment meetings for all three of these stocks concluded that the information presented “provided sound scientific analyses based on the best available information” for the stocks (DFO 2015g). ***Other Canadian stocks likely would benefit from framework assessments and, in particular, the safety net approach currently applied to Atlantic halibut.***

Across all 125 stocks we examined, the types of data and model outputs provided in their stock assessments varied considerably (Table 4.2). Ninety per cent of the stock assessments (n=116) included data on total catch or total landings (Table 4.2). Almost two thirds (63 per cent) of recent stock assessments also included a population dynamics model, from which an estimate of stock abundance (total biomass, spawner stock biomass or total abundance) was generated (n=79; Table 4.2). On the Atlantic coast, this included all flatfish (except for 3Ps witch flounder), most forage fish, all groundfish (except for Atlantic cod in 3Ps and 4X5Yb, white hake in 4RS and spiny dogfish), most northern shrimp and redfish, as well as swordfish, bluefin tuna and porbeagle shark.

However, for most invertebrate stocks, including American lobster, Arctic surfclam, rock crab, sea scallop, and almost all snow crab, there are no abundance estimates (Table 4.2). For American lobster, at least, this stems from the lack of research surveys and independent catch rate indices for this species. On the Pacific coast, all stocks except for Pacific sardine, big skate (n=4) and longnose skate (n=4) had an associated estimate of abundance. Overall, only one-third of Canadian stocks (n=39) had an estimate of the size of mature portion of their population (i.e., spawner stock biomass or spawner stock numbers) (Table 4.2).

Table 4.2: Assessment methods used* and data available for each stock

For the most recent year that time series were available: TL: Total landings, TC: Total catch, CPUE: Catch per unit effort, TB: Total Biomass, SSB: spawning stock biomass (also includes spawning stock number estimates), TN: Abundance, R: Recruitment, F: Fishing mortality, ER: Exploitation rate. Checkmarks in parentheses (✓) indicate data that were presented in assessments but was unavailable for entry into the RAM database at the time of report writing. Totals include data that were presented in assessments but unavailable for entry into the RAM database.

#	Species	Stock Code	Taxa	Method	Year	TL	TC	CPUE	TB	SSB	TN	R	F	ER
ATLANTIC COAST														
1	**American plaice**	AMPL23K	Flatfish	SPM	2012	✓	✓	-	✓	-	✓	-	-	-
2		AMPL3LNO	Flatfish	VPA	2007	✓	-	-	✓	✓	-	✓	✓	✓
3		AMPL3Ps	Flatfish	BSPM	2013	✓	-	-	-	-	-	-	-	-
4		AMPL4T	Flatfish	VPA	2012	-	✓	-	-	✓	✓	✓	-	-
5		AMPL4VWX	Flatfish	SBM	2010	✓	-	-	-	✓	-	-	-	✓
6	**Atlantic halibut**	ATHAL3NOPs4VWX5Zc	Flatfish	unknown	2014	✓	-	-	✓	✓	✓	✓	-	-
7	**Greenland halibut**	GHAL23KLMNO	Flatfish	SURBA	2010	-	-	-	-	-	-	-	-	-
8		GHAL4RST	Flatfish	SURBA	2010	✓	-	-	✓	✓	✓	-	✓	✓
9	**Winter flounder**	WINFLOUN4T	Flatfish	VPA	2012	✓	✓	-	-	✓	✓	✓	✓	-
10	**Witch flounder**	WITFLOUN3Ps	Flatfish	SURBA	2013	✓	-	-	-	-	-	-	-	-
11		WITFLOUN4RST	Flatfish	BSPM	2011	✓	-	-	-	✓	-	-	-	✓
12	**Yellowtail flounder**	YELL3LNO	Flatfish	unknown	2015	-	✓	✓	-	✓	-	-	-	-
13		YELLGB	Flatfish	SURBA	2014	✓	✓	-	-	-	✓	-	-	-
14	**Capelin**	CAPE4RST	Forage Fish	unknown	2012	✓	-	-	-	-	-	-	-	-
15	**Herring**	HERR4RFA	Forage Fish	VPA:SPA	2003	-	-	-	✓	-	-	-	-	-
16		HERR4RSP	Forage Fish	VPA:SPA	2004	-	-	-	✓	-	-	-	-	-
17		HERR4S	Forage Fish	VPA:SPA	2010	-	✓	-	-	-	-	-	-	-
18		HERR4TFA	Forage Fish	VPA:SPA	2014	✓	✓	✓	-	✓	✓	-	✓	-
19		HERR4TSP	Forage Fish	VPA:SPA	2014	✓	✓	✓	-	✓	✓	-	✓	-
20		HERR4VWX	Forage Fish	unknown	2012	✓	✓	✓	-	✓	✓	-	-	✓
21		HERRNFLDESC	Forage Fish	unknown	2014	✓	-	-	-	-	-	-	-	-
22	**Mackerel**	MACKNWATLSA3-4	Forage Fish	unknown	2014	✓	-	-	✓	✓	-	✓	-	-

#	Species	Stock Code	Taxa	Method	Year	TL	TC	CPUE	TB	SSB	TN	R	F	ER
23	**Atlantic cod**	COD2J3KL	Groundfish	SURBA	2014	✓	-	-	✓	✓	✓	✓	-	-
24		COD3NO	Groundfish	Unknown	2011	-	✓	-	✓	-	-	-	-	✓
25		COD3Pn4RS	Groundfish	VPA:SPA	2015	✓	-	✓	✓	✓	✓	✓	✓	✓
26		COD3Ps	Groundfish	Unknown	2011	✓	-	-	✓	-	✓	-	-	-
27		COD4TVn	Groundfish	SCA	2015	✓	-	✓	-	✓	✓	-	✓	-
28		COD4VsW	Groundfish	Unknown	2002	(✓)	✓	-	(✓)	✓	-	-	-	✓
29		COD4X5Yb	Groundfish	VPA	2009	✓	-	-	-	✓	✓	-	✓	-
30		COD5Zjm	Groundfish	VPA	2010	✓	✓	-	-	✓	✓	-	-	-
31	**Haddock**	HAD3LNO	Groundfish	SURBA	2013	✓	-	-	✓	-	✓	-	-	-
32		HAD4X5Y	Groundfish	VPA	2014	✓	✓	-	✓	-	-	-	-	-
33		HADGB	Groundfish	VPA	-	-	✓	-	✓	-	✓	-	✓	-
34	**Pollock**	POLL3Ps	Groundfish	SURBA	2013	✓	-	-	-	-	-	-	-	-
35		POLL4VWX	Groundfish	SURBA	2011	✓	-	-	-	-	-	-	-	-
36	**Silver hake**	SHAKE4VWX	Groundfish	BDM	2015	✓	-	-	✓	-	-	✓	✓	-
37	**White hake**	WHAKE3NOPs	Groundfish	BSPM	2015	✓	-	-	(✓)	-	-	-	(✓)	-
38		WHAKE4RS	Groundfish	SURBA	2014	✓	-	-	-	-	-	-	-	-
39		WHAKE4T	Groundfish	VPA:SPA	2010	✓	-	-	✓	✓	✓	✓	✓	-
40	**American lobster**	LOBSTERLFA15-18	Invertebrate	Unknown	2011	✓	-	✓	-	-	-	-	-	-
41		LOBSTERLFA19-21	Invertebrate	Unknown	2011	✓	-	✓	-	-	-	-	-	-
42		LOBSTERLFA22	Invertebrate	Unknown	2011	✓	-	✓	-	-	-	-	-	-
43		LOBSTERLFA23-26AB	Invertebrate	Unknown	2011	✓	-	-	-	-	-	-	-	-
44		LOBSTERLFA27-33	Invertebrate	Unknown	2010	✓	-	✓	-	-	-	-	-	-
45		LOBSTERLFA3-14	Invertebrate	Unknown	2012	✓	-	✓	-	-	-	-	-	-
46		LOBSTERLFA34	Invertebrate	Unknown	2012	✓	-	✓	-	-	-	-	-	-
47		LOBSTERLFA35-38	Invertebrate	Unknown	2012	✓	-	✓	-	-	-	-	-	-
48		LOBSTERLFA41	Invertebrate	SURBA	2012	✓	-	✓	-	-	-	-	-	-
49	**Arctic surfclam**	ARCSURF4RST	Invertebrate	SURBA	2014	✓	-	✓	-	-	-	-	-	-
50		ARCSURFBANQ	Invertebrate	Unknown	2010	✓	✓	✓	-	-	-	-	-	-
51		ARCSURFGB	Invertebrate	SURBA	2010	✓	-	(✓)	-	-	-	-	-	-
52	**Northern shrimp**	PANDAL4RST	Invertebrate	unknown	2012	✓	✓	✓	-	-	-	-	-	-
53		PANDALSFA2-3	Invertebrate	SURBA	2015	-	✓	-	✓	✓	-	-	-	-
54		PANDALSFA4	Invertebrate	OgMap	2012	-	✓	✓	✓	✓	✓	✓	-	-
55		PANDALSFA5	Invertebrate	OgMap	2012	-	✓	✓	✓	✓	✓	✓	-	-
56		PANDALSFA6	Invertebrate	OgMap	2012	-	✓	✓	✓	✓	✓	✓	-	-
57	**Rock crab**	ROCKCRABLFA 23-26	Invertebrate	SURBA	2010	✓	-	✓	-	-	-	-	-	-

#	Species	Stock Code	Taxa	Method	Year	TL	TC	CPUE	TB	SSB	TN	R	F	ER
58		ROCKCRABQCW	Invertebrate	SURBA	2012	✓	-	✓	-	-	-	-	-	-
59	**Sea scallop**	SCALL4T	Invertebrate	SURBA	2014	✓	-	✓	-	-	-	-	-	-
60		SCALLSFA16-20	Invertebrate	SURBA	2012	✓	-	✓	-	-	-	-	-	-
61	**Snow crab**	SNOWCRAB2HJ	Invertebrate	STRAP	2008	-	-	-	-	-	-	-	-	-
62		SNOWCRAB3K	Invertebrate	STRAP	2013	✓	-	✓	-	-	-	-	-	-
63		SNOWCRAB3LNO	Invertebrate	STRAP	2008	-	-	-	-	-	-	-	-	-
64		SNOWCRAB3Ps	Invertebrate	STRAP	2013	✓	-	✓	-	-	✓	-	-	-
65		SNOWCRAB4R3Pn	Invertebrate	STRAP	2013	-	-	-	-	-	-	-	-	-
66		SNOWCRABSCMA12-17	Invertebrate	unknown	2013	✓	-	✓	-	-	-	✓	-	-
67		SNOWCRABSGSL	Invertebrate	SURBA	2014	✓	-	✓	✓	-	-	✓	-	✓
68	**Redfish species**	ACADRED2J3K	Redfish	BSPM	2011	-	✓	-	✓	-	-	-	-	-
69		ACADRED3LNO-UT12	Redfish	BSPM	2011	-	✓	-	✓	-	-	-	-	-
70		ACADREDUT3	Redfish	BSPM	2011	-	✓	-	✓	-	-	-	-	-
71		REDDEEP2J3K-3LNO	Redfish	BSPM	2011	-	✓	-	✓	-	-	-	-	-
72		REDDEEPUT12	Redfish	BSPM	2011	-	✓	-	✓	-	-	-	-	-
73		REDFISHSPP3LN	Redfish	unknown	2013	-	✓	✓	-	-	-	-	-	-
74		REDFISHSPP3Pn4RSTVn	Redfish	unknown	2000	✓	-	✓	-	-	-	-	-	-
75	**Porbeagle shark**	PORSHARATL	Sharks and Skates	SBM	2014	✓	✓	(✓)	(✓)	✓	✓	✓	-	-
76	**Smooth skate**	SMOOTHSKA2J3K	Sharks and Skates	SURBA	2012	-	✓	-	-	-	-	-	-	-
77		SMOOTHSKA4T	Sharks and Skates	SURBA	2010	✓	✓	-	-	-	-	-	-	-
78	**Spiny dogfish**	SDOG4VWX5	Sharks and Skates	SBM	2013	✓	-	-	(✓)	(✓)	✓	✓	(✓)	-
79	**Thorny skate**	TSKA3LNOPs	Sharks and Skates	CatchMSY	2013	✓	-	-	-	-	-	-	-	-
80		TSKA4T	Sharks and Skates	SURBA	2010	✓	✓	-	-	-	-	-	-	-
81	**Bluefin tuna**	ATBTUNAWATL	Tuna and Swordfish	unknown	2015	-	✓	-	-	✓	-	-	✓	✓
82	**Swordfish**	SWORDNATL	Tuna and Swordfish	BDM	2015	-	✓	✓	✓	-	-	-	✓	-

#	Species	Stock Code	Taxa	Method	Year	TL	TC	CPUE	TB	SSB	TN	R	F	ER
PACIFIC COAST														
83	**Pacific halibut**	PHALNPAC	Flatfish	AD-CAM	2014	-	✓	-	✓	✓	-	-	✓	✓
84	**Rock sole**	RSOLE5AB	Flatfish	SCA	2013	✓	✓	✓	-	✓	-	✓	-	✓
85		RSOLEHSTR	Flatfish	SCA	2013	✓	✓	✓	-	✓	-	✓	-	✓
86	**Eulachon**	EULAPCOASTC CDU	Forage Fish	BSRM	2012	-	-	-	✓	-	✓	-	-	-
87		EULAPCOASTF RDU	Forage Fish	BSRM	2012	-	✓	-	✓	-	✓	-	-	-
88		EULAPCOASTN SDU	Forage Fish	BSRM	2012	-	-	-	✓	-	✓	-	-	-
89	**Pacific herring**	HERRCC	Forage Fish	CAM	2015	-	✓	-	✓	✓	-	✓	-	-
90		HERRPRD	Forage Fish	CAM	2015	-	✓	-	✓	✓	-	✓	-	-
91		HERRQCI	Forage Fish	CAM	2015	-	✓	-	✓	✓	-	✓	-	-
92		HERRSOG	Forage Fish	CAM	2015	-	✓	-	✓	✓	-	✓	-	-
93		HERRWCVANI	Forage Fish	CAM	2015	-	✓	-	✓	✓	-	✓	-	-
94	**Pacific sardine**	SARDBC	Forage Fish	SURBA	2012	✓	-	-	-	-	-	-	-	-
95	**Pacific cod**	PCOD5AB	Groundfish	BDM	2014	-	✓	✓	✓	-	-	✓	✓	-
96		PCODHS	Groundfish	BDM	2014	-	✓	✓	✓	-	-	✓	✓	-
97	**Pacific hake**	PHAKEPCOAST	Groundfish	SSM	2015	-	✓	-	-	✓	-	✓	-	✓
98	**Northern shrimp**	PANDALSMA14	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
99		PANDALSMA16	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
100		PANDALSMA18-19	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
101		PANDALSMAFR	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
102		PANDALSMAGTSE	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
103		PANDALSMAPRD	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
104	**Sidestripe shrimp**	SSSHRIMPSMA14	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
105		SSSHRIMPSMA16	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
106		SSSHRIMPSMA 18-19	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
107		SSSHRIMPSMAFR	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
108		SSSHRIMPSMAG TSE	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
109		SSSHRIMPSMAP RD	Invertebrate	SURBA	2011	✓	-	-	✓	-	-	-	-	-
110	**Lingcod**	LINGCODSOG	Rockfish	SCA	2014	-	✓	-	-	✓	-	-	-	-
111	**Rockfish**	BOCACCBCW	Rockfish	unknown	2012	-	✓	-	✓	-	-	-	-	✓
112		CROCKWCVANIS OGQCI	Rockfish	unknown	2009	-	✓	-	✓	✓	-	-	-	✓

#	Species	Stock Code	Taxa	Method	Year	TL	TC	CPUE	TB	SSB	TN	R	F	ER
113		PERCHQCI	Rockfish	SCA	2012	-	✓	-	✓	✓	-	✓	-	✓
114		PERCHWCVANI	Rockfish	SCA	2012	-	✓	-	✓	✓	-	✓	-	✓
115		QROCKPCOASTIN	Rockfish	BSSPM	2010	-	✓	-	(✓)	-	-	-	-	-
116		QROCKPCOAST OUT	Rockfish	BSSPM	2010	-	✓	-	(✓)	-	-	-	-	-
117		YEYEROCKP COASTIN	Rockfish	BSSPM	2009	-	-	-	(✓)	-	-	-	-	-
118	**Big skate**	BIGSKA3CD	Sharks and Skates	CatchMSY	2011	-	✓	(✓)	-	-	-	-	-	-
119		BIGSKA4B	Sharks and Skates	SURBA	2011	-	✓	(✓)	-	-	-	-	-	-
120		BIGSKA5AB	Sharks and Skates	CatchMSY	2011	-	✓	(✓)	-	-	-	-	-	-
121		BIGSKA5CDE	Sharks and Skates	CatchMSY	2011	-	✓	(✓)	-	-	-	-	-	-
122	**Longnose skate**	LNOSESKA3CD	Sharks and Skates	CatchMSY	2011	-	✓	-	-	-	-	-	-	-
123		LNOSESKA4B	Sharks and Skates	SURBA	2011	-	✓	-	-	-	-	-	-	-
124		LNOSESKA5AB	Sharks and Skates	CatchMSY	2011	-	✓	-	-	-	-	-	-	-
125		LNOSESKA5CDE	Sharks and Skates	CatchMSY	2011	-	✓	-	-	-	-	-	-	-
					Total	73	59	41	61	39	27	28	18	18

*Model Codes: AD-CAM: an AD-Model builder statistical Catch at Age Model, BDM: Biomass Dynamics Model, BSSSPM: Bayesian State Space Surplus Production Model, BSR: Bayesian Stock Reduction Model, CAM: Catch-at-age model, CatchMSY: Catch resilience model, OgMap: OGive MAPping, SCA: Statistical Catch at Age model, SBM: Stage-based model, SPM: Surplus Production Model, STRAP: Stratified Analysis Programs, SURBA: Survey-based stock assessment model, VPA: Virtual Population Analysis, VPA-SPA: Virtual Population Analysis: Sequential Population Analysis, XSA: Extended Survivor Analysis.

Of the stocks with biomass estimates available from their most recent assessment, the length of the available biomass time series also varied widely (Figures 4.4, 4.5). On the East Coast, biomass data for 25 marine fish stocks extend to the 1970s, with most of the remaining fish time series starting in the 1980s or early 1990s (Figure 4.4). In contrast, biomass time series data were only available for five of the invertebrate stocks. The latter time series did not start until 1996 (n=3), 2005 (n=1) or 2006 (n=1), reflecting the more recent development of these fisheries following the collapse of groundfish in the early 1990s.

On the West Coast, biomass time series data for almost all marine fish stock are available from 1970 (Figure 4.5). The exceptions are Pacific halibut, whose current assessment extends only to 1996, and three eulachon stocks, which began shortly thereafter. In contrast, biomass data for 12 shrimp stocks are only available since 1998 or later (Figure 4.5). On this coast, fish biomass also dominates that of the invertebrates.

Among the stocks with population dynamics models, several different types of models were used, with similar types typically employed for the same species (Table 4.2). For example, many groundfish are assessed with a type of Virtual Population Analysis (VPA), and most West Coast shrimp stocks are assessed with a survey based-stock assessment model (Table 4.2). The quality of any individual assessment depends to a large extent on the quality of input data available, and as such, individual evaluations of the quality of each assessment are not possible in this report. Sophisticated stock assessment modelling approaches, including AD-model builder statistical catch-at-age models and Bayesian state space surplus production models, are being employed for Pacific halibut and some West Coast rockfish stocks (Table 4.2).

Accurate estimates of fishing intensity are critically important for managing and recovering wild populations yet only one-quarter of the stocks we reviewed had an estimate of fishing mortality and/or an exploitation rate (n=31 total, of which 29 were available, Table 4.2). On the East Coast, there are estimates of fishing mortality or exploitation rates for only 21 stocks. These included two American plaice stocks, one Greenland halibut, one witch flounder, one winter flounder, five Atlantic cod stocks, bluefin tuna and swordfish. Estimates were not available for a single redfish stock and were only available for one of the 28 invertebrate stocks (a snow crab), for three out of nine forage fish stocks and for one of six elasmobranch stocks. On the West Coast, fishing mortality or exploitation rate estimates were not available for Pacific herring, eulachon or shrimp stocks but were available for Pacific halibut, Pacific hake and several rockfish stocks.

Figure 4.4: Time period for which biomass data are available from Atlantic coast stock assessments
Stocks are sorted from largest (top) to smallest (bottom), with their average total biomass printed on the left-hand axis.

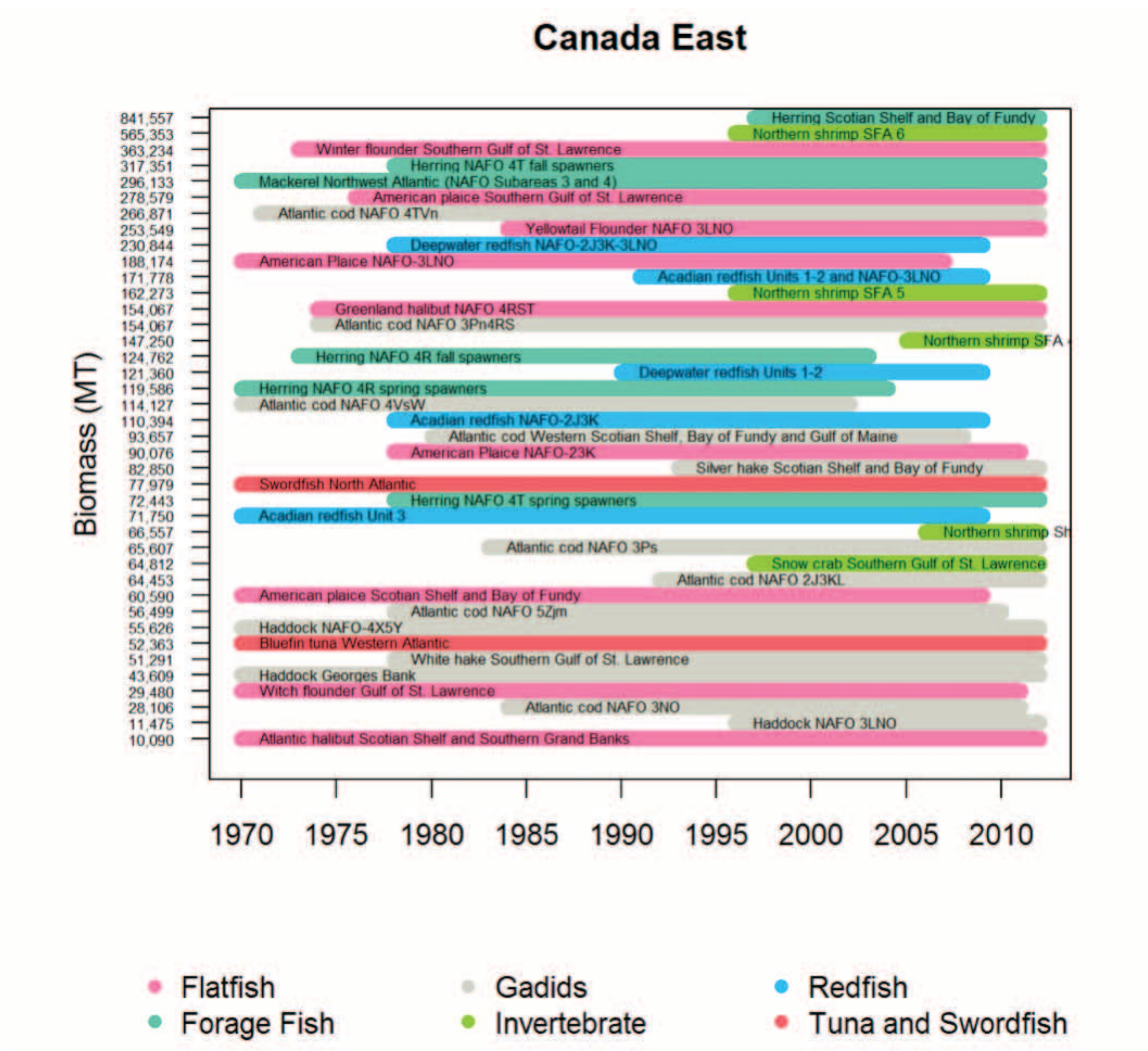
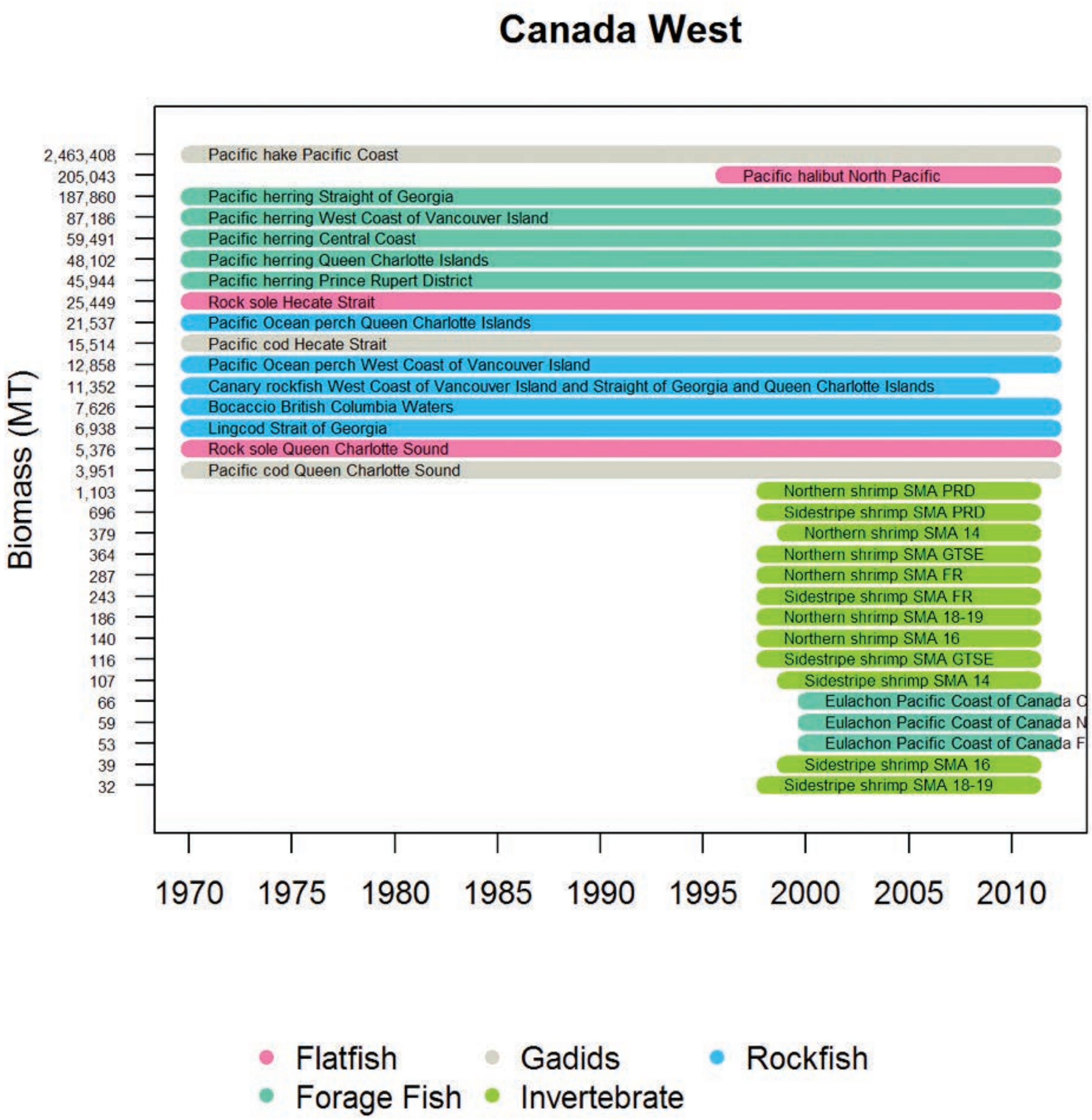


Figure 4.5: Time period for which biomass data are available from Pacific coast stock assessments

Stocks are sorted from largest (top) to smallest (bottom), with their average total biomass printed on the left-hand axis.

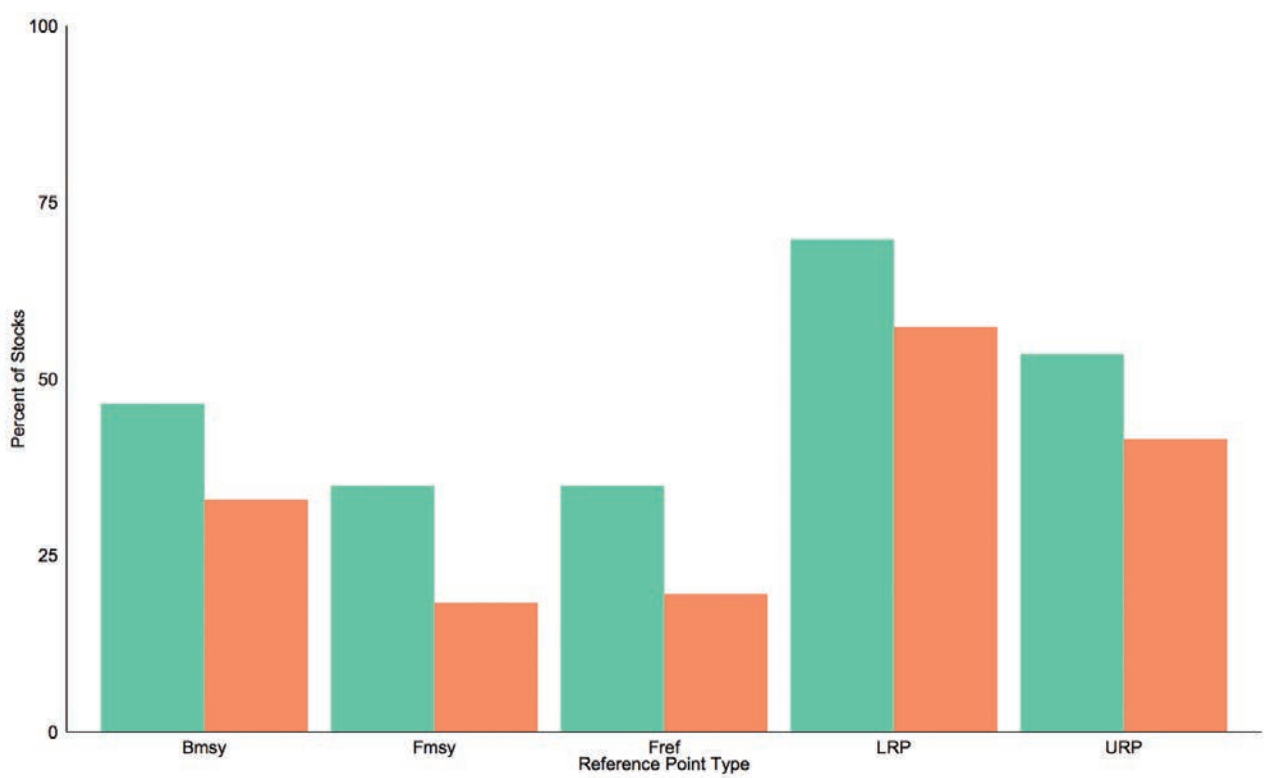


There is considerable room for improvement in Canadian stock assessments with respect to estimating reference points. Just over one third (n=47) of stocks have B_{MSY} estimated, and only one-quarter (n=30) of stocks have F_{MSY} estimated (Table B2, A3). Almost the same number of stocks have an alternative F-based reference point estimated (Table B2). The proportion of stocks with MSY-based reference points differs by coast: along the Atlantic coast, 33 per cent and 18 per cent of stocks have B_{MSY} and F_{MSY} estimated, respectively, while on the Pacific coast 72 per cent of stocks have B_{MSY} and 35 per cent of stocks have F_{MSY} (Figure 4.6; Table B2, B3). Upper and lower reference points have been estimated for 46 per cent and 62 per cent of Canadian stocks, respectively (Table B2, B3). Again, the proportion of Atlantic stocks with these reference points estimated (41 per cent and 57 per cent respectively) is lower than on the Pacific coast (53 per cent and 70 per cent respectively) (Figure 4.6).

Finally, for those stocks without any estimates of abundance in their assessment, 24 had at least an index of relative abundance (i.e., catch per unit effort) (Table 4.2). These included Atlantic halibut in the Gulf of St. Lawrence, eight out of nine American lobster stocks, all three Arctic surfclam stocks, both rock crab and both sea scallop stocks, two redfish, two snow crab, and the big skate stocks. Of concern, however, are the 22 stocks (18 per cent) without any existing measure of abundance or relative abundance. Over three-quarters of these stocks are on the Atlantic coast, including 3Ps American plaice and witch flounder, both pollock stocks, Gulf of St. Lawrence capelin, one Greenland halibut stock, two herring stocks, 4RS white hake, one American lobster, three snow crab stocks, and both smooth skate and both thorny skate stocks (n=15) (Table 4.2). On the Pacific coast, Pacific sardine and four longnose skate stocks are the only ones lacking either abundance or relative abundance data (Table 4.2).

Figure 4.6: Percentages of Atlantic and Pacific stocks with reference points

Pacific (green, n=43) and Atlantic (orange, n=82) with B_{MSY}, F_{MSY}, F_{REF} (any other fishing mortality reference point), LRP (lower reference point), or USR (upper stock reference point) determined.



4.2.3 Current status of Canadian stocks – RAM Legacy Stock Assessment Database

Here, we review aggregated trends in stock biomass and exploitation rates on Canada's Atlantic and Pacific coasts, as well as trends in these two metrics relative to their reference points, using the RAM Legacy database system.

In examining the broad biomass trends for Atlantic coast Canadian stocks from the RAM database (and noting that the depicted patterns reflect both the particular stocks and years represented in the database, as well as the stocks' biomass), it appears that overall aggregated biomass has remained fairly stable over the past two decades (Figure 4.7 top). This pattern reflects the relative stability of invertebrates and forage fish following the cod collapse (Figure 4.7 middle and bottom). For each taxonomic group, these graphs show only the continuous year range in which the ratio of the summed biomass to the maximum of the summed biomass of the fishery type is greater than 0.5. Thus, for example, gadids peaked in the mid-1980s and are not plotted after 1990, after which these stocks collapsed (Figure 4.7 middle).

For the Pacific coast, the aggregated biomass of stocks extends over a longer time frame and is more variable but with a distinct peak in the late 1980s (driven by a corresponding gadid peak) and a declining trend since then (Figure 4.8 top). Since the early 1980s, the aggregated biomass of forage fish has been variable but generally stable; the biomass of gadids was stable in the 1970s, peaked in the mid-1980s and then declined; while rockfish species have exhibited a substantial decline (Figure 4.8 middle and bottom). Invertebrates show a slight increasing tendency since the late 1990s (Figure 4.8 bottom).

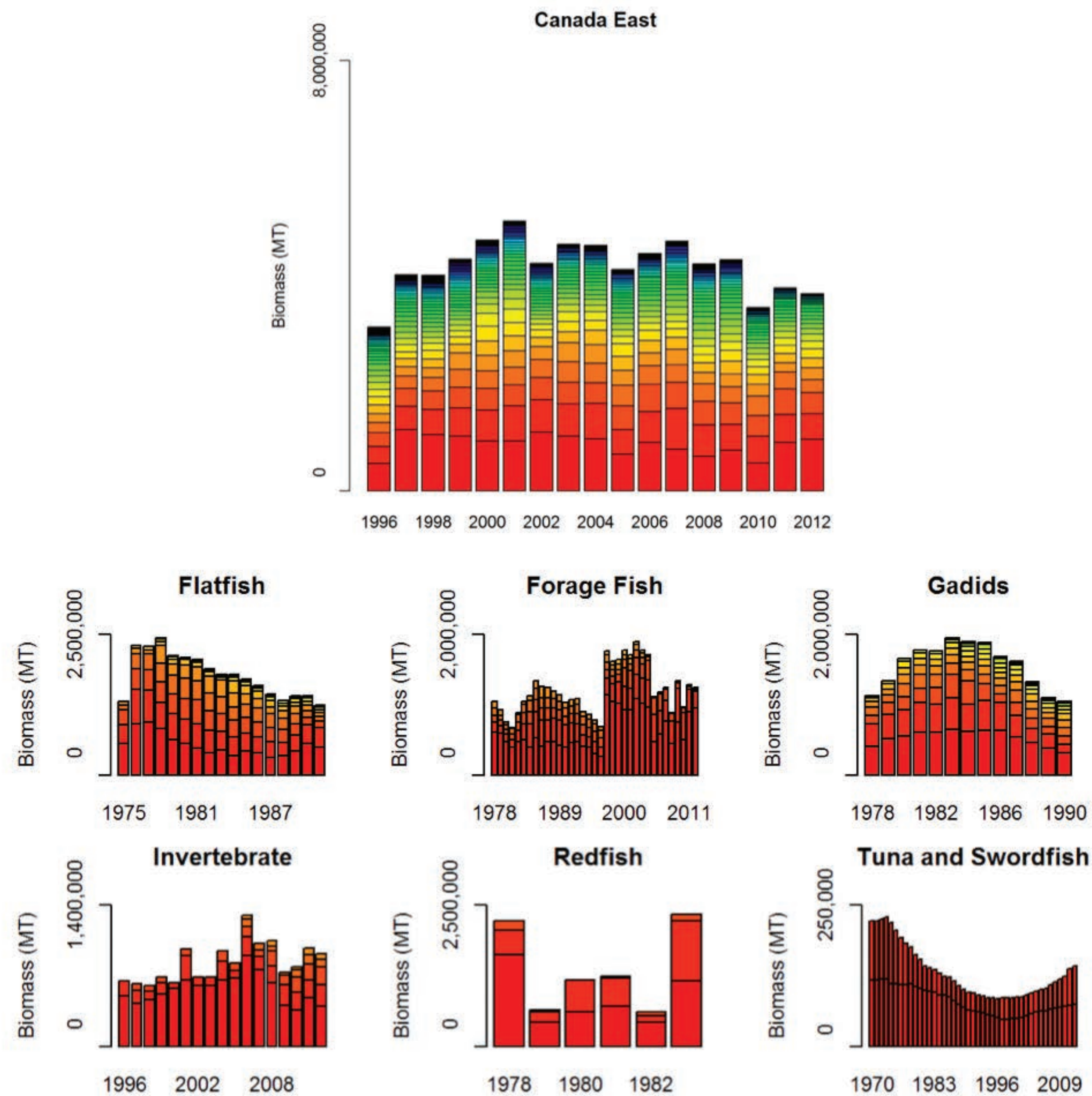
For the Atlantic coast, trends in aggregated biomass relative to the stock's biomass reference points reveal clear decline from 1970 through to the early 1990s, reflecting a decline in northern cod and other groundfish over this period, followed by an increasing trend until present (Figure 4.9 top). Apart from the first four years and the most recent few years, the aggregation of East Coast stocks has been below the reference level, reflecting the very low biomass levels to which many marine fish stocks have been fished (Figure 4.9 top). Today, almost 80 per cent of Atlantic stocks (with reference points) are fully exploited, overfished, or crashed (Figure 4.9 bottom). We note, however, that the number of Atlantic stocks included in these plots is low because of a lack of biomass time-series and biomass-based reference points for most stocks, and thus they should be interpreted with some caution.

On the Pacific coast, there is also a declining trend in biomass between 1970 and present. In contrast to the Atlantic coast, for the majority of this time the aggregation of stocks have been above the reference biomass level (Figure 4.10 top). In particular, whereas the fished community on the Atlantic coast reached alarmingly low levels in the early 1990s, on the Pacific coast the community was still above the reference biomass target level at that point. On the West Coast, the biomass decline is largely due to depletion in groundfish fisheries, including rockfish and small pelagics such as herring. Now, almost 90 per cent of Pacific stocks (with reference points) are fully exploited, overfished, or crashed; the majority are fully exploited (Figure 4.10 bottom). Again, we note that the number of Pacific stocks included in these RAM database plots is low because of the lack of biomass time-series and biomass-based reference points for most stocks, and thus they should be interpreted with some caution.

Fishing mortality levels present another view on the status of exploited stocks and are important to consider with respect to potential fisheries recovery, as they can shape the future trajectory of stocks (Figures 4.11, 4.12). We qualify that, as with the biomass target plots, these plots must be interpreted cautiously, since fisheries reference points are estimated for so few Canadian stocks. Still, the familiar pattern of very high fishing mortality levels – almost all above the target level – is evident on Canada's Atlantic coast from the early 1970s up until the mid-1990s, just after the northern cod collapse (Figure 4.11 top). Although fishing mortality declined thereafter, it remained above the target level until the early 2000s (Figure 4.11 top). On the West Coast, aggregated fishing mortality has been below the target level throughout the past four decades, at least when considering those stocks for which fisheries reference points have been estimated (Figure 4.12 top).

Figure 4.7: Trends in Atlantic coast stock total biomass

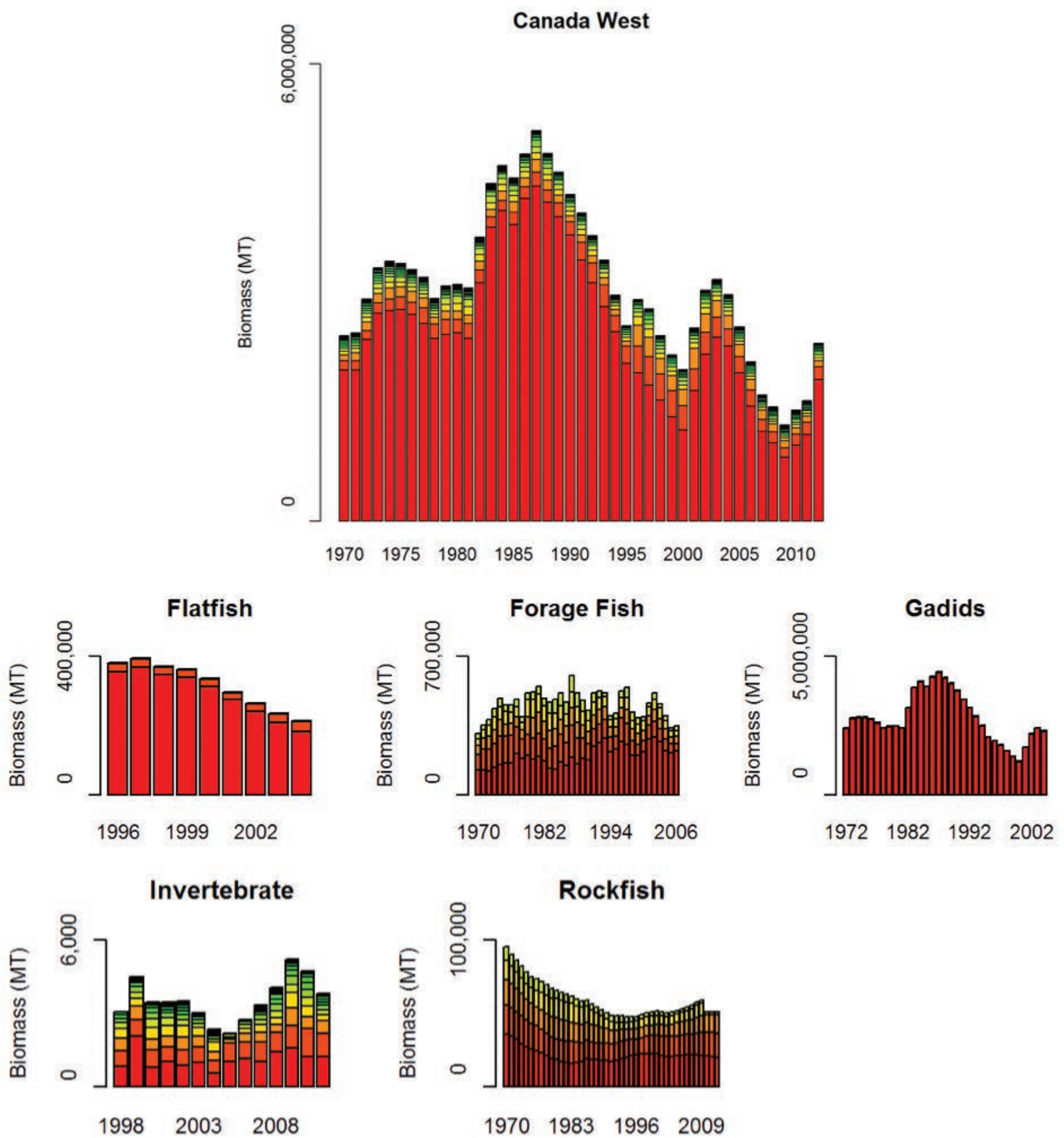
RAM Legacy database: all stocks combined (top) and categorized into six broad taxonomic groups (middle, bottom; note the different y-axis limits) to see how these groups have changed over time. Within each plot, each stock is represented by a different colour/segment.[1]



[1] Note that the trends in total biomass are a function of both the stocks that are represented and the abundance of stocks. Thus, most of these graphs will show an increase at the beginning of the time series as more stocks are added to the database, and a decline at the end as stocks drop out of the data base (as not all assessments bring the abundance data up to present).

Figure 4.8: Trends in Pacific coast stock total biomass

RAM Legacy database: all stocks combined (top) and categorized into five broad taxonomic groups (middle, bottom; note the different y-axis limits), enabling the viewer to see how these groups have changed over time. Within each plot, each stock is represented by a different colour/segment.[1]



[1] Note that the trends in total biomass are a function of both the stocks that are represented and the abundance of stocks. Thus, most of these graphs will show an increase at the beginning of the time series as more stocks are added to the database, and a decline at the end as stocks drop out of the data base (as not all assessments bring the abundance data up to present).

Figure 4.9: Atlantic coast biomass status

Top: Boxplot showing aggregated stock status relative to the target level. Each stock is given equal weight. Dashed lines represent the 95 per cent confidence intervals, the coloured box represents the 50 per cent interval, and circles highlight individual outliers.

Bottom: Status proportions over time. Stocks are classified as underexploited (biomass >1.5 BTARGET), fully exploited (biomass <1.5 BTARGET & >0.5 BTARGET), overfished (biomass <0.5 BTARGET & >0.2 BTARGET) and crashed biomass (<0.2 BTARGET), following RAM Legacy.

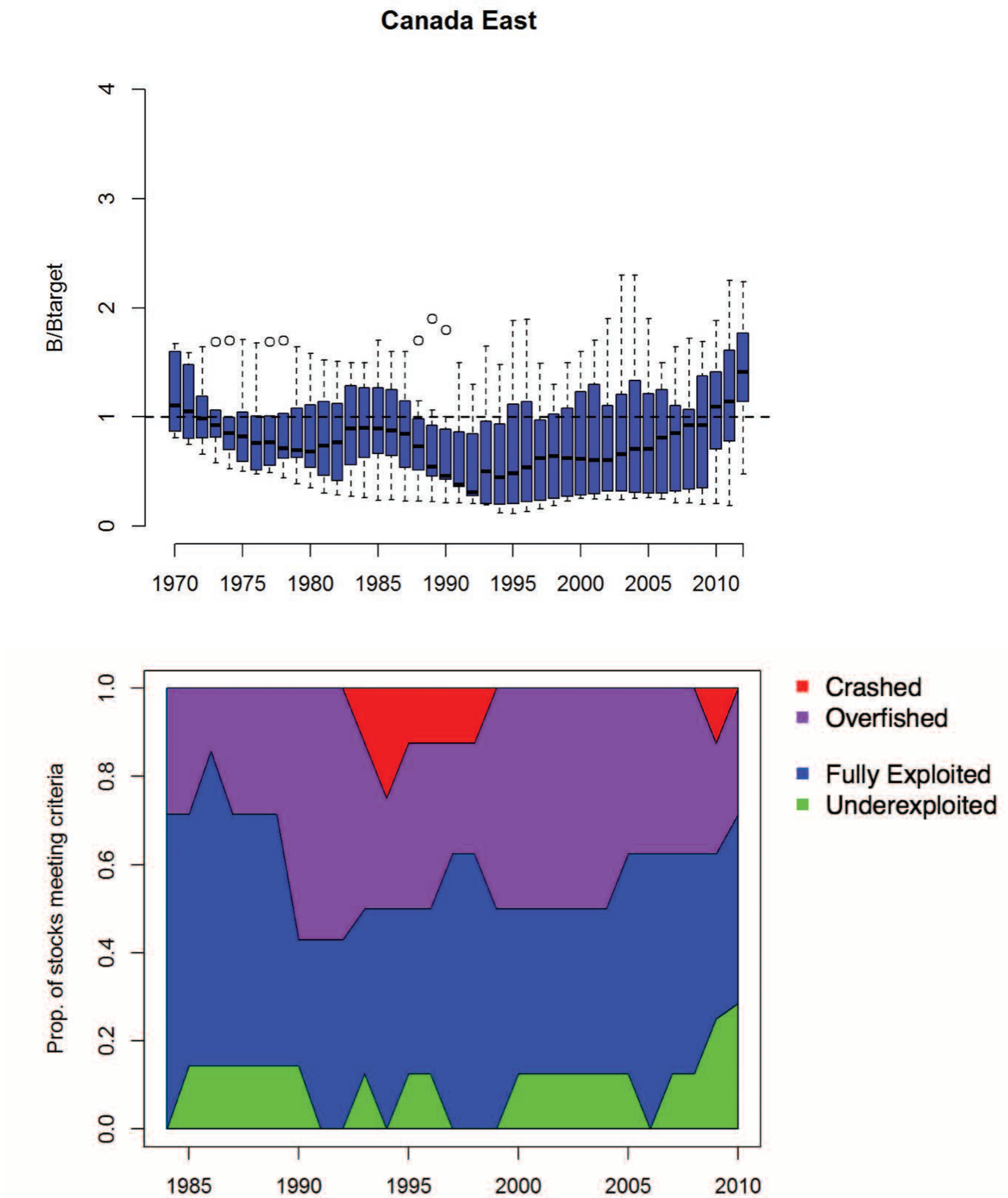


Figure 4.10: Pacific coast biomass status

Top: Boxplot showing aggregated stock status relative to the target level. Each stock is given equal weight. Dashed lines represent the 95 per cent confidence intervals, the coloured box represents the 50 per cent interval, and circles highlight individual outliers.

Bottom: Status proportions over time. Stocks are classified as underexploited (biomass >1.5 BTARGET), fully exploited (biomass <1.5 BTARGET & >0.5 BTARGET), overfished (biomass <0.5 BTARGET & >0.2 BTARGET) and crashed biomass (<0.2 BTARGET), following RAM Legacy.

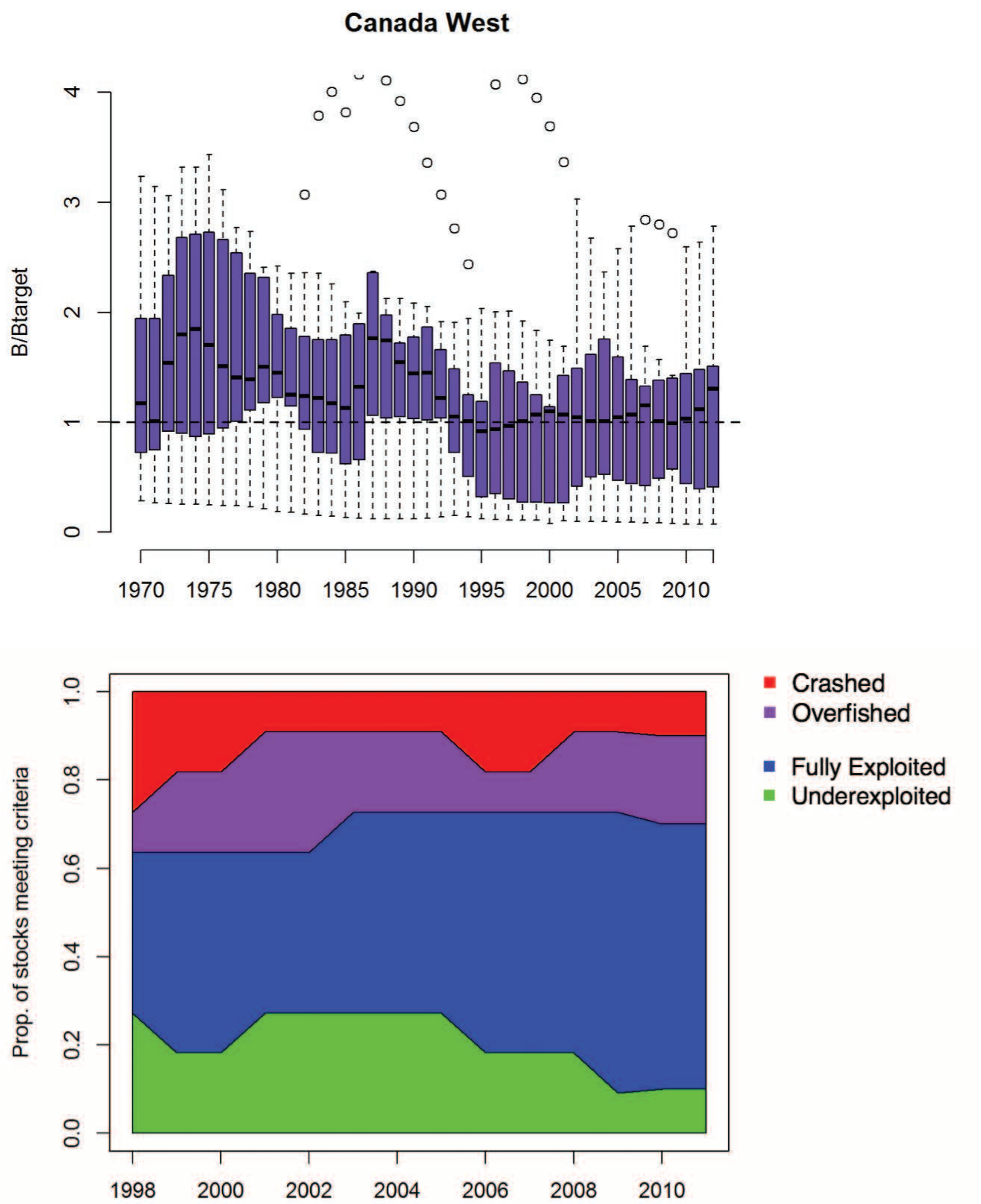
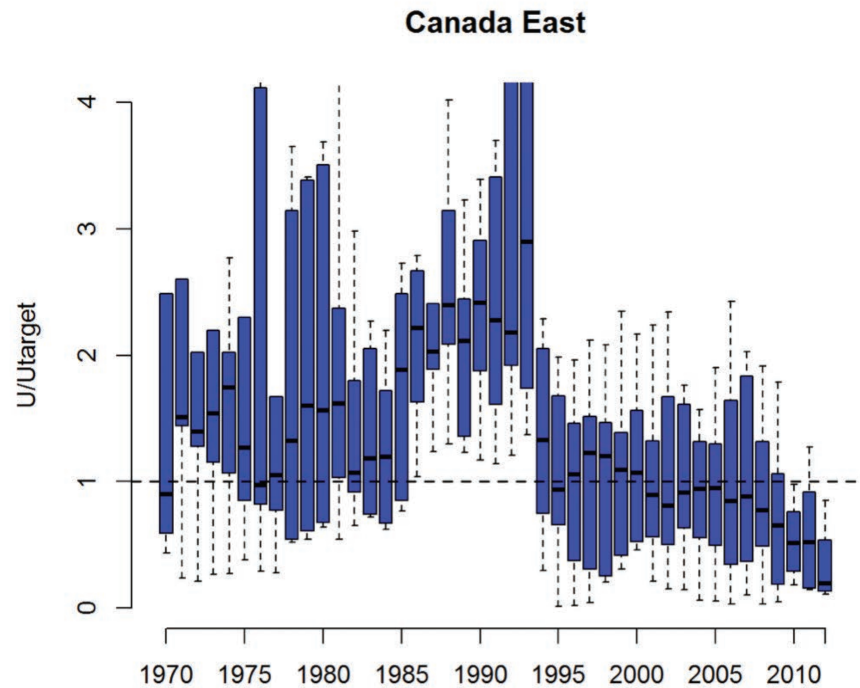


Figure 4.11: Atlantic coast fishing pressure

Top: Boxplot showing aggregated fishing mortality rate relative to the rate that would produce the target level. Each stock is given equal weight. Dashed lines represent the 95 per cent confidence intervals, the coloured box represents the 50 per cent interval, and circles highlight individual outliers.

Bottom: Fishing proportions over time. Stocks are classified as overexploited (U >1.5 UTARGET), fully exploited (U >0.5 UTARGET U <1.5 UTARGET), underexploited (U >0.2 UTARGET U <0.5 UTARGET), and hardly exploited (U <0.2 UTARGET), following the RAM Legacy Database.



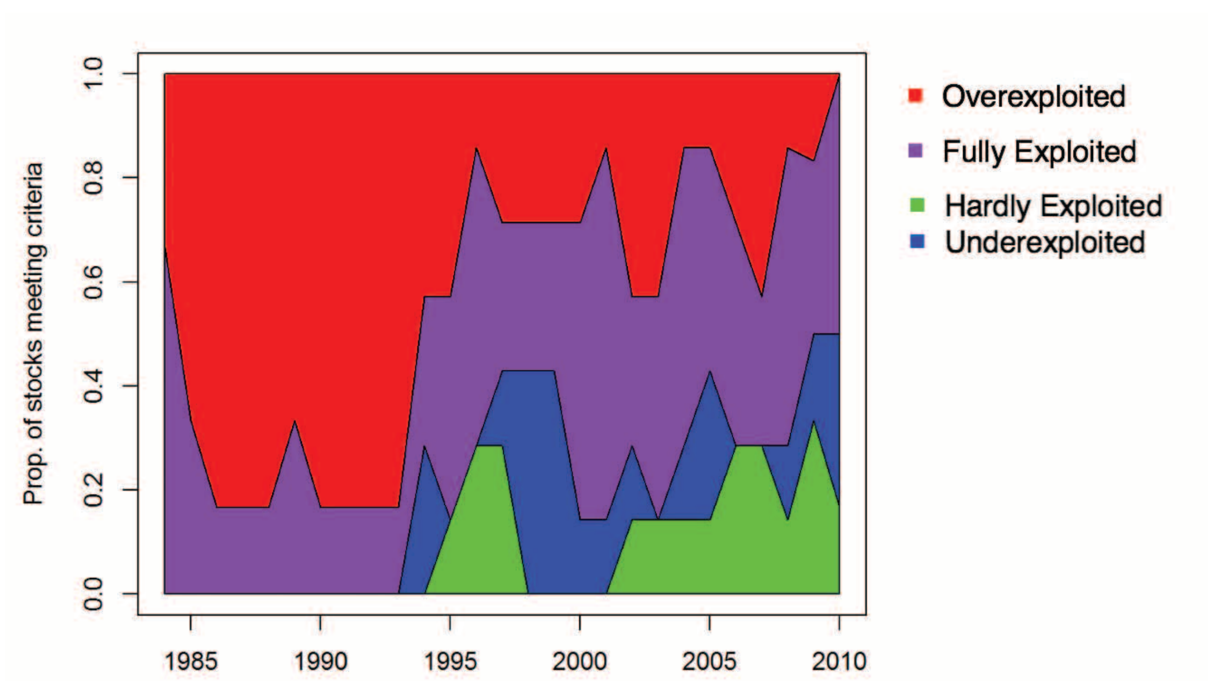
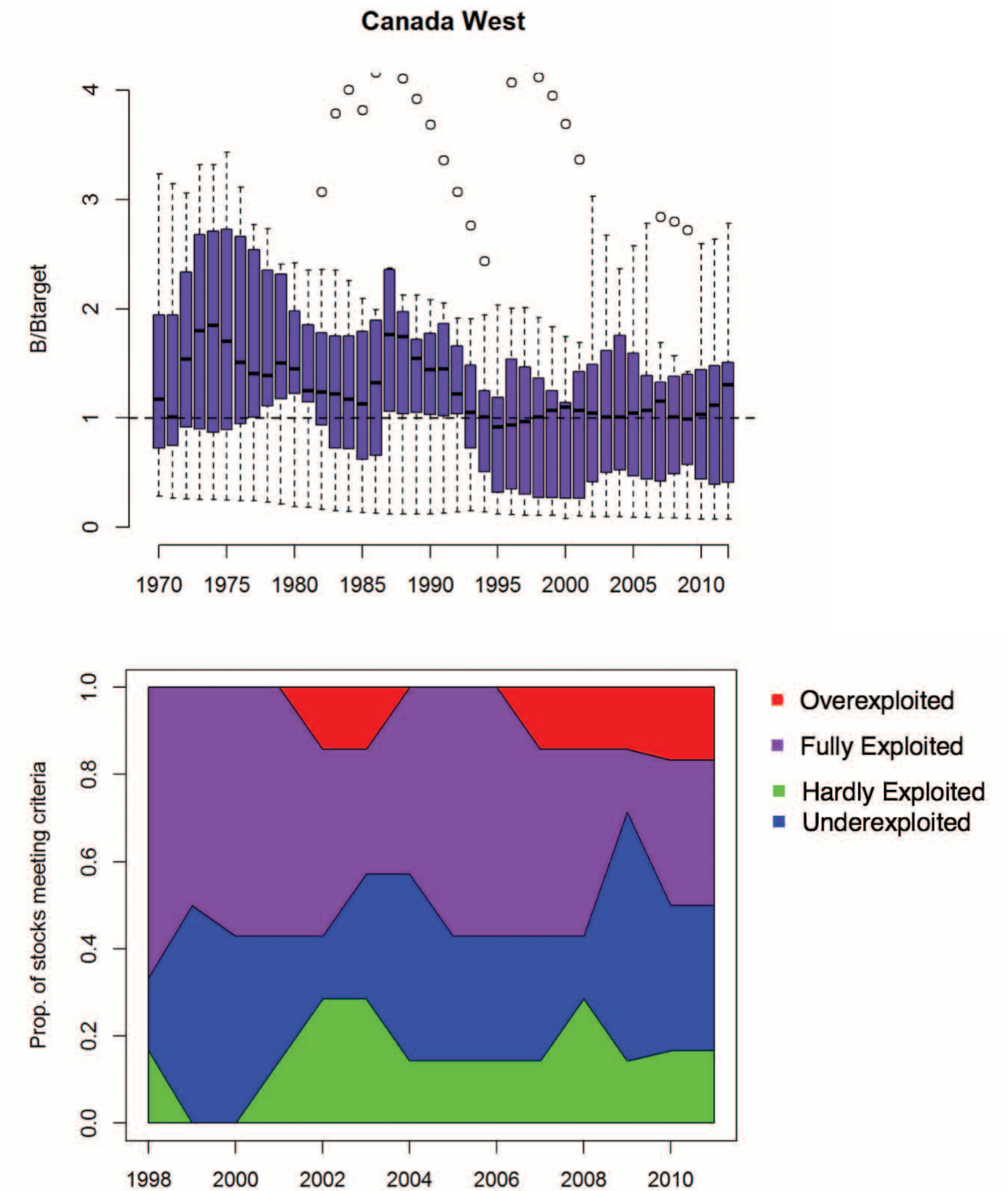


Figure 4.12: Pacific coast fishing pressure

Top: Boxplot showing aggregated fishing mortality rate relative to the rate that would produce the target level. Each stock is given equal weight. Dashed lines represent the 95 per cent confidence intervals, the coloured box represents the 50 per cent interval, and circles highlight individual outliers.

Bottom: Fishing proportions over time. Stocks are classified as overexploited (U >1.5 UTARGET), fully exploited (U >0.5 UTARGET U <1.5 UTARGET), underexploited (U >0.2 UTARGET U <0.5 UTARGET), and hardly exploited (U <0.2 UTARGET), following the RAM Legacy Database.



4.2.4 Current status of Canadian stocks - DFO Precautionary Approach Framework

An examination of the state of Canada's marine fish and invertebrate stocks from the perspective of DFO's Precautionary Approach Framework reveals that few stocks (24 per cent) are currently considered by DFO to be in a healthy state: only 15 stocks on the Atlantic coast and 13 stocks on the Pacific coast (Figure 4.13).

On the other end of the spectrum, DFO considers 18 stocks to be in a critical state; a further 17 stocks are considered to be in a state warranting caution (nine on the Atlantic coast and eight on the Pacific coast; Figure 4.13).

Worryingly, 45 per cent of Canada's stocks are currently in an unknown state (n=52) (Figure 4.13).

Figure 4.13: Stock status designations by region for 115 stocks as determined by DFO

The designated status for Canadian fisheries are based upon DFO's Precautionary Approach Framework and determined based on the stock status and fishing mortality in relation to defined reference points. Stocks are designated as being critical (red), cautious (yellow), or healthy (green) state, or are undeclared in cases where the status is unknown. The 10 stocks not shown on this figure include those managed by authorities other than DFO, such as ICCAT, which do not use the Precautionary Approach Framework designation method for fisheries.

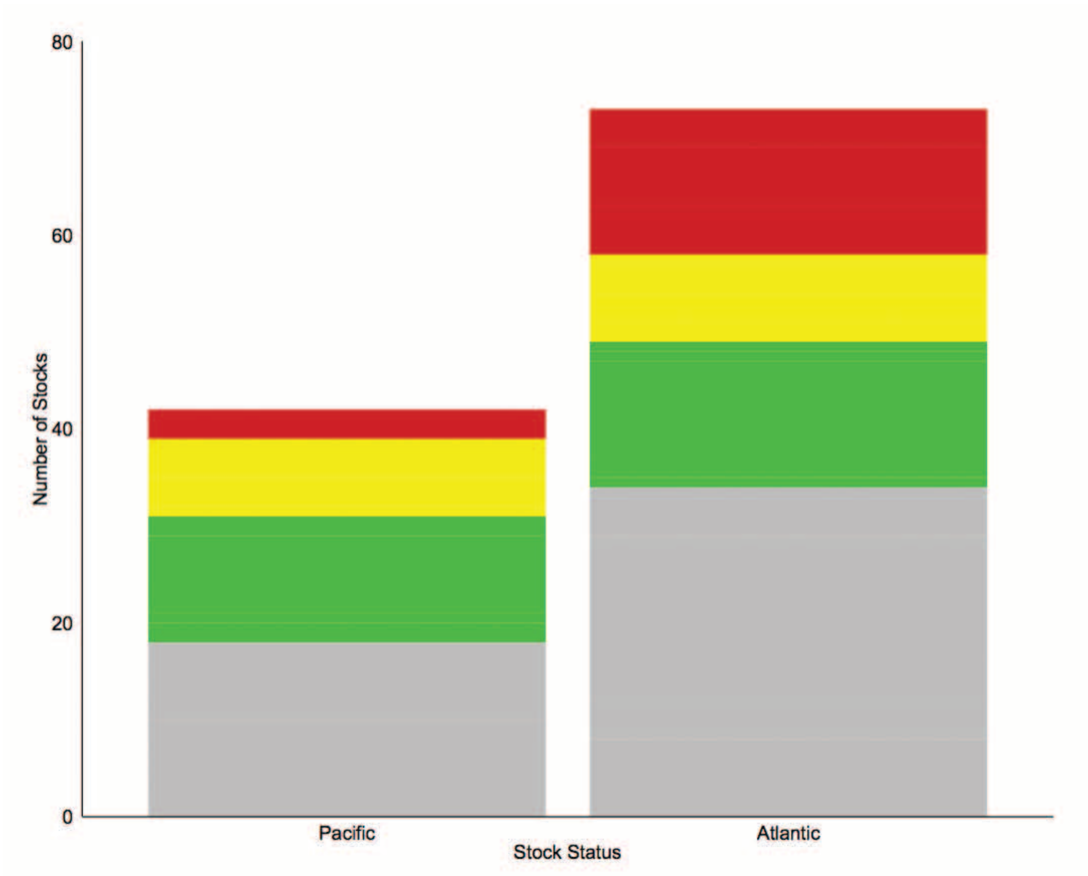
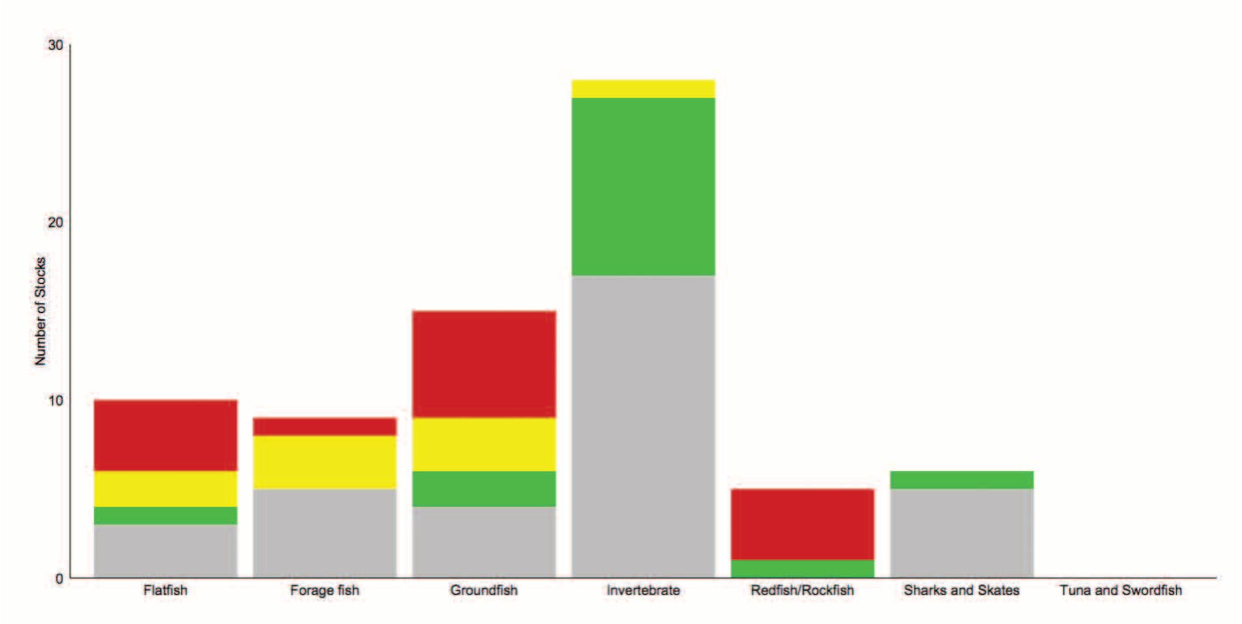
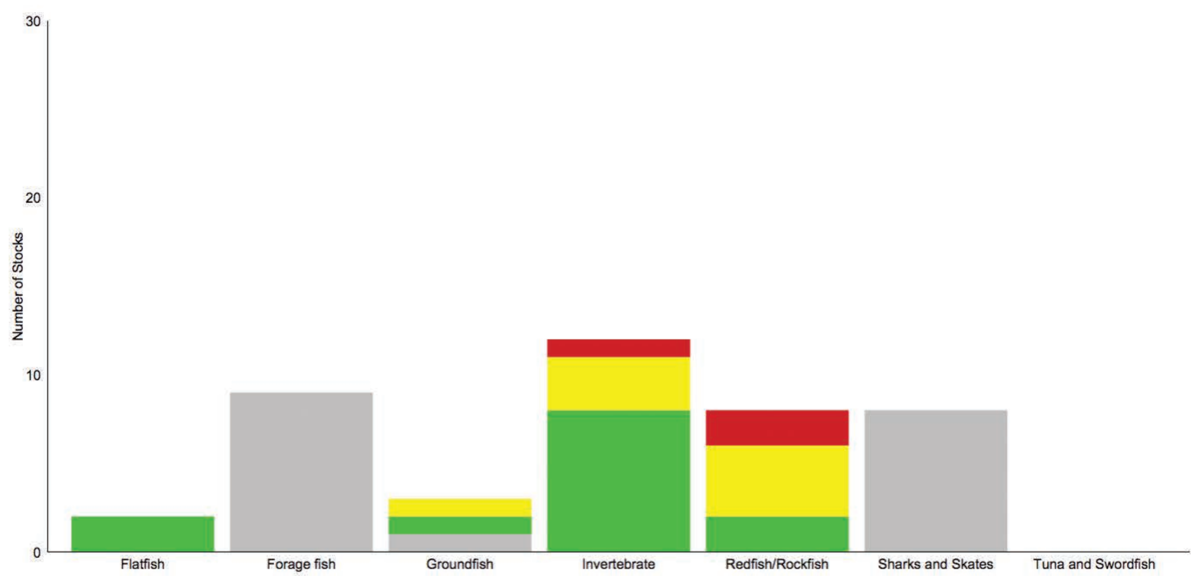


Figure 4.14: Atlantic (top) and Pacific (bottom) fisheries stock status designations by fishery type

The designated status for Canadian fisheries are based on the Precautionary Approach and are determined based on the stock status and fishing mortality in relation to defined reference points. Stocks are designated as critical (red), cautious (yellow), or healthy (green) or are undeclared in cases where the status is unknown. Stocks not shown on this figure include those managed by authorities other than DFO, such as ICCAT, which do not use the Precautionary Approach designation method for fisheries.



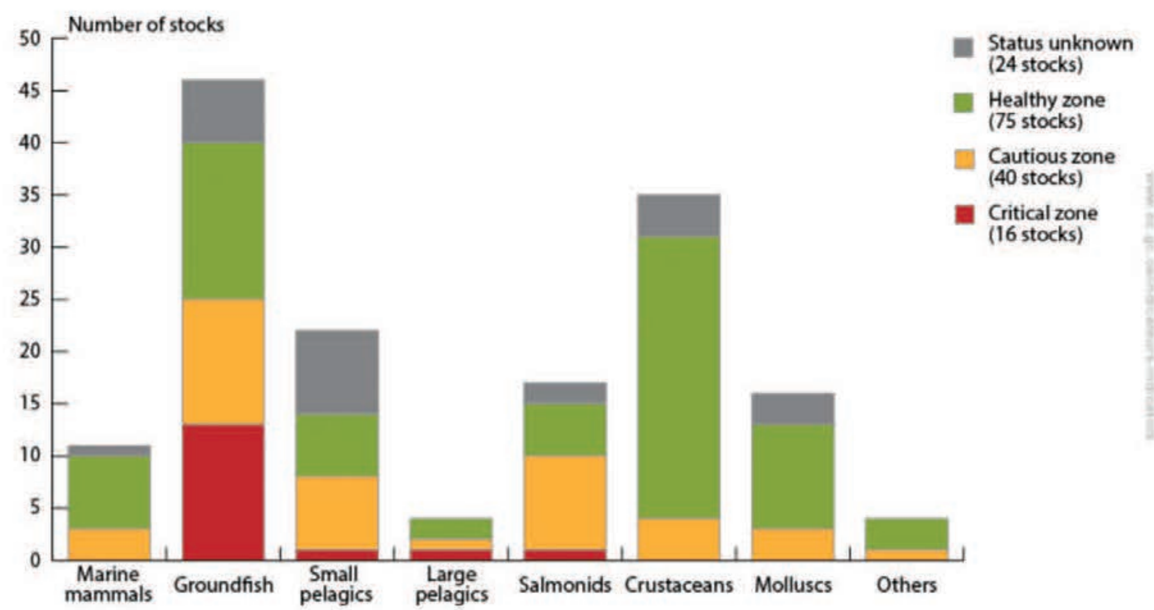


In the Atlantic, 15 stocks are considered to be in a critical state (Figure 4.14 top). Unsurprisingly, these include five cod stocks (northern cod, as well as cod in NAFO regions 3Pn4RS, 4TVn, 4X5Yb, and 5Zjm) (Table B3). Three American plaice stocks also are considered to be in critical condition (NAFO regions 23K, 3Ps, and 4T), along with witch flounder (NAFO 4RST), white hake (NAFO 4RS), mackerel and four redfish stocks (Table B3). The situation for mackerel is particularly worrisome because the current management decision directly contradicts the scientific advice to drastically reduce the quota for the stock (Box 3.3). No Atlantic invertebrates or elasmobranch stocks are considered to be "critical," but this may primarily reflect a dearth of knowledge about these stocks rather than the absence of a problem: more than 60 per cent of invertebrates and 80 per cent of elasmobranchs are classified as "unknown" (Figure 4.14).

On the Pacific coast, only three stocks are considered critical (northern shrimp in SMA 18-19, bocaccio and yelloweye rockfish; Figure 4.14, Table B3). All forage fish and elasmobranchs on this coast are, however, classified as unknown, making it impossible to determine the true status of the entire fished community (Figure 4.14).

There are striking discrepancies between our assessment of the status of Canada's marine stocks (n=115 of 125 presented in Figures 4.13 and 4.14) and the recent assessment, *Canadian Environmental Sustainability Indicators: Status of Major Fish Stocks*, by Environment and Climate Change Canada (2016; Figure 4.15), despite the fact that the information for stocks is ostensibly the same.

Figure 4.15: The status of 155 major "fish" stocks in Canada
Based on DFO's Fisheries Checklist, which is not publicly available (Source: ECCC 2016).



The ECCC report summarizes the state of 155 marine "fish" stocks in Canada, which include marine mammals, marine fishes, invertebrates, and others (Figure 4.15). According to the report, almost half of Canada's marine stocks (n=75) are healthy (Figure 4.15; ECCC 2016), which is substantially more than our calculations based on an examination of all available individual assessments (n=28). We note that the difference in sample size between our compilations cannot (alone) account for this discrepancy. Moreover, whereas we report 45 per cent of Canadian stocks as having an unknown status (n=52), ECCC reports that only 15 per cent (n=24) are unknown. ECCC reports one-quarter (n=40) of stocks are in the cautious zone in comparison to our 15 per cent (n=17), and a similar number of stocks (n=16) as being critical as we do (n=18).

Because the data that were used to develop the ECCC report are not included in the report, we are unable to fully understand these discrepancies. The methodology was also opaque: it is unclear which individual stocks have been included and evaluated since no list is available in the document (ECCC 2016); nor is DFO's Fisheries Checklist, upon which the document is based, publicly available. Finally, it is unclear why a federal department other than DFO, which is responsible for Canada's fisheries, would publish such a document.

4.2.5 Current status of Canadian stocks – COSEWIC and DFO statuses

Species that have been assessed by COSEWIC as endangered or threatened or by DFO as critical should all be considered a high priority for recovery management actions (Table 4.3). For species (or stocks) with both types of assessments, the two approaches are reasonably well aligned, with the following exceptions: (i) several non-target species assessed by COSEWIC as endangered do not have recent DFO stock assessments; (ii) three stocks are assessed by COSEWIC as threatened or special concern but by DFO as healthy (an Acadian redfish stock, spiny dogfish in the Atlantic and yellowmouth rockfish), iii) three stocks that have not been assessed by COSEWIC are currently assessed by DFO as critical (Gulf of St. Lawrence witch flounder, Atlantic mackerel, and northern shrimp in SMA 18 and 19, although this invertebrate stock has fluctuated across various DFO stock status categories recently and thus is of less concern) (DFO 2012d) (Table 4.3). One of these overlooked stocks, Atlantic mackerel, is currently on the list of COSEWIC priorities for assessment as a "moderate" concern (COSEWIC 2016).

DFO is required to complete Recovery Potential Assessments (RPAs) for species assessed by COSEWIC, prior to the SARA-listing process. Recovery Potential Assessments evaluate current and recent species status, which is important because COSEWIC assessments occur on average only every 10 years for each species (unless there are special circumstances that require a shorter time frame). The RPA process is also intended to assess the scope for fisheries management to facilitate recovery and to explore scenarios for mitigation and alternatives to the primary activities that threaten the species or population of interest (DFO 2007d). Despite their importance, RPAs have not been conducted for many of the species highlighted in Table 4.3. Many of the RPAs that have been conducted are now several years old (Table 4.3), and it is unclear what progress, if any, has been toward recovery for these species.

Table 4.3: Conservation and fisheries status of Canadian marine fishes and invertebrates

Status and reference points of those marine species that have been assessed by COSEWIC as endangered (EN), threatened (TR) or special concern (SC), or assessed by DFO as being in the critical zone. Taxonomic codes: F=Flatfish, FF=Forage fish, G=Groundfish, I=Invertebrate, R=Redfish/rockfish, SS=Sharks and skates, TS=Tuna and swordfish. COSEWIC typically assesses marine fishes at a broader spatial scale than DFO. For Atlantic species, DFO stock names refer to NAFO divisions. NLR=No longer at risk; NL=Not listed; "Included" indicates if the stock is included (1) or not (0) in the 125 stocks reviewed herein. Year refers to the year of the most recent recovery potential assessment (RPA Year) and stock assessments (Assess Year); Ref. points=reference points estimated in the most recent stock assessment: lower (LRP) and upper (USR) stock reference point, FMSY=F at MSY, Blim=Other biomass limit reference point. Stock status=Status under DFO's Precautionary Approach Framework: H=Healthy, C=Cautious, CR=Critical, U=Unknown. NA=Assessed by NAFO and so does not have status under the Precautionary Framework.

Species	Scientific name	Taxa	COSEWIC population	DFO Stock	COSEWIC status	SARA listing	Inclu-ded	RPA year	Assess year	Ref. points	Stock status
ATLANTIC COAST											
American plaice	***Hippoglossoides platessoides***	F	Newfoundland and Labrador	23K	TR	NL	1	2011	2014	LRP	U
				3Ps			1	2011	2012	LRP, USR	CR
				3LNO			1	2011	2014	-	NA
		F	Maritimes	4VWX	TR	NL	1	2011	2012	LRP, USR, FMSY	C
				4T			1	2011	2012	LRP	CR
Witch flounder	***Glyptocephalus cynoglossus***	F	Gulf of St. Lawrence	4RST	NL	NL	1	-	2012	LRP, FMSY	CR
Mackerel	***Scomber scombrus***	FF	Atlantic	Atlantic	NL	NL	1	-	2014		CR
Atlantic cod	***Gadus morhua***	G	Laurentian North	3Pn4RS	EN	NL	1	2011	2015	LRP	CR
				3Ps			1	2011	2016	LRP, USR	C
		G	Laurentian South	4TVn	EN	NL	1	2011	2015	LRP	CR
				4VsW			1	2011	2011	LRP, USR	C
		G	Southern DU	4X5Yb	EN	NL	1	2015	2015	LRP	CR
				5Zjm			1	2015	2015	LRP, USR	CR
		G	Newfoundland	2J3K	EN	NL	1	2011	2015	LRP	CR
				3NO			1	2011	2013	-	NA
Atlantic wolffish	***Anarhichas lupus***	G	Arctic, Atlantic	Atlantic	SC	SC	0	-	2014	-	U
Cusk	***Brosme brosme***	G	Atlantic	Atlantic	EN	NL	0	2014	2014	LRP, USR	C

Species	Scientific name	Taxa	COSEWIC population	DFO Stock	COSEWIC status	SARA listing	Inclu-ded	RPA year	Assess year	Ref. points	Stock status
Northern wolffish	***Anarhichas denticulatus***	G	Arctic, Atlantic	Atlantic	TR	TR	0	-	2014	-	U
Roughhead grenadier	***Macrourus berglax***	G	Atlantic	-	SC	NL	0	-	-	-	-
Roundnose grenadier	***Coryphaenoides rupestris***	G	Atlantic	Atlantic	EN	NL	0	2011	2011	-	U
Spotted wolffish	***Anarhichas minor***	G	Arctic, Atlantic	-	TR	TR	0	-	2014	-	U
White hake	***Urophycis tenuis***	G	Southern Gulf of St. Lawrence	4T	EN	NL	1	-	2012	-	U
		G	Atlantic, Northern Gulf of St. Lawrence	4RS	TR	NL	1	-	2015	-	CR
				4VWX5			0	-	2013	-	U
				3NOPs			1	-	2012	-	NA
Acadian redfish	***Sebastes faciatus***	R	Atlantic	3LNO Units 1 and 2	TR	NL	1	2011	2011	LRP, USR, FMSY	CR
				Unit 3			1	2011	2011	LRP, USR, FMSY	H
Deepwater redfish	***Sebastes mentella***	R	Gulf of St. Lawrence, Laurentian Channel	Units 1 and 2	EN	NL	1	2011	2011	LRP, USR, FMSY	CR
		R	Northern population	23K	TR	NL	1	2011	2011	LRP, USR, FMSY	CR
Basking shark	***Cetorhinus maximus***	SS	Atlantic		SC	NL	0	-	2008	-	-
Blue shark	***Prionace glauca***	SS	Atlantic		SC	NL	0	-	2015	-	-
Porbeagle shark	***Lamna nasus***	SS	Atlantic		EN	NL	1	2015	2015	USR, FMSY	U
Shortfin mako	***Isurus oxyrhinchus***	SS	Atlantic		TR	NL	0	2006	2006	-	-
Smooth skate	***Malancorja senta***	SS	Laurentian-Scotian population	4T	SC	NL	1	-	2012	-	U
				4VWX			0	-	2011	-	U
			Funk Island Deep	Funk Island Deep DU (2J3K)	EN	NL	1	2013	2013	-	U
Spiny dogfish	***Squalus acanthias***	SS	Atlantic	Atlantic	SC	NL	1	-	2015	LRP, USR, FMSY	H

Species	Scientific name	Taxa	COSEWIC population	DFO Stock	COSEWIC status	SARA listing	Inclu-ded	RPA year	Assess year	Ref. points	Stock status
Thorny skate	***Amblyraja radiata***	SS	Atlantic	3LNOPs	SC	NL	1	-	2014	Blim, FMSY	NA
				4T			1	-	2012	-	U
				4VWX			0	-	2011	-	U
White shark	***Carcharodon carcharias***	SS	Atlantic		EN	EN	0	2006	2006	-	-
Winter skate	***Leucoraja ocellata***	SS	Gulf of St. Lawrence	4T	EN	NL	0	2006	2006	-	-
		SS	Eastern Scotian Shelf Newfoundland	4VW	EN	NL	0	2006	2006	-	-
		SS	Georges Bank-Western Scotian Shelf-Bay of Fundy		NLR	NL	0	-	-	-	-
Atlantic bluefin tuna	***Thunnus thynnus***	TS	Atlantic		EN	NL	1	2011	2012	-	-
PACIFIC COAST											
Eulachon	***Thaleichthys pacificus***	FF	Nass/Skeena	Nass/ Skeena	SC	NL	1	2012	2012	-	U
		FF	Central Coast	Central Coast	EN	NL	1	2012	2012	-	U
		FF	Fraser River	Fraser River	EN	NL	1	2015	2015	LRP, FMSY	U
Northern shrimp	***Pandalus borealis & P. jordani***	I	Pacific	SMA 18 and 19	NL	NL	1	-	2011	LRP, USR	CR
Bocaccio	***Sebastes paucispinis***	R	Pacific	Pacific	EN	NL	1	-	2012	LRP, USR, FMSY	CR
Canary rockfish	***Sebastes pinniger***	R	Pacific	Pacific	TR	NL	1	-	2009	LRP, USR	C
Darkblotched rockfish	***Sebastes crameri***	R	Pacific	Pacific	SC	NL	0	-	2008	-	-
Longspine thornyhead	***Sebastolobus altivelis***	R	Pacific	Pacific	SC	SC	0	-	2005	-	-
Quillback rockfish	***Sebastes maliger***	R	Pacific	Inside Strait of Georgia	TR	NL	1	2011	2011	LRP, USR, FMSY	C
		R	Pacific	Outside Strait of Georgia			1	2011	2011	LRP, USR, FMSY	C
Rougheye rockfish type I	***Sebastes sp. Type I***	R	Pacific		SC	SC	0	-	2005	-	-
Rougheye rockfish type II	***Sebastes sp. Type II***	R	Pacific	Pacific	TR	TR	0	-	2005	-	-

Species	Scientific name	Taxa	COSEWIC population	DFO Stock	COSEWIC status	SARA listing	Inclu-ded	RPA year	Assess year	Ref. points	Stock status
Yelloweye rockfish	***Sebastes ruberrimus***	R	Pacific	Strait of Georgia	SC	SC	1	2012	2015	LRP, USR, FMSY	CR
Yellowmouth rockfish	***Sebastes reedi***	R	Pacific	Pacific	TR	NL	0	2012	2012	LRP, USR, FMSY	H
Basking shark	***Cetorhinus maximus***	SS	Pacific	Pacific	EN	EN	0	2009	2009	-	-
Bluntnose sixgill shark	***Hexanchus griseus***	SS	Pacific		SC	SC	0	-	-	-	-
North Pacific spiny dogfish	***Squalus suckleyi***	SS	Pacific	Inside Strait of Georgia	SC	NL	0	-	2011	-	-
				Outside Strait of Georgia			0	-	2011	-	-
Tope shark	***Galeorhinus galeus***	SS	Pacific		SC	SC	0	-	-	-	-

4.2.6 Integrated Fisheries Management Plans

Of the 125 stocks assessed here, 80 have Integrated Fisheries Management Plans (IFMPs) (Table B4). As with many of the findings, there is a sharp contrast between Canada's East and West Coast: only 48 per cent of stocks in the Atlantic have IFMPs, whereas 95 per cent of those in the Pacific have IFMPs that are either publicly available online or have a summary with contact information available for the fisheries manager from whom a full copy of the plan can be requested.

In Atlantic Canada, Newfoundland has published groundfish IFMPs for 2+3KL areas and 3Ps and these include a suite of groundfish species. However, there is no equivalent in the Maritimes or Gulf Region, where there are no groundfish IFMPs included on the DFO website. Also missing from Atlantic Canada IFMPs for herring and scallop, both of which are major fisheries in the area. Finally, Atlantic IFMPs tend to be out of date, while Pacific IFMPs are for the current and subsequent year. For the stocks included here, only IFMPs for two stocks of eulachon were missing from the Pacific (Table B4).

4.3 Summary of results

Stock assessments

- We identified 165 stocks and accessed the data for 125 of them. The remaining 40 stocks had DFO stock assessments but were not included in our analyses either because we were unable to obtain the required data (n=15), the data were deemed unreliable (n=5) or the stock assessments were outdated (n=20).

- Of the 125 stocks we examined, 82 are found on Canada's Atlantic coast (n=28 species total) and 43 are on Canada's Pacific coast (n=18 species total).

- For 23 Canadian stocks, the data already present in the RAM database were from the most recent stock assessment. For the other 102 stocks (82 per cent), we provided updated stock assessment data or additions of new stocks to the database (n=62 Atlantic stocks, n=40 Pacific stocks).

- The infrequency with which stock assessments are being conducted and the lack of Research Documents for some recent assessments should be regarded as significant impediments to sound fisheries management and fisheries recovery in Canada.

- Framework assessments are the most comprehensive type of stock assessment conducted in Canada.

- Ninety per cent of the stock assessments (n=116) included data on total catch or total landings (Table 4.2). Almost two-thirds (63 per cent) of recent stock assessments also included a population dynamics model, from which an estimate of stock abundance was generated (n=79, Table 4.2). Accurate estimates of fishing intensity are critically important for managing and recovering wild populations, yet only one-quarter of the reviewed stocks had an estimate of fishing mortality or exploitation rate (Table 4.2). Moreover, there are 22 stocks (18 per cent) without any existing measure of abundance or relative abundance.

Abundance estimates

- Of the 79 stocks with an abundance estimate available from their most recent stock assessment, the length of the available abundance time series varied widely (Figures 4.4, 4.5). In Atlantic Canada, abundance data for 25 marine fish stocks extend to the 1970s, with most of the remaining fish time series starting in the 1980s or early 1990s. In contrast, abundance data were only available for five of the invertebrate stocks. In Pacific Canada, abundance data for all but one marine fish stock are available going back to 1970, whereas data for the 12 shrimp stocks are available only since the late 1990s (Figure 4.5).

Reference points

- Just over one third (n=47) of overall stocks have B_{MSY} estimated, and only one-quarter (n=30) have F_{MSY} estimated (Figure 4.6, Table B2). Almost the same number has an alternative F-based reference point estimated (Table B2). The proportion of stocks with MSY-based reference points differs by coast: along the Atlantic coast, 33 per cent and 18 per cent of stocks have B_{MSY} and F_{MSY} estimated, respectively, while on the Pacific coast, 72 per cent of stocks have B_{MSY} and 35 per cent of stocks have F_{MSY} (Figure 4.6). Upper and lower reference points have been estimated for 46 per cent and 62 per cent of Canadian stocks, respectively. Again, the proportion of Atlantic stocks with these reference points estimated (41 per cent and 57 per cent) is lower than on the Pacific coast (53 per cent and 70 per cent respectively) (Figure 4.6).

Stock status

- According to our compilation of individual DFO stock assessments (and the Precautionary Approach Framework categories reported within each assessment), very few of Canada's marine fish and invertebrate stocks (24 per cent) are currently considered healthy by DFO: 15 on the Atlantic coast and 13 on the Pacific coast (Figure 4.13). Forty-five per cent of Canada's stocks are currently in an unknown state. Eighteen stocks are considered critical (Figure 4.13).

- We have highlighted a dangerous gap between the scientific advice for Canada's mackerel quota and what is implemented by management (Box 3.3). The implemented quota will need to be brought in line with the scientific advice if this stock is going to have a chance to recover. Substantial discrepancies between scientific and management advice may exist for other Canadian stocks, but until DFO's management decisions are made public, it will not be possible to identify these discrepancies or align competing figures.

- We have also highlighted a striking discrepancy between our results and those of the 2016 Environment and Climate Change Canada report on the status of Canada's stocks, which presents a much more optimistic portrait of the status of Canada's stocks regarding the proportion of stocks reported as healthy and those with an unknown status.

5. WHAT IS PREVENTING FISHERIES RECOVERY?

Overfishing remains the primary reason why many of Canada's commercially harvested marine fish and invertebrate stocks are depleted and in need of recovery. This section reviews the drivers of overfishing in Canada and highlights areas for improvement.

5.1 The drivers of overfishing

5.1.1 Targeted fishing

Exploiting fish at higher levels than can be sustained by population replacement or supported by the ecosystem leads to long-term population decline and impacts the ability to recover. The main factor of overfishing is the level of exploitation that consistently exceeds scientific advice, typically estimated by fishing mortality (F) (Rosenberg 2003).

Setting and enforcing science-based catch limits is critical to ensuring that exploitation rates are sustainable. Managers responsible for setting catch limits must account for multiple interacting factors and competing interests: scientific advice for setting catch limits is often given a lower priority when pitted against political, social and economic pressures. There is no requirement in Canada that quotas or Total Allowable Catch (TAC) levels be set at levels recommended by science, or even at catch levels when those levels are below the scientific advice. Recent examples in Canada include setting the 2014 mackerel quota at 8,000 tonnes, when the scientific advice was for 800 tonnes (DFO 2015e; Box 3.3) and setting the 3Ps cod quota at 13,225 tonnes in 2014-2015 when catches were less than 5,600 tonnes and total spawning stock biomass estimates were less than 16,000 tonnes (DFO 2016c). Additionally, the vast amount of ministerial discretion inherent in the *Fisheries Act* allows for politically motivated fisheries management decisions.

In Canada, there is evidence of sequential overfishing and at increasingly lower trophic levels, where resources are exploited at increasingly lower levels on the marine ecosystem food chain (Pauly et al. 2001). The increasing volume and value of invertebrate fisheries, particularly in Atlantic Canada, is indicative of the depletion of many Canadian fish stocks and of predation release (i.e. reduced predation from the large fish) of the invertebrates having occurred.

Overfishing has also been linked to trophic cascades, where the reduction in a target species has unintended consequences on lower trophic levels (Myers et al. 2007, Daskalov et al. 2007, Baum and Worm 2009). In addition to disrupting the marine ecosystem, overfishing requires management responses that often result in a significant reduction in fishing access and quotas, which in turn disrupts the social and economic dynamics of fishing communities.

While directed overfishing is the most obvious factor leading to stock decline and collapse, catch of juveniles, non-target species, habitat impacts through fishing gear and failure to consider the impacts of the ecosystem on fisheries can all lead to the depletion of commercially exploited fish populations.

5.1.2 Bycatch and discards of target species, non-target species and species at risk

Impacts on non-target species and on non-target individuals within target populations (e.g. undersized individuals) through bycatch, fishery discards and high-grading can drive population declines and have further collateral impacts on marine ecosystems.

Information about ecosystem impact is lacking in many Canadian fisheries. Observers are often required to report only on discarded species of commercial value, and non-commercial discards are often ignored, particularly in Atlantic Canada (Gavaris et al. 2010). The Integrated Pacific Groundfish Management Plan in the Pacific region requires fleet-wide bycatch limits and monitoring and catch reporting (DFO 2012b). DFO's 2013 Policy for Managing Bycatch provides the basis for managing bycatch and discards; however it has not been implemented fully in any particular fishery since it was adopted.

In Atlantic Canada, there has not been a comprehensive, quantitative overview of bycatch; however Gavaris et al. (2010) reviewed data on bycatch in NAFO areas 4VWX and 5YZ between 2002 and 2006. They note that the level of observer coverage is not sufficient to provide overall bycatch estimates. Bycatch in the lobster fishery, which is Atlantic Canada's largest fishery by volume and value, also includes at-risk marine fish that are not listed (Pezzack et al. 2014), but the bycatch-related mortality of these species is not generally included in estimates of overall fishing mortality.

Discards of sharks in the swordfish fishery, skates and spiny dogfish in the groundfish fishery, herring and basking shark in the silver hake fishery and flatfish in the shrimp fishery are some examples of discards of non-target species that are of concern. In the Pacific groundfish trawl fishery, discarded bycatch amounted to 20 per cent by biomass of the total catch between 1996 and 2006 (Driscoll et al. 2009). Of these discards, 30 per cent were non-commercial species, for which there are no management measures in place. A 2006 Groundfish Pilot Integration Program focused on improving bycatch management in the Pacific groundfish bottom trawl fishery and included individual quotas on bycatch species and 100 per cent at-sea electronic monitoring or on-board observers (see summary IFMP for 2016 measures, DFO 2016d).

Bycatch of juveniles of target species

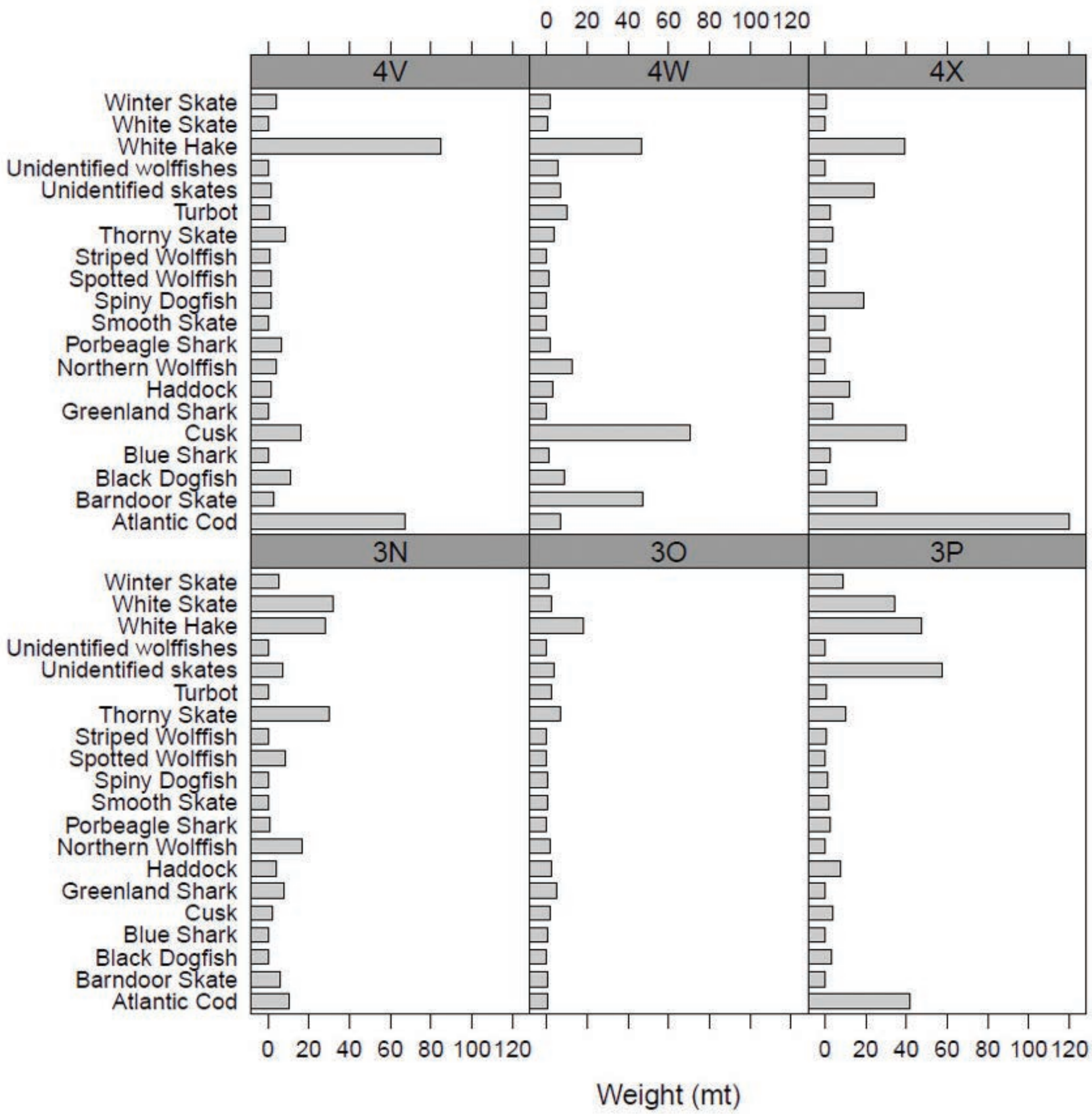
An example of overfishing of juveniles in Atlantic Canada is the impact that Canada's groundfish trawl fishery used to have on juvenile Atlantic halibut prior to the general groundfish collapse (Trzcinski and Bowen 2016). This impact has only been realized after the fact. Atlantic halibut have been one of the few groundfish stocks in Atlantic Canada to demonstrate consistent recovery since the 1990s. Its recovery is attributed to reduced fishing mortality on its juveniles resulting from the various moratoria on Canada's groundfish fisheries. This has allowed those cohorts to spawn and in turn increase the spawning stock biomass to a time series high in the most recent assessment (DFO 2015i). In this instance, depletion of halibut was not only caused by direct overfishing by the bottom longline fleet but also by overfishing of juveniles by the trawl fleet.

Bycatch of non-target species

Negative impacts on non-target species are prevalent in most Canadian fisheries. The few exceptions occur where the gear type is highly selective (i.e., swordfish harpoon, dive fisheries for scallops, urchins and sea cucumbers) (Fuller et al. 2008, Gavaris et al. 2010). There are several examples of the impacts of target fisheries on non-target species, although this is sometimes difficult to clarify, given the multispecies nature of many of Canada's fisheries, for groundfish in particular.

However, as stocks recover, it is critical that the impacts of increased Total Allowable Catches and fishing effort on the target fishery do not inadvertently impact depleted species that are part of the bycatch of the recovering target fishery. The Atlantic halibut fishery can be used as an example in this case as well, with more than 70 species caught as bycatch, and with the most abundant bycatch species – white hake, Atlantic cod and cusk – all considered endangered by COSEWIC (Figure 5.1).

Figure 5.1: Estimated bycatch from the halibut-directed longline fishery in 2013 by NAFO area based on the at-sea observer catches (2009-2013) (Source DFO 2015i).



As fisheries have shifted largely to invertebrates on the Atlantic coast, there has been a lack of monitoring of bycatch of other species, making it impossible to quantify impacts on bycatch species. This is especially true in the lobster fishery. Gavaris et al. (2010) estimated that 400 tonnes of cod were caught as bycatch in the lobster fishery in southwest Nova Scotia, yet none of this fishing mortality is included in stock assessments for cod. On the Pacific coast, bycatch of eulachon in the pink shrimp fishery is of concern (DFO 1999). Efforts to reduce this bycatch have been attempted in the Oregon shrimp fishery in the U.S, by adding lights to the shrimp trawl gear (Hannah et al. 2015).

In Canada, efforts have been made to reduce the entanglement of SARA-listed species, including North Atlantic right whales and leatherback turtles: most fisheries that overlap the ranges of these at-risk species have voluntary guidelines to ensure live releases as part of their recovery plans (DFO 2006b, DFO 2009b).

Canada would benefit from a comprehensive review of bycatch across management regions and a subsequent implementation of the Bycatch Policy in priority fisheries once they are identified. DFO does collect information on many commercial fisheries through its Fisheries Checklist, however this information is not made public, so it is currently impossible to evaluate the level of overfishing that is occurring as a result of bycatch or non-targeted catch.

5.1.3 Illegal, unreported and unregulated (IUU) fishing

Illegal and unreported fishing activity is fishing that contravenes the law or established regulations, and unregulated fishing occurs when there are no management measures for a fishery. Canada has a relatively sophisticated fisheries management system, as well as monitoring, control and surveillance systems ranging from dock-side monitoring and vessel-monitoring systems to vessel boarding by fisheries officers and aerial surveillance in some regions. As a result, the amount of IUU fishing as compared to other regions is likely relatively low (Pauly and Zeller 2016).

A 2010 European Union (EU) regulation on IUU fishing has meant that Canada must validate that all seafood being exported to the EU comes from legal sources. Despite this, there are examples of illegal, unreported and unregulated fishing that negatively impact Canada's fisheries. As an example, Atlantic halibut have increased substantially in recent years, representing one of the few recoveries of Canada's groundfish. The harvest control rule (HCR) for this fishery limits quota increases to no more than 15 per cent per year. This strict HCR is beneficial for halibut recovery; however it has also led to a tendency for fishers to overfish their quota allocations because they are seeing more halibut than they have in decades. This resulted in a concentrated effort by DFO Conservation and Protection (C&P) to identify illegal halibut fishing. Several charges were laid in 2014 and 2015, with fines totalling more than $1 million (DFO 2015j). High-grading bluefin tuna in the recreational fishery was also detected in the Gulf of St. Lawrence, with a recent licence suspension (CBC coverage 2016).

Unregulated fisheries do not run rampant in Canada, as all recreational and commercial fisheries need licences. However, there are many examples where the amount of fish that is taken is unregulated, either without a set catch limit, landings reported or available management plan. One of the most obvious examples of this is the bait fishery for Atlantic mackerel, which does not require that fishers report their catches. This could be considered unregulated, as there are no estimates of fishing mortality on this portion of the fishery, no set Total Allowable Catch, nor any management regulations placed on the bait fishery.

Non-compliance with fishing limits and regulations and other forms of illegal fishing further undermine fishing mortality targets and estimates of stock abundances, driving further decline. Monitoring and estimates for illegal, unreported and unregulated catch (IUU) is inherently difficult to quantify accurately. Estimates for British Columbia's salmon and groundfish fisheries suggest that better enforcement, enhanced data collection and compulsory observer programs within the Pacific groundfish trawl fishery have contributed to declines in discards, illegal catch and unreported catch (Ainsworth and Pitcher 2005). Compliance issues in Canadian fisheries include failing to comply with reporting requirements, fishing in unlicensed areas, late submission of log books and offload reports, lack of proper weighing of species and product type at offload and unattended gear.

5.1.4 Gear impacts on bycatch species and habitat

Fishing gear with the greatest ecological impacts, including bycatch and habitat impacts, include bottom trawls, bottom gillnets and dredges (Fuller et al. 2008). This is a similar finding to a gear impact study conducted in the U.S. (Chuenpagdee et al. 2003).

Lower-impact gear types are available, such as bottom longlines for groundfish and harpoons or rod and reel for large pelagics, but management decisions are not made based on the ecosystem impacts of fishing. A notable example is the allocation of 90 per cent of the swordfish quota to the pelagic longline fleet, which catches sharks, leatherback turtles, tuna and juvenile swordfish as bycatch (Gavaris et al. 2010). Swordfish can be caught using harpoons, which have no bycatch, yet this gear type is allocated to only 10 per cent of the quota (DFO 2015k). Pelagic longliners can fish using harpoon, but there is no mandatory use of this gear type. Significant reductions in bycatch could be achieved by adjusting the allocation by gear type.

Damage to the seafloor habitat from fishing gear is a significant contributor to the ecological impact of fishing activity and can have impacts on commercial species and on marine diversity (Thrush and Dayton 2002, Althuas et al. 2009, Bolam et al. 2014). Progress has been made in Canada to identify significant structural habitats, including cold-water coral and sponges (Kenchington et al. 2010). However, the direct link between these habitats and their importance to commercial fisheries has been less clear. In situ evidence on the West Coast demonstrates that rockfish prefer complex habitats (Du Preez and Tunnicliffe 2011).

Selective fishing practices include using gear and practices that avoid or release non-target species, and they are included in DFO's Policy for Selective Fishing in Canada's Pacific Fisheries (DFO 2001). However, there are no indicators or data to show the conservation effects of this Policy and the selective fishing techniques developed (DFO 2005), nor has a national policy on selective gear been developed.

Spatial measures to mitigate gear impacts

Some efforts to better understand the trawl footprint in Canada have been made, particularly on the West Coast (Wallace et al. 2015). On the East Coast, mapping the change in trawl effort after the groundfish moratorium (Kulka and Pitcher 2001) has led to more recent efforts in Atlantic Canada (DFO 2016e): there are two coral and two glass sponge closures in Maritimes region (Figure 5.2) and a management closure in the eastern Arctic, all of which restrict fishing and total 14,705 km^2 (DFO 2015).

Initiatives by the British Columbia trawl fleet to close areas to fishing that contain corals and sponges and to adopt a fleet-wide bycatch limit on coral and sponge bycatch are examples of proactive conservation measures taken by the fishing industry (DFO 2010b, Wallace et al. 2015). The British Columbia trawl fleet is now attempting to further reduce its impact with mid-water trawling where possible. Such measures will reduce the impacts of fishing gear damage and loss and reduce impacts on the seafloor ecosystem.

Further, the Pacific Region outlines the areas that are open and closed to bottom trawling, including 186 rockfish conservation areas, established in 2007, that are closed to bottom trawling (DFO 2007b) (Figure 5.3). This is a considerably more precautionary and conservation-oriented approach than that of the Atlantic Region.

Figure 5.2: Coral and sponge conservation areas in Maritimes Region
including the Northeast Channel and *Lophelia* closures for deep-sea coral, closures for glass sponges (*Vazella pourtalesii*) and the Gully Marine Protected Area (Source DFO: 2015r).

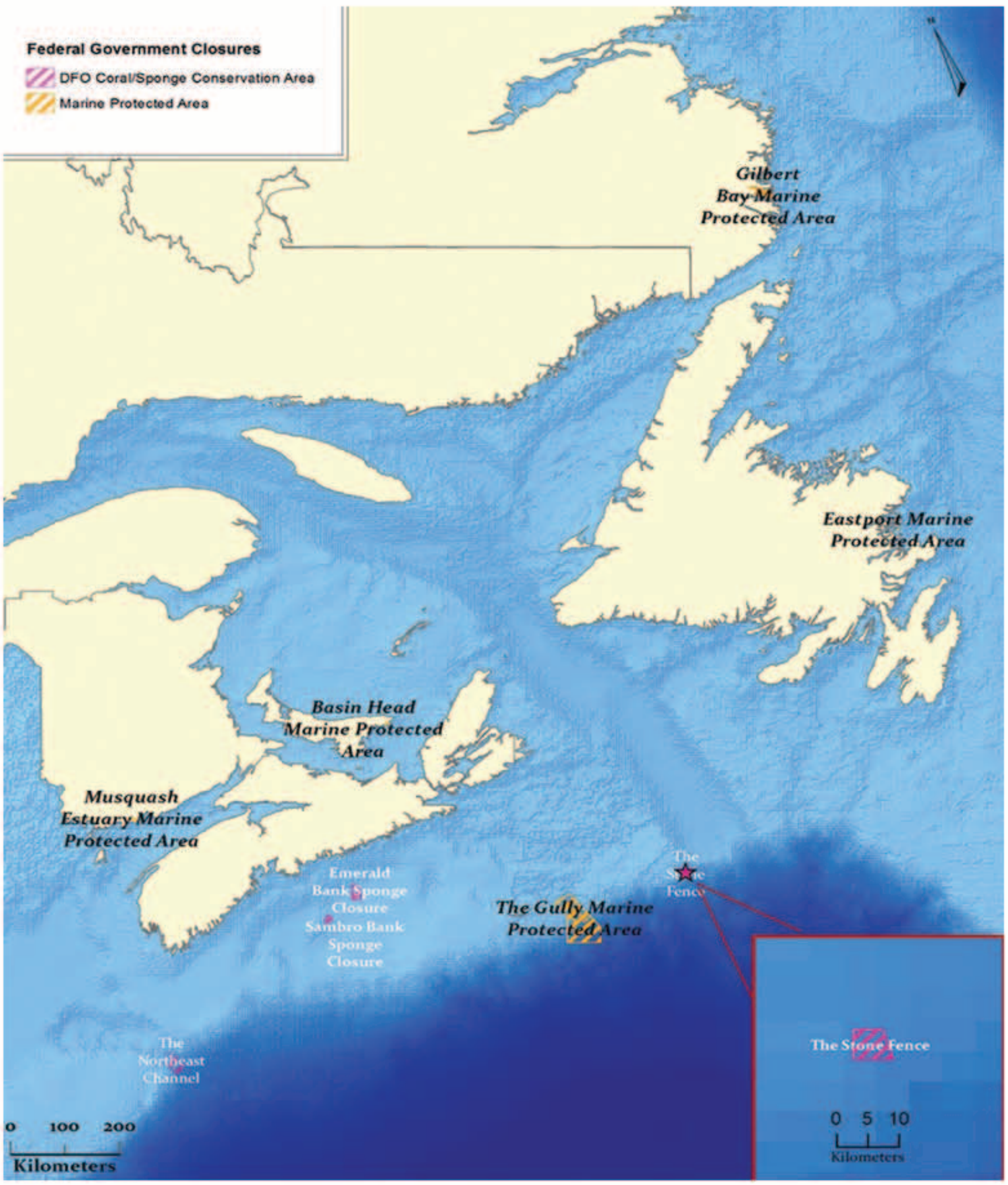
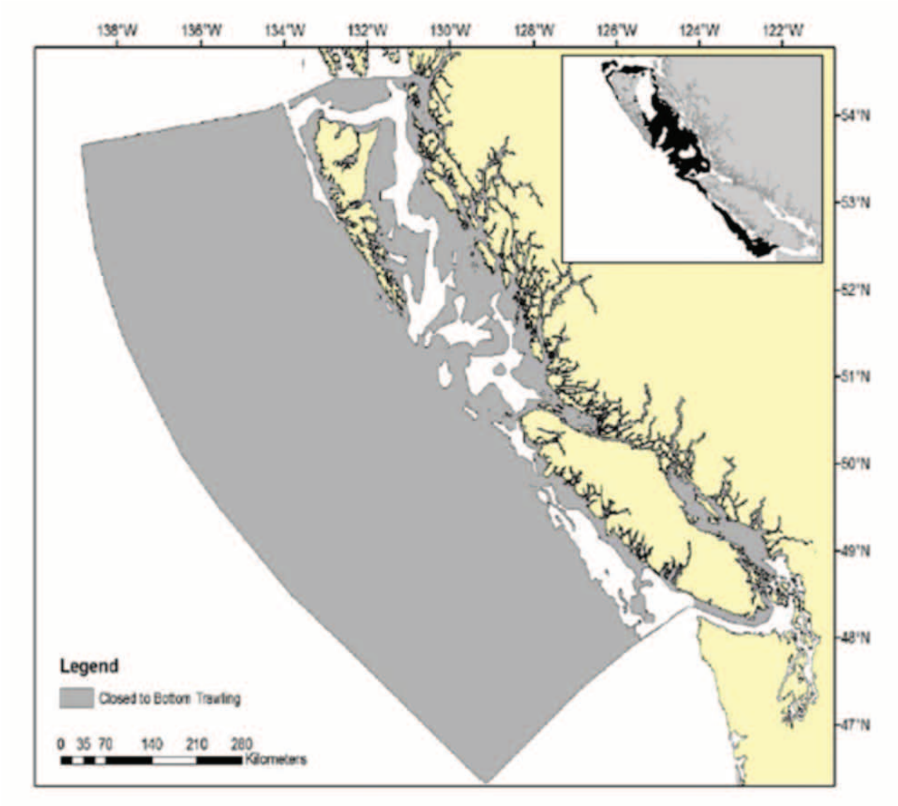


Figure 5.3: Areas on Canada's Pacific coast closed to bottom trawl fishing since 2012
Consistent with the new habitat conservation measures for corals and sponges (Source: COSEWIC 2013).



Other jurisdictions have set aside large areas of their continental shelves from destructive fishing activity. For example, New Zealand has restricted bottom trawling in areas both within and beyond its Exclusive Economic Zone (EEZ), totalling approximately 30 per cent as of 2007 and covering 1.2 million square kilometres. The United States has protected two-thirds of its waters from bottom trawling and dredging. The 2006 United Nations Sustainable Fisheries Resolution called on all states to avoid impacts of bottom trawling on the high seas and to protect vulnerable marine ecosystems. To date, the Northwest Atlantic Fisheries Organization (NAFO) and its contracting parties have set aside 20 areas from bottom trawling, including seamounts and coral, sponge and seapen populations (NAFO 2015). Canada has made some progress in protecting areas from the impacts of fishing, but there is considerable work to be done, particularly in the Labrador Shelf and Eastern Arctic.

In addition to closing some areas of cold-water coral and sponges to fishing activity, Canada has also closed some spawning areas that are important for commercial species and has a mandate to implement Marine Protected Areas (MPAs) under the *Oceans Act*. MPAs can be used as fisheries management tools to recover depleted species and protect critical habitat; however they generally have broader biodiversity protection objectives. The value of spawning closures and MPAs in terms of protecting and recovering depleted fish populations has not been evaluated in Canada. Additionally, Canadian MPA management tends to also allow fishing in certain zones – generally a measure used to ensure that the fishing industry does not oppose their establishment.

5.1.5 Failure to consider marine fisheries in an ecosystem context

Ecosystem-based fisheries management includes mitigating fishing gear impacts on non-target life stages and species, closing coral and sponge areas to bottom fishing activity, protecting spawning grounds and establishing MPAs. To date, Canada has not effectively implemented ecosystem-based management, although elements of such management exist. The Sustainable Fisheries Framework incorporates elements of the ecosystem approach but has yet to be applied comprehensively across any fishery (McDevitt-Irwin et al. 2015).

To help build an ecosystem-based approach in the Northwest Atlantic Fisheries Organization (NAFO), the Working Group on Ecosystem Assessment (WG-ESA) has been developing a roadmap that includes analyzing the productive capacity of the ecosystem and predator-prey interactions (NAFO 2015). DFO's Science Management Board established a framework for ecosystem science (DFO 2007c), but there has been no evaluation of how this framework has been applied.

An ecosystem-based approach is critical to achieving population recovery. For example, Atlantic cod and Northern shrimp cannot recover simultaneously, and understanding how and where critical habitat needs to be protected is important for the recovery of many groundfish species. An ecosystem-based approach is also needed to reduce bycatch, particularly of juveniles in the shrimp fishery and bottom trawl fishery in Atlantic Canada. Establishing area closures, including spawning closures, protecting vulnerable marine ecosystems, and having MPAs as part of effective fisheries management are all critical aspects of the ecosystem approach.

Canada has taken a piecemeal approach to managing Pacific groundfish across fisheries, with bycatch limits, area closures and reducing the trawl footprint making it as close to full ecosystem-based management as any fishery in Canada. Climate change will have increasing impacts on the marine ecosystem and on the ability of depleted species to recover, with some benefitting from warmer ocean temperatures and others being negatively impacted. Therefore, a comprehensive understanding of these impacts is needed.

5.2 Conclusion

Fish species and populations that are identified as threatened or endangered by COSEWIC can be considered to be in crisis. Fisheries in the DFO's critical zone can also be considered in crisis, and those in the cautious zone are in a state of depletion and require management measures to ensure that they are rebuilt to the healthy zone. Above and beyond this, however, Canada appears to be experiencing an even greater crisis in effectively implementing existing policies to achieve better fisheries management.

The management system within which recovery can be achieved is under conflicting pressures, particularly to respond to socio-economic, rather than biological, concerns. Without legally mandated, science-based recovery targets and timelines, prioritizing biological recovery will continue to be a significant challenge.

There are some examples of unregulated fisheries in Canada, primarily those without science-based allocations and management plans. Illegal and unreported fisheries are less common, although quantifying illegal fishing activities outside of known enforcement measures is difficult.

Despite the well-known negative impacts of some fishing gear on habitat and bycatch, Canada has yet to address these impacts by mandating low-impact gear to reduce bycatch of juvenile target species and non-target species. Some efforts have been made to close known areas of coral and sponge diversity, and the Pacific groundfish fishery has adopted innovative measures to reduce and avoid impacts on complex sea floor habitats. However, such a comprehensive approach has not been adopted nationally, and Canada could make progress by mandating that the least damaging fishing gear be used. A recent analysis of the use of trawls versus creels in Scottish fisheries for nephrops found that lower impact gear provided more employment and resulted in less environmental impact (Save Scottish Seas 2015).

5.3 Recommendations

The following measure should be taken to limit overfishing and impacts of fishing in Canada:

- Ensure that fisheries managers can reduce exploitation levels sufficiently as soon as overfishing is detected through setting and enforcing science-based catch limits. Precautionary harvest control rules should be established to ensure that there is adherence to science-based decision-making. Fishing mortality estimates should be obtained for species depleted from target and non-target fisheries, if possible.

- Identify and protect essential fish habitat where possible, especially for species that spend significant parts of their life histories on the seafloor, as has been done with rockfish conservation areas on the West Coast.

- Eliminate unregulated fisheries by ensuring quotas or effort controls are put in place for all commercial fisheries and that they all have up-to-date integrated fishery management plans.

- Where possible, provide incentives such as spatial measures and/or quota allocations to encourage use of lower-impact gear.

- Create a consistent national approach to identifying areas where bottom trawling can and cannot occur, rather than the current regional patchwork approach that differs widely between the Atlantic and the Pacific.

- As part of a broad ecosystem approach, incorporate knowledge of life history characteristics, Allee effects and vulnerability to climate change into fisheries recovery plans and rebuilding initiatives.

6. WHAT IS THE RECOVERY POTENTIAL FOR CANADIAN FISHERIES?

6.1 Key elements for recovery

Recovery of overfished marine populations is possible, and it can occur relatively quickly once fishing mortality is sufficiently reduced (Neubauer et al. 2013). Across species, exact recovery times vary depending on life history characteristics and the extent to which fishing mortality is decreased. Although long-lived, slow-growing species sometimes require many decades for recovery, a comparative analysis across 153 marine populations indicated that in many cases recovery back to MSY can occur within 10 years (Neubauer et al. 2013). Delays in management action to reduce fishing mortality not only delay recovery but also increase uncertainty in the recovery process itself.

Eight case studies illustrate that recovery is possible across a range of trophic levels, from apex predators (Northwest Atlantic swordfish) and groundfish species (Atlantic halibut, Georges Bank haddock) to small pelagics (Norwegian spring spawning herring) and invertebrates (Atlantic scallop) (Appendix A). While the targets for recovery vary, and there are few fisheries that have been restored to historical levels, it is clear that with proper fisheries management and reduction of fishing-related mortality, fish populations can increase following extensive overexploitation (Table 6.1).

In Canada, Atlantic halibut stands out as one of the only recovery success stories (Table 6.1). Its spawning stock biomass has increased significantly (B > B_{MSY}), catch rates are above the long-term average, and there is continued presence of pre-recruits in research trawl surveys (Trzcinski and Bowen 2016, DFO 2015i). While there is no rebuilding plan or specific closed areas for spawning or habitat, the groundfish moratoria following the cod collapse is expected to have reduced mortality of juveniles (Trzcinski and Bowen 2016). A harvest control rule is in place that restricts quota increases or decreases to no more than 15 per cent in a given year. While Atlantic halibut spawning stock is at the highest point in the time series (1970-2013), the fishery was established well before 1970, and as such, the recovery should be considered in a broader time frame in order to ensure adequate fisheries management and conservation and protection measures. Atlantic halibut are also considered to be highly vulnerable to climate change impacts (Hare et al. 2016).

Outside of Canada, there are several other recovered or recovering marine fish populations (Table 6.1). Eastern Georges Bank haddock are also considered to be recovered, with the stock considered healthy (current biomass at 208 per cent above target levels) and no overfishing occurring (NOAA 2015b). While there is no formal rebuilding plan, this stock is managed by the U.S. National Marine Fisheries Service, and under the Magnuson-Stevens Act there is a legal requirement to rebuild overfished populations. Both cod in 3M (Flemish Cap) and 3LN redfish are assessed by NAFO, which imposed moratoria on directed fishing that started in 1998 and were lifted in 2009.

Redfish are long lived and slow growing, and while the fishery has been reopened, recovery is considered to be still in progress as landings are considerably lower than historical levels and the stock is at 1.4 B_{MSY}.

The 3M cod fishery was the first of all Northwest Atlantic cod stocks to be considered recovered. However, the TAC has been exceeded in recent years, partially because the increase in cod has resulted in a concomitant decline in shrimp in 3M, a fishery that is now closed to directed fishing.

Lingcod in the Canadian Pacific have been under a moratoria on directed fishing since 1990, and while there are signs of recovery, it has been slow. Currently the stock is estimated at 0.8 B_{MSY}.

Sea scallops in the U.S. Northeast recovered as a result of closed areas, indicating that spatial protection is an effective mechanism for bivalve fisheries. Norwegian spring spawning herring recovered after a significant reduction in fishing mortality rate and an agreed rebuilding plan. Their subsequent significant recovery has been followed by a decline in numbers, but management measures are in place to constrain fishing effort.

Northwest Atlantic swordfish have recovered to above 1974 levels after a rebuilding plan was agreed at ICCAT. Spatial protections were put in place, including areas closed to directed fishing and an overall reduction in fishing effort.

Table 6.1: Overview of recovery elements for the eight species highlighted as recovery case studies (Appendix A), including science inputs to management, fisheries management tools, bycatch, habitat, ecosystem considerations and monitoring efforts. For each species, a checkmark indicates that the element is in place for the species (or for certain stocks of that species where individual stocks are denoted). The case studies include Canadian and international examples (Appendix A). Taxonomic Group: F=Flatfish, G=Groundfish, I=Invertebrate, SP=Small pelagic, LP=Large pelagic. Recovery stage: R=Recovered; IP=Recovery in progress. Recovery elements: NDF=No directed commercial fishing; RF=Recreational fishery; Min. Size=Minimum size restrictions; In dev.=In development; Mor.=Moratoria. MSA=Magnuson-Stevens Act, which legally requires a rebuilding plan. Climate vulnerability: L=Low, M=Medium, H=High.

	Atlantic halibut	**Eastern Georges Bank haddock**	**Flemish Cap (3M) cod**	**3LN Redfish**	**Lingcod**	**Atlantic sea scallops (U.S.)**	**Norwegian spring spawning herring**	**North Atlantic swordfish**
Taxa	F	G	G	G	G	I	SP	LP
Recovery Stage	R	R	R	R	IP	R	IP	R
Stock Status	$B \geq B_{MSY}$	Healthy	$SSB > B_{lim}$	$1.4B_{MSY}$	$0.8B_{MSY}$	$B > B_{target}$	$SSB < SSB_{MGT}$	$B \geq B_{MSY}$
Recovery Elements:								
Science Inputs								
Accurate estimates of stock biomass (or abundance) and stock status	✓	✓	✓	✓	✓ (Poor data availability)	✓	✓	✓
Science-based reference points, including LRP, URP and estimates for B_{MSY}	✓	✓	✓	✓	✓	✓	✓	✓

	Atlantic halibut	Eastern Georges Bank haddock	Flemish Cap (3M) cod	3LN Redfish	Lingcod	Atlantic sea scallops (U.S.)	Norwegian spring spawning herring	North Atlantic swordfish
Management Tools								
Quota, catch limit or effort control that aligns with scientific advice in place	✓	✓	X[1]	✓	✓	✓	✓	✓
Harvest control rules	✓	?	In dev.	?	?	✓	✓	In dev. at ICCAT
Reduced F	✓	✓	✓ (Mor. 1999-2009)	✓ (Mor. 1998-2009)	✓ (NDF since 1990)	✓	✓	✓
Rebuilding or recovery plan	-	✓ (MSA)	✓ (Mor. 1998-2009)-	✓ (Mor. 1998-2009)	✓ [2]	✓ (MSA)	✓	✓
Other	Min. size	Min. size	-	-	Min. size – RF	-	Min. size	Min. size
Bycatch								
Reduction in non-target fisheries	✓	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Habitat								
Closed areas for spawning	-	-	✓ (Mor. 1999-2009)	✓ (Mor. 1998-2009)	✓ [3]	✓	-	✓
Areas closed to directed fishing	-	-	-✓ (Mor. 1999-2009)	-✓ (Mor. 1998-2009)	-	-	-	✓
Ecosystem Considerations								
Climate vulnerability	H	L	-	M	-	H	-	-
Other	[4]	[5]	-	-	[6]	-	[7]	-
Monitoring								
Observer program	✓ (low)	✓ (100% in mobile gear)	✓	✓ (100% in NAFO area)	NDF	✓	-	✓ (2-10%)
Vessel Monitoring	✓	✓	✓	✓	N/A	✓	-	✓
Dockside Monitoring	✓	✓	-	✓	N/A	-	-	✓

[1] Catch has exceeded TAC in recent years, F>Flim and TAC set above advice; [2] Management framework with rebuilding target; [3] Spawning closures and rockfish conservation areas; [4] The directed Atlantic halibut fishery also catches high levels of COSEWIC-assessed species as bycatch; [5] Decrease in size at age, age at maturity; [6] Oceanographic changes may be further impeding recovery; [7] Variable stock dynamics, increasing uncertainty in assessments.

In all eight cases, there were science-based estimates of abundance, reference points, effort control and reduced fishing mortality, either through reduced quotas or through implementation of moratoria on directed fishing (Table 6.1, Appendix A). From these case studies, it is clear that the following elements are critically important to fisheries recovery:

- Estimates of stock status or abundance;
- Reference points or appropriate proxy for reference points;
- Implementation of effort control that is in line with scientific advice;
- Establishment of harvest control rules;
- Reducing fishing mortality, either through moratoria on directed fishing or significantly restricting F, including for non-target fisheries (bycatch);
- Existence of a rebuilding or recovery plan;
- Establishment of minimum size limits to protect juveniles;
- Spatial or temporal closures for spawning or critical habitat protection; and
- Catch monitoring, including observer programs, vessel monitoring systems and dockside monitoring.

6.2 Focal species for fisheries recovery in Canada

We recommend that species within three taxonomic groups be given priority for focused recovery strategies and management actions (Tables 6.2, 6.3):

1. Groundfish and benthic elasmobranchs, including a suite of species on the Atlantic coast, and rockfish on the Pacific coast (Table 6.2);
2. Forage fish: mackerel on the Atlantic coast and eulachon on the Pacific coast (Table 6.3); and
3. Apex predators: Atlantic bluefin tuna and blue shark (Table 6.3).

These species are chosen from among those assessed by COSEWIC as endangered, threatened, or special concern, and those assessed by DFO as critical (Table 4.3). This process thus encompasses two sources of review, one from the perspective of biodiversity protection and one from the perspective of fisheries stock status.

The species groups are chosen strategically with a focus on species where – with concerted effort – either recovery or significant conservation improvements are possible within a time frame of approximately 10 years. We have not included any species that are already listed under the *Species at Risk Act* primarily because they have a legally binding requirement for recovery strategies (i.e., action plans for endangered and threatened species and management plans for species considered of special concern, such as Atlantic wolfish, spotted wolfish and northern wolfish, white shark, Pacific basking shark). We have also not focused on species like the porbeagle shark, which will require a much longer time frame for recovery.

Table 6.2: Overview of recovery elements for focal Canadian groundfish and skate species, including science inputs to management, fisheries management tools, bycatch, habitat, ecosystem considerations and monitoring. Taxonomic Group: F=Flatfish, G=Groundfish, SS=Sharks and Skates, R=Redfish/Rockfish. For each species, a checkmark indicates that the element is in place for the species (or for certain stocks of that species where individual stocks are denoted). NDF=No directed fishing; Climate vulnerability: L=Low, M=Medium, H=High.

	Atlantic								**Pacific**
	American plaice	**Atlantic cod**	**White hake**	**Cusk**	**Redfish**	**Smooth skate**	**Thorny skate**	**Winter skate**	**Rockfish**
Taxa	F	G	G	G	G	SS	SS	SS	R
Recovery Elements:									
Science Inputs									
Accurate estimates of stock biomass (or abundance) and stock status	✓	✓	✓ (3NOP, 4T)	-	✓	-	-	-	✓
Recovery Potential Assessment conducted	✓	✓	in progress	✓	✓	✓	-	✓	✓ (quillback, yellow-mouth)
COSEWIC Status assigned	✓	✓	✓	✓	✓	✓	✓	✓	✓
Management Tools									
Quota, catch limit or effort control that aligns with scientific advice in place	✓ (3Ps)	✓	✓	✓	✓	-	✓	-	
Reference Points established			-	-	✓	-	-	-	
Harvest Control Rule in place	✓ (4VWX)	✓ (3Ps)	-	-	-	-	-	-	
Reduced F	NDF (23K3LNO)	✓	NDF	NDF		NDF	NDF	NDF	✓
Rebuilding or Recovery Plan	-	✓ (3Ps)							
Up-to-date IFMP	✓ (23KL, 3Ps)	✓ (23KL, 3Ps)	✓ (23KL, 3Ps)		✓ (23KL, 3Ps)	✓			✓
Management decision publicly available	✓ (23KL, 3Ps)	✓	✓ (4VWX5)	✓	✓	✓ (4VsW, 3Ps)	✓ (4VsW, 3Ps)	✓ (4VsW, 3Ps)	
Bycatch									
Reduction in non-target fisheries	✓	✓	✓ (4RS, 4VWX5)	✓	✓	✓ (4VsW, 3Ps)	✓ (4VsW 3LNOPs)	✓ (4VsW, 3Ps)	
Habitat									
Spawning closures	-	✓		-	-	-	-	-	
Habitat closures	-	-	✓ (4T)	-	-	-	-	-	✓

	Atlantic								Pacific
	American plaice	**Atlantic cod**	**White hake**	**Cusk**	**Redfish**	**Smooth skate**	**Thorny skate**	**Winter skate**	**Rockfish**
Ecosystem Considerations									
Climate vulnerability	L	M	M	H	M	M	H	L	
Other									
Monitoring									
Observer program (level of coverage)	✓ (3Ps, 4T)	✓ (3P4RS: 5%, 4TVn)	✓ (3Ps, 4RS, 4VWX5)	✓ (low)	✓	✓	✓	✓ (4T, 4VsW, 3Ps)	✓ (100%)
Vessel monitoring	✓ (3Ps, 4T)	✓ (3Pn4RSTVn)	✓ (3Ps, 4RS, 4VWX5)	✓	✓	✓	✓	✓ (4T, 4VsW, 3Ps)	✓
Dockside monitoring	✓ (4T)	✓ (2J3KLPn4RS)	✓ (4RS)						✓
Monitoring data integrated into assessments	✓ (4T)								
References	1-8	1-3, 9-14	1-3,15-18	1-3, 19, 20	1-3, 21, 22	1-3, 23-25	1-3, 23, 26, 27	1-3, 28	1-3, 29-35

(1) DFO 2015m; (2) DFO 2016f; (3) Hare et al. 2016; (4) Fowler 2012; (5) Morgan et al. 2014; (6) Morgan et al. 2013; (7) Morin et al. 2013; (8) Morin et al. 2012; (9) Brassard et al. 2016; (10) DFO 2015n; (11) Rideout et al. 2016; (12) Swain et al. 2015; (13) Mohn and Rowe 2012; (14) Clark et al. 2015; (15) Simon and Cook 2013 (16) Simpson et al. 2015; (17) Nozères et al. 2015; (18) Swain et al. 2012a; (19) DFO 2014d; (20) Harris et al. 2012; (21) McAllister and Duplisea 2011; (22) Duplisea et al. 2012; (23) Simon et al. 2012; (24) Swain et al. 2012b; (25) Simpson et al. 2013; (26) Swain et al. 2012c; (27) Simpson et al. 2014; (28) Swain et al. 2006; (29) Stanley et al. 2012; (30) Edwards et al. 2012; (31) Yamanaka et al. 2012a; (32) Yamanaka et al. 2012b; (33) Stanley et al. 2009; (34) Edwards et al. 2014a; (35) Edwards et al. 2014b.

Table 6.3: Overview of recovery elements for focal small and large pelagic species, including science inputs to management, fisheries management tools, bycatch, habitat, ecosystem considerations and monitoring. For each species, a checkmark indicates that the element is in place for the species (or for certain stocks of that species where individual stocks are denoted). NDF=No directed fishing; Climate vulnerability: L=Low, M=Medium, H=High.

	Small pelagics		**Large pelagics**	
	Pacific	**Atlantic**	**Atlantic**	
	Eulachon	Mackerel	Bluefin tuna	Blue shark
Recovery Elements				
Science Inputs				
Accurate estimates of stock biomass (or abundance) and stock status;	✓	✓	✓	✓ (Data poor)
Recovery Potential Assessment conducted	✓	N/A	✓	-
Other				
Management Tools				
Quota, catch limit or effort control that aligns with scientific advice in place	✓	✓	✓	
Reference Points established			✓	-
Harvest Control Rule in place	✓	-	-	-
Reduced F	✓	-	-	NDF
Rebuilding or Recovery Plan		-	✓	
Up-to-date IFMP	✓ (Fraser River)	✓	-	-
Management decision publicly available		✓	-	-
Bycatch				
Reduction in non-target fisheries	-	-	N/A	-
Bycatch of non-target species, species at risk	N/A	✓	-	-
Habitat				
Spawning closures	✓	-	-	-
Habitat closures	-	-	-	-
Ecosystem Considerations			-	-
Climate vulnerability	-	M	-	-
Other				
Monitoring				
Observer program (level of coverage)	✓	✓	✓ (Low)	✓ (Low)
Vessel monitoring	✓	✓	✓	✓
Dockside monitoring	-	✓	✓	-
Monitoring data integrated into assessments*	-	-	-	-
References	1, 2, 4	1, 2, 3, 5	1, 2, 6	1, 2, 7

(1) DFO 2015m; (2) DFO 2016f; (3) Hare et al. 2016; (4) Schweigert et al. 2012; (5) Grégoire 2014; (6) Maguire et al. 2012; (7) Campana et al. 2015a

6.2.1 Atlantic groundfish and skates

American plaice

Current status: In Atlantic Canada, all five assessed American plaice stocks are considered threatened by COSEWIC. They are either in the critical zone (NAFO 3Ps, 4T), the stock status is unknown (NAFO 23K), or in the case of the 4VWX (Scotian Shelf) population, in the cautious zone. Because American plaice in NAFO 3LNO is assessed by NAFO, it is not given a stock status within the Canadian Precautionary Framework (Table 4.3). Only the 4VWX stock has a full suite of reference points in place. American plaice is considered Threatened by COSEWIC across its Atlantic Canadian distribution. An RPA was completed for American plaice in Newfoundland and Labrador (NAFO 23K3LNOPS) in 2011.

Management: There is an IFMP for American plaice in Newfoundland Region including NAFO 23KL and NAFO 3Ps stocks, however there is no current IFMP for stocks in the Gulf Region (4T) or Scotia Fundy Region (4VWX). There is no rebuilding plan.

Directed fishery: While there is a moratoria on directed fishing for American plaice in NAFO areas 2JK3LNO, there are small directed fisheries in 4T, 4VW and 3Ps. There are directed fisheries for American plaice in 4RST and 4VWX.

Bycatch: American plaice is caught as bycatch in the directed fisheries for yellowtail flounder, Greenland halibut (turbot), redfish, witch flounder and shrimp.

Habitat protection: There is currently no habitat protection or spatial closures specifically to protect American plaice.

Ecosystem considerations: American plaice has a low vulnerability to climate change, at least in the southern part of its range.

Recommended recovery action: In order to recover American plaice across its range, given that the greatest threat continues to be either directed fishing or bycatch in other fisheries, reductions in fishing mortality will yield the greatest recovery. There are several scenarios depicted in the 2011 RPA for recovery of American plaice over a 48-year time period in 23K3LNO3Ps; all scenarios include either a maintenance of low fishing mortality (F) or a further reduction in F. Development of a rebuilding plan for American plaice would establish a suite of measures including increased monitoring of bycatch, establishment of a full set of reference points for all stocks and establishment of harvest control rules.

Atlantic cod

Current status: Seven Atlantic cod stocks are either in the critical zone (NAFO 3Pn4RS, 4TVn, 4X5Yb, 5Zjm, 2J3K) or cautious zone (NAFO 3Ps, 4VsW); the 3LNO cod stock is assessed by NAFO and therefore is not assigned a status under DFO's Precautionary Framework. All eight Atlantic cod stocks have been assessed by COSEWIC as Endangered (Table 4.3). RPAs were completed for the Newfoundland and Labrador designatable unit (DU) (NAFO 2GHJ3KLNO), the Laurentian North DU (NAFO 3Pn4RS, 3Ps) and the Laurentian South DU (NAFO 4TVn 4VsW) in 2015 and for the Southern DU (NAFO 4X5Yb5Zjm) in 2011 and 2015. Atlantic cod is considered Endangered across all designatable units following declines in excess of 90 per cent.

Management: There is an IFMP in place for 2JK3l cod as of 2013 and 3Ps cod in Newfoundland as of 2013. There is no current IFMP in place for other regions. Only 3Ps cod has a rebuilding plan under the Sustainable Fisheries Framework.

Directed fishery: Following the groundfish closure in 1992 where many directed fisheries for cod were closed, there are now directed fisheries for Atlantic cod in 3Ps, 3Pn4RS, 2J3KL, 3LNO and 4X5Yb5Zjm. There are no directed fisheries in 4VsW or 4TVn.

Bycatch: Cod is caught as bycatch in directed fisheries for other species within Atlantic Canada, including Greenland halibut, Atlantic halibut, Northern shrimp, haddock, lobster and winter flounder.

Habitat protection: There are some spawning closures in place. There are no specific habitat protection measures in place.

Ecosystem considerations: Cod is viewed as being moderately vulnerable to climate change, with its lack of recovery in the Gulf of Maine recently attributed to warming trends (Pershing et al. 2015). However, this has also been disputed (Swain et al. 2016).

Recommended recovery action: Reducing fishing mortality in both directed fisheries and in bycatch fisheries is viewed as the most effective recovery mechanism. Currently, there is an unknown amount of cod caught as bycatch in the lobster fishery, an amount that is not considered in fishing mortality estimates. In some areas cod is seen to be recovering. The Northern cod stock in 2J3KL has seen recent increases, although it is still well below its LRP, and acoustic surveys have shown increased abundance (Rose and Rowe 2015). There has been some recovery in 3Ps, although the stock remains below the USR. In other areas, the population continues to decline (4VWX) (DFO 2015h). There is some concern about high natural mortality in the Scotian Shelf and Gulf populations, as well as in 3Ps, particularly for fish over the age of five. Cod recovery must be considered on a stock basis, given differing trajectories, impact of climate change and natural mortality. As well, historic overfishing has had an impact on life history characteristics, including age and size at maturity (Hutchings 2005). All stocks should be managed through an up-to-date IFMP, and rebuilding plans should be developed across all Atlantic cod populations.

Cusk

Current status: We were unable to obtain data to include in our stock assessments. Cusk have been assessed by COSEWIC in 2014 and are considered Endangered throughout the Atlantic region. Their population is concentrated in the 4VWX5Y area of the Scotian Shelf / Gulf of Maine. An RPA was completed in 2014.

Management: Cusk are not included in any current IFMP. Cusk are currently being considered for SARA listing, and public consultation has recently been conducted by the DFO.

Directed fishery: There is no directed fishery for cusk.

Bycatch: Cusk are caught in the Atlantic halibut fishery, groundfish fisheries as well as in the lobster fishery.

Habitat protection: There are no current habitat protection measures for cusk.

Ecosystem considerations: Cusk is considered highly vulnerable to climate change (Hare et al. 2016).

Recommended recovery action: There is a need for increased data and monitoring of cusk bycatch in the lobster fishery. Any increase in the Atlantic halibut fishery should be considered in terms of its impact on cusk. A rebuilding plan for cusk should be developed, and cusk should be considered within an IFMP for groundfish in the Scotia Fundy Region. All fishing mortality should be reduced, the establishment of closed areas should be considered to protect critical habitat for cusk, and retention of cusk should be reduced in bycatch fisheries.

Acadian and Deepwater Redfish

Current status: Both Acadian and deepwater redfish are considered to be in the critical zone by DFO. They have been assessed by COSEWIC in 2011 and are considered Threatened and Endangered, respectively. An RPA for both species was completed in 2011 (Table 4.3).

Management: Acadian and deepwater redfish are included in the Newfoundland Groundfish IFMP for 2&3JK and 3Ps. There is no IFMP for the Gulf Region or for Scotia Fundy / Maritimes Region. The redfish fishery is managed according to nine management units based on NAFO Divisions: West of Greenland (Sub-area 1), Labrador Shelf (2GHJ-3K), Flemish Cap (3M), north and east of the Grand Banks (3LN), Southwest of the Grand Banks (3O), Gulf of St. Lawrence (Unit 1, consisting of 4 RST, 3Pn4Vn Quebec, Newfoundland and Labrador, (Unit 2, consisting of 3Ps4Vs4Wfgj, 3Pn4Vn Scotian Shelf (Unit 3, consisting of 4WdehklX) and Gulf of Maine (sub-area 5).

Directed fishery: The directed fishery has been under a moratorium in Unit 1 since 1995 and in 2J3K3LN since 1998. However, it was re-opened in 2009 in 3LN.

Bycatch: Redfish are caught as bycatch in the Greenland halibut fishery in Atlantic Canada, representing one to two per cent of landings during the 2000s. Modification of the shrimp trawl through the addition of the Nordmore grate has reduced adult bycatch in the shrimp fishery. However, juvenile redfish continue be caught in shrimp fisheries, and in 2J3K redfish comprised about one per cent of the shrimp catch. Bycatch of juveniles could impact redfish recovery. Unreported catches and bycatch in other fisheries may also impact recovery.

Habitat protection: Redfish live in cold waters along the bank slopes and deep channels, at depths of 100 to 700 metres. Both species are distributed according to depth. *S. fasciatus* are typically found in shallower waters (150 to 300 metres), while *S. mentella* is found at depths exceeding 300 metres. Research from the Pacific indicates that rockfish tend to prefer complex habitat and impacts on this habitat from fishing gear may be detrimental to these species (Du Preez and Tunnicliffe 2011). In Atlantic Canada, there are no habitat closures specifically for redfish.

Ecosystem considerations: Redfish are considered moderately vulnerable to climate change (Hare et al. 2016). Recovery of *Sebastes* spp. is likely to be impacted by climate change because the larvae cannot tolerate water temperatures greater than 14 C° and deep-water species are likely to be impacted by increases in oxygen minimum zones. Redfish are a genus of species that are particularly sensitive to overfishing because of their longevity, late age at maturity and slow growth rates. Redfish recruitment rates also vary, with strong year classes only occurring every 5 to 12 years.

Recommended recovery action: Reducing fishing mortality in directed fisheries and bycatch of juveniles in the shrimp fishery is likely to aid redfish recovery. Redfish larvae have been found on sea pens in the Northwest Atlantic (Baillon et al. 2014). Redfish will likely benefit from additional area closures, particularly to bottom trawling, in canyons and slope areas and other complex habitat through implementation of the Sensitive Benthic Areas policy.

Smooth skate, Thorny skate, Winter skate

Current status: Stock status for thorny skate is unknown. The species was assessed by COSEWIC in 2014 and designated as Special Concern across the Atlantic. There is no RPA for thorny skate. Stock status is also unknown for smooth skate. Smooth skate was assessed by COSEWIC in 2013 and is considered Endangered in the Gulf of St. Lawrence and of Special Concern in Newfoundland and the Maritimes. An RPA was conducted in 2013 for the Newfoundland/Funk Island Deep smooth skate population. Stock status for winter skate is unknown. It was assessed by COSEWIC in 2005 and again in 2015. The Eastern Scotian Shelf/Newfoundland winter skate population is considered Endangered, while the Western Scotian Shelf/Georges Bank winter skate population is considered Not at Risk. An RPA for the Eastern Scotian Shelf winter skate population was conducted in 2005.

Management: Skates are included in IFMPs for Newfoundland Groundfish in 23K and 3Ps. There is no available IFMP for groundfish in the Maritimes Region or Gulf Region.

Directed fishery: There are no directed fisheries for skates, although there is a 2016 NAFO quota of 7,000 tonnes outside the 200-mile limit.

Bycatch: Skates are caught as bycatch in bottom trawl and dredge fisheries. It is difficult to tell some skate species apart, and as such there is unreliable observer data on bycatch.

Habitat protection: There is no habitat protection for skate, despite that fact that skate egg cases are deposited on the seafloor and often attached to sessile epifauna. Widespread trawling and dredging may impact juvenile hatching and survivability.

Ecosystem considerations: Skates are believed to be highly vulnerable to exploitation due to their large body size and associated life history traits such as slow growth, late maturation and low fecundity relative to bony fish (Dulvy et al. 2014).

Recommended recovery action: Recovery of skates has been documented, including barndoor skate in the Northwest Atlantic. Stock status and reference points, or another relevant proxy, need to be established for smooth, thorny and winter skates. Reducing fishing mortality in non-target species is the single most important action to be taken for all skate species across bycatch fisheries. Improved catch monitoring as well as fleet-wide bycatch limits across all fisheries that impact skate should be implemented and enforced.

White hake

Current status: White hake has been assessed by COSEWIC and is considered Endangered in the Southern Gulf of St. Lawrence (4RST) and Threatened in the Atlantic and Northern Gulf of St. Lawrence. While the RPA for white hake was held in January 2015 (DFO 2015o), it has not been made publicly available as of April 2016 (Gerard Chaput, DFO personal communication).

Management: As of 2013, white hake is included in the 3Ps Groundfish IFMP in the Newfoundland Region. There is no IFMP for the Gulf of St. Lawrence or Scotian Shelf groundfish fishery.

Directed fishery: There is a directed fishery for white hake in 3NOPs. There is no direct fishing for 4Rs, 3Pn, 4VWX or 4T white hake stocks.

Bycatch: White hake are caught as bycatch in fisheries for Atlantic halibut, redfish, Atlantic cod, pollock, haddock and other groundfish.

Habitat protection: There are no habitat protections or spawning ground protections in place for white hake.

Ecosystem considerations: White hake is considered to be moderately vulnerable to climate change (Hare et al. 2016).

Recommended recovery action: Since the RPA is not available, specific recovery recommendations by DFO cannot be detailed here. However, reduction in fishing mortality in the directed fishery and in fisheries where white hake is caught as bycatch are likely the most effective recovery measures. Additionally, white hake needs to be considered within the development of up-to-date IFMPS, and reference points should be developed as part of a rebuilding plan.

6.2.2 Pacific groundfish

Pacific rockfish
Current status: Bocaccio is considered in the critical zone and COSEWIC has assessed it as Endangered. Canary and quillback are considered Threatened and in the cautious zone of the Precautionary Framework. An RPA for quillback was completed in 2011. Yellowmouth rockfish are considered to be in the healthy zone, despite being considered Threatened by COSEWIC. An RPA for yellowmouth was completed in 2012.

Management: There is a comprehensive and up-to-date IFMP for all Pacific rockfish species, which includes bycatch limit and closed areas.

Directed fishery: There is a directed commercial fishery for rockfish through the Pacific multi-species groundfish fishery, and the B.C. recreational fishery also targets rockfish.

Bycatch: There is 100 per cent bycatch monitoring in the B.C. groundfish fishery.

Habitat protection: There are 186 Rockfish Conservation Areas in place since 2007.

Ecosystem considerations: Rockfish are long-lived and slow growing and prefer complex habitat. Effective habitat protection combined with reduced bycatch in target and non-target fisheries, both commercial and recreational, will impact recovery potential.

Recommended recovery action: Updated stock assessments should be conducted for canary and quillback rockfish species. Efficacy of and enforcement of Rockfish Conservation Areas should be assessed. As fleet-wide bycatch limits have already been established, these should be reviewed with a goal of recovery of depleted rockfish species.

6.2.3 Forage fish

Atlantic Mackerel
Current status: Atlantic mackerel is considered to be in the critical zone. Mackerel has not been assessed by COSEWIC.

Management: The available IFMP for Atlantic mackerel is from 2007.

Directed fishery: Because Atlantic mackerel is managed across Atlantic Canada's four DFO regions (Maritimes Region, Gulf Region, Newfoundland and Labrador Region and Quebec Region), it is difficult to further reduce the quota from current levels of 8,000 tonnes without exploring the options for regionally based allocations – a difficult and complicated process. This provides a partial explanation for the fact that the Total Allowable Catch is well above the scientific advice for 800 tonnes in 2014 to 2015. Landings have been below the Total Allowable Catch, with 2014 catches at 6,540 tonnes. In addition to the directed commercial fishery, there is a directed fishery for bait that is not included in the overall quota and, therefore, fishing mortality related to the bait and recreational fisheries is also not included in the stock assessment.

Bycatch: Bycatch in other fisheries is not a threat to mackerel recovery.

Habitat protection: There is no habitat protection for mackerel.

Ecosystem considerations: Because mackerel is an important forage species, the stock assessment and related management plan should assess and then consider the amount of mackerel that needs to be left in the ocean to accommodate the biological needs of higher trophic levels.

Recommended recovery action: Understanding the level of catch in bait and recreational fisheries is critical to understanding the overall impact of the fishery on the mackerel population. An updated IFMP should be developed. Mackerel should be assessed within the framework of the Policy for New Forage Fisheries.

Eulachon

Current status: An RPA for the Fraser River population was completed in 2015.

Management: The most recent IFMP for Fraser River eulachon is from 2013. A summary is available online, and the full IFMP is available from DFO upon request.

Directed fishery: The only fishery currently authorized in the Fraser River is the First Nations FSC fishery.

Bycatch: Eulachon is caught as bycatch in other fisheries, particularly the shrimp fishery.

Habitat protection: Protection of in-river spawning areas, including from land-based impacts.

Ecosystem considerations: Eulachon are impacted by land-based activities, particularly in river habitat.

Recommended recovery action: There is a high probability of achieving recovery of the Fraser River eulachon population within 4-, 8- and 17-year timelines. However, the extent of recovery is highly dependent on reducing in-river catches. Eulachon should be assessed within the framework of the Policy for New Forage Fisheries. Reducing the fishing mortality of spawning populations from directed catches, which currently are limited to First Nations FSC fisheries, will positively impact recovery timelines. Additionally, reducing bycatch in the offshore shrimp trawl could significantly reduce fisheries-related mortality. Modifications of the footrope have been effective in reducing bycatch of eulachon in the shrimp trawl fishery by 33.9 per cent (Hannah et al. 2011), and the addition of LED lights on the fishing line resulted in bycatch reduction of 91 per cent (Hannah et al. 2015). Although research is in progress, there is no information available on appropriate ecosystem-based conservation limits for eulachon. Determining these limits should be a priority so there is a better understanding of the amount of biomass that is available and necessary for higher trophic levels.

6.2.4 Apex predators

Atlantic bluefin tuna

Current status: Bluefin tuna is assessed by ICCAT. Stock status depends on the recruitment scenario. Bluefin tuna has been assessed by COSEWIC as Endangered. An RPA was completed in 2011.

Management: There is no up-to-date IFMP for bluefin tuna and the most recent IFMP is from 2008.

Directed fishery: There is a directed fishery for Atlantic bluefin tuna in the Northwest Atlantic both within and outside Canadian waters. Canada's quota share is approximately 30 per cent at ~ 450 MT and includes transfers from other countries. The ICCAT total quota for Western Atlantic bluefin in 2016 is 2,000 tonnes.

Bycatch: Bluefin tuna is caught as bycatch in the Atlantic Canadian swordfish longline fishery, as well as in the trap and weir fisheries for small pelagics.

Habitat protection: There are no habitat protection measures in place for Atlantic bluefin and no spawning closures within Canadian waters.

Ecosystem considerations: Atlantic bluefin tuna migrate into Canadian waters, primarily the Gulf of St. Lawrence, to feed in the spring and summer. Overfishing of prey species, such as herring and mackerel, may limit recovery.

Recommended recovery action: Reducing fishing mortality, particularly in bycatch fisheries, as well as eliminating high-grading in the directed fishery would effectively reduce F for bluefin tuna. ICCAT needs to determine harvest control rules as well as come to agreement on the recruitment scenario for bluefin tuna. As long as post-release mortality remains low, a greater quota could be allocated to the catch-and-release recreational fishery, which would further reduce overall F. Seasonal or temporal closures could be considered to further reduce non-target bycatch of tuna.

Blue shark

Current status: The blue shark in the Atlantic is assessed by ICCAT. Within Canada, there are no reference points established or estimates of fishing mortality. There is also no fishery-independent index of abundance. The per centage of total mortality in the North Atlantic that occurs in Canadian waters is small, and these levels of fishing mortality seem sustainable due to the relatively high productivity of the species and the lack of adult females captured in Canada. Due to the high uncertainty of the stock status, however, fishing mortality levels should not be increased beyond what they are currently (Campana et al. 2015). Blue shark previously has been assessed as Special Concern by COSEWIC (Table 4.3). New COSEWIC assessments are currently underway for both blue shark and shortfin mako shark (A. Sinclair, pers. comm.).

Management: There is no IFMP for blue shark.

Directed fishery: There is no directed commercial fishery for blue shark in Canadian waters. However, blue sharks are caught in the shark recreational fishery, which is catch-and-release except for shark derbies, where blue sharks make up 99 per cent of landings.

Bycatch: Blue sharks are the primary bycatch species in pelagic longlines directed at tuna, swordfish and porbeagle shark. Since 2000, blue sharks have made up 46 per cent of observed catch weight in large pelagic longlines. Additionally, blue sharks are captured in gillnet and trawl fisheries directed at cod, white hake, yellowtail flounder and monkfish.

Habitat protection: There is no habitat protection for blue sharks within Canadian waters.

Ecosystem considerations: Blue sharks in the Atlantic are highly migratory and wide-ranging and do not appear to have year-round residency in Canadian waters. This means stock assessments must continue to be done at the international level.

Recommended recovery action: Because assessments and management actions are determined at the international level, ICCAT needs to determine reference points and agree on catch levels for blue shark and these need to be enforced within Canada. Canada is one of the few remaining countries still resisting improved shark management measures (including catch limits and stricter shark finning bans) at ICCAT. Canada should start supporting, and leading, new measures for improved shark conservation in internationals waters.

6.3 Challenges to achieving recovery

Efforts have been made to set the foundations for recovery, with adequate data, scientific advice, precautionary fisheries management that includes science-based reference points and harvest control rules. Despite these efforts and despite political will to recover fish populations, there remain challenges to recovery that must be considered. These challenges include: estimating maximum sustainable yield and its utility as a recovery target; shifting baselines, and determining at what levels will recovery be achieved; addressing the increasing impacts of climate change on fisheries; and balancing short-term socio-economic needs with the potential for long-term prosperity.

6.3.1 Estimating MSY

Maximum sustainable yield is notoriously challenging to estimate accurately with confidence. Its utility as a target for population recovery, as opposed to a lower limit, can also be questioned. As such, even when the aforementioned recovery elements are in place, it may be unclear if the target for population is correct or sufficient to achieve long-term resilience.

6.3.2 Shifting baselines

There is a tendency to claim a stock is recovered once it begins to increase (Rose and Rowe 2015), largely because there is pressure to reopen closed fisheries or provide new allocations to the fishing industry based on historical access. Developing rebuilding plans is one of the pillars of fisheries recovery, since they set clear parameters and long-term management goals, but recovery targets are often set quite low.

For example, when the recovery target for North Atlantic swordfish was set to B_{MSY}, the stock was seen to have recovered once it reached 1974 levels. However, the biomass continues to be well below historical levels (Case Study 8). Another example is the recovery of Atlantic cod. There has only been one rebuilding plan developed within Canada for 3Ps cod on the southern coast of Newfoundland. The target for recovery is twice the limit reference point (LRP) and noted as the upper stock reference point (USR). However, the LRP is set at $B_{recover}$, the lowest point from which the stock has been seen to have sustained recovery, equivalent to the biomass in 1994 following the collapse of Northern cod and subsequent moratoria in 1992. From a biomass perspective, the USR is approximately 21,000 tonnes. According to the rebuilding plan, recovery will be achieved when the stock is above the USR, an order of magnitude less than historical landings (DFO 2016c).

In short, there is a tendency to ignore historical biomass levels to achieve tacit success in stock rebuilding when there is merely a change from a trajectory of decline to a trajectory of increase.

6.3.3 Climate change

Current efforts to establish responsible fisheries management regimes include establishing precautionary harvest rates, setting reference points and avoiding overfishing. However, such measures may not achieve actual conservation or rebuilding of fish populations if vulnerability to climate change is not taken into consideration (Mills et al. 2013).

Climate change impacts on fisheries in Canadian waters or adjacent ocean jurisdictions have already been documented. Examples include the reduction in available habitat for snow crab in Atlantic Canada and the expansion of lobster abundance further north (DFO 2014e) while lobster nursery areas recede in the U.S. (Wahle et al. 2015). The failure of cod in the Gulf of Maine to recover has been attributed to low reproduction and high mortality caused by increasing temperatures (Pershing et al. 2015). This finding has been contested however (Swain et al. 2016), and as such, the role of climate change on fisheries clearly needs concerted scientific focus to reduce uncertainties in recovery potential.

Canada does not consider climate change in fisheries management decisions and vulnerability to climate change is not considered in stock assessment processes. However, climate change is known to affect commercially fished species in a number of ways, including raising water temperatures and acidifying oceans. Given these impacts, considering climate change in fisheries management decisions should be a priority for DFO, particularly in the case of COSEWIC-assessed species, where climate impacts may preclude recovery.

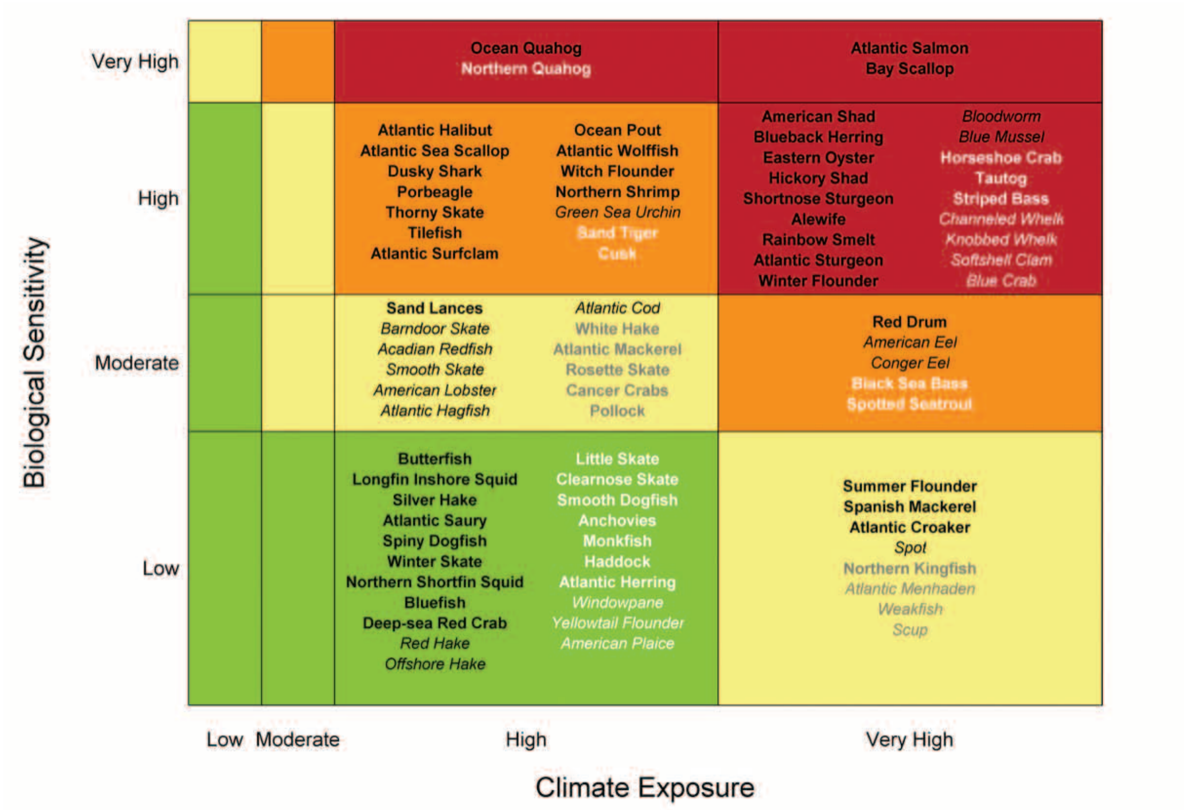
In contrast, the U.S. National Marine Fisheries Service (NMFS) has established the Fish Species Climate Vulnerability Assessment Model and recently assessed 82 commercially fished species from the Northeast Atlantic. According to this assessment, diadromous and benthic invertebrates were most likely to be negatively impacted, with some species of fish positively impacted by climate change (Hare et al. 2016) (Figure 6.1).

6.4 The value of recovery

Establishing fisheries recovery as a priority and accounting for the impacts of climate change on fisheries are imperative to build resilience for Canada's marine ecosystems, fishing industry and coastal communities.

Although restoring Canada's depleted fish populations could lead to increased prosperity for some coastal communities, it is important to consider that Canada's invertebrate fisheries, especially those on the Atlantic coast, are much more economically valuable than groundfish fisheries. As such, it is difficult to make the case that recovering groundfish will lead directly to increased economic prosperity. With the exception of Atlantic cod and a few other species, most of the Canadian marine fish stocks that are severely depleted have never been major fisheries that contributed to the economic well-being of Canadians.

Figure 6.1: Overall climate vulnerability is denoted by color: low (green), moderate (yellow), high (orange) and very high (red). Certainty in score is denoted by text font and text color: very high certainty (>95 per cent, black, bold font), high certainty (90 to 95 per cent, black, italic font), moderate certainty (66 to 90 per cent, white or grey, bold font), low certainty (less than 66 per cent, white or grey, italic font) as per Hare et al. 2016.



In order to determine if increased economic prosperity will result from recovery of the stocks recommended here, it would be important to determine who would fish the recovered population, in what size vessels, with what gear type and whether or not there are new markets for these species that might reward increased stewardship of the fishery. In order to understand with some certainty the specific elements and initiatives related to increasing prosperity in Canada from the fishing industry, there also is a need to comprehensively assess current and future labour markets, the monetary importance of the fishing industry in specific communities, the relative costs associated with various types of fishing, and the flow of financial benefits through the supply chain. This would require investment in social science as well as economics and a clear understanding of the values related to prosperity, all of which are outside the scope of this report. It also will be important to work closely with provincial counterparts as well as municipalities and fishing associations to better understand the impacts of these industries on local communities, the levels of employment related to specific fisheries (e.g., inshore groundfish versus offshore shrimp) and the overall contribution to jurisdictional GDP.

Well-managed fisheries that take into consideration the entire marine ecosystem put a priority on allocating quota to low-impact gear fisheries, respect closed areas and have effective monitoring, control and enforcement will increase the resilience of the ecosystem as well as the resilience of the communities who depend on fisheries for their livelihoods. Avoiding the boom-and-bust nature that has typified Canadian fisheries should contribute to long-term economic and social prosperity, as well as more resilient marine ecosystems.

7. CONCLUSION

Canada's fisheries have the potential to remain a significant part of the nation's culture and economy, particularly in coastal provinces and territories. Although many fish populations are depleted and in critical and cautious zones, there is potential for recovery and a return to a diverse and multi-species fishery.

Canada has the solid basis for a legal and policy framework that can achieve recovery, but it could be strengthened by requiring fisheries rebuilding. Fisheries rebuilding must also become a priority from a political perspective, and fisheries managers must be guided in making decisions directed towards long-term ecosystem health, rather than short-term economic gains.

The responsibility and public accountability of DFO would be vastly improved by establishing legally binding targets and timelines for recovery, as well as publicly reporting the status of fish stocks and the level of fishing pressure. In the United States, the Magnuson-Stevens Act (MSA) provides a legal requirement for stock rebuilding and mandates annual public accounting toward meeting the requirements of the Act (NOAA 2016).

It is clear from the results in Chapter 4 that Canada has a good portion of the information needed to track stock status and rebuilding of fish stocks, where it is occurring. However, DFO should make a concerted effort to prioritize and fund annual updates on all Canadian fisheries, including their population health and related management decisions.

There is a clear need for transparency in data and management decisions to establish a solid foundation for fisheries recovery. There is also a clear need to make this information publicly available in a timely manner. The fact that Environment and Climate Change Canada reports on the status of fish stocks in Canada, using data from DFO's internally held Fisheries Checklist, suggests that DFO does not see its role as including public accountability regarding stock status and the effectiveness of its fisheries management measures.

In contrast, the United States' National Oceanic and Atmospheric Administration (NOAA) is legally mandated to report annually on the status of fish stocks to the U.S. Congress and has demonstrated progress in reducing the number that are considered overfished. As part of this reporting, NOAA produces a publicly accessible table on stock status and provides links to all stock assessments as well as an overview of rebuilding trends, where they are evident (NOAA 2015a).

Successful fisheries recovery requires an integrated management system and a variety of modern approaches. This includes establishing appropriate scientific capacity and legally binding requirements for science-based rebuilding plans that set realistic recovery targets. Biological factors such as species life history, trophic level and, increasingly, the role of climate change must also be taken into consideration when developing recovery and rebuilding plans.

Recovery has been achieved for a variety of species in other jurisdictions, and there are several species for which recovery is possible in Canada. It is important to fully consider the impacts of climate change, and Canadian fisheries management does not do this adequately. However, there are practical applications from other jurisdictions that could be applied to the Canadian context.

There are indications of a willingness to restore lost scientific capacity and provide political leadership for improved management of Canada's fisheries and oceans. One example is a recent reinvestment in Canadian fisheries science in the form of 135 marine scientist job openings with DFO in May 2016. Another example is the stated commitment to science-based decision-making in the federal Ministerial Mandate Letters in 2015. Furthermore, the Canadian government has made a commitment to meet at least once of its international targets under the Convention on Biological Diversity, by protecting 10 per cent of the nation's marine and coastal areas. Public and stakeholder engagement can serve to mobilize governments and the fishing industry to work toward fisheries recovery and spatial protection for Canada's three oceans.

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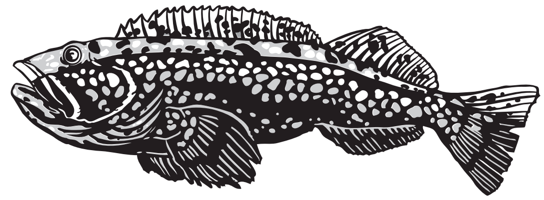
APPENDIX A. CASE STUDIES OF RECOVERING OR RECOVERED MARINE STOCKS

This appendix contains eight case studies highlighting the recovery process for marine fish and invertebrate stocks from the East and West Coast of Canada, as well as from the U.S. and Europe.

Lingcod

Ophiodon elongates



Stock Area(s):	Strait of Georgia, British Columbia
Fishing Gear Used:	Hook & line, trawl
Recent Assessments:	2015,[1] 2005,[2] 2001[3]
COSEWIC Status:	Not listed[4]
SARA Status:	Not listed[5]
MSC Certified:	No
Stock Status:	Depleted, Cautious Zone (0.4 B_{MSY} - 0.8B_{MSY}; 58% probability)[1]
Population Trajectory:	↑
Recovery Prospects:	Possible, limited, high degree of uncertainty

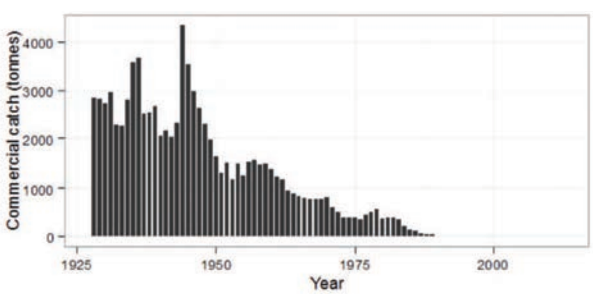


Figure 1. Commercial catches for directed Lingcod fisheries (hook & line and trawl gear combined) in the strait of Georgia. Figure from DFO 2015/014[1].

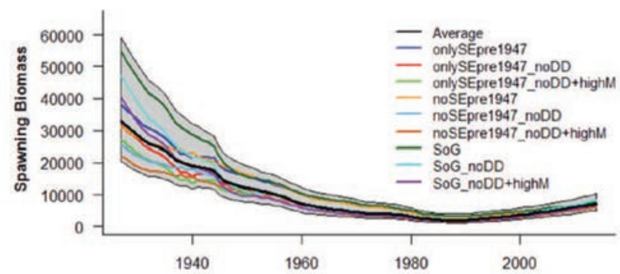


Figure 2. Posterior mean estimates of spawning biomass (in tonnes) over time for a scenario-averaging approach (solid black line). Grey shading shows the 5th and 95th percentiles of the scenario-averaged trajectory, while the multi-coloured solid lines show the posterior median estimates from each of the nine individual scenarios. Figure and caption from DFO 2015/014[1].

Life History & Fishery Description

Lingcod are endemic to the west coast of North America, distributed from California to Alaska with highest abundances off the British Columbia coast. Lingcod are typically found in nearshore rocky habitats between 10 and 100m deep. Adult lingcod feed mainly on herring and Pacific hake.

Commercial fishing for lingcod using handlines began in the 1860s. In the 1940s, trawling for lingcod in the Strait of Georgia began. During this time, lingcod was the fourth largest fishery in British Columbia, with average landings of 4,000t per year. Today, B.C. populations are managed and assessed as five units: one inside stock in the Strait of Georgia and four outside stocks (Fig. 3). Lingcod are managed under the Integrated Groundfish program, introduced in 2006.[6]

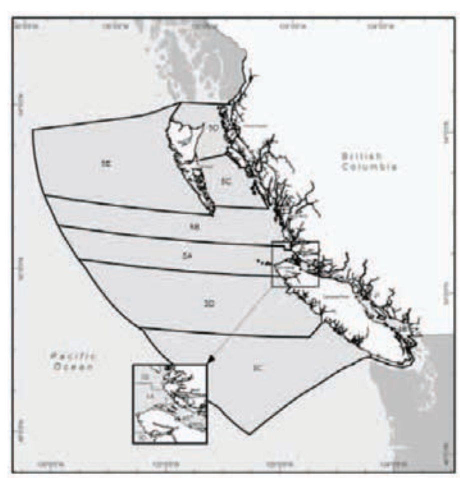


Figure 3. Groundfish management areas in British Columbia, including offshore lingcod areas (Area 3C, Area 3D, Areas 5AB and Areas 5CDE) and inshore lingcod area stock in the Strait of Georgia inset box (Area 4B). From DFO 2011/051.[7]

Critical Management Intervention

Large declines in the inshore lingcod stock between 1927 and the 1980s (Fig. 2) led to closure of the area's commercial fishery in 1990, and in 2002 the recreational fishery was closed as well. A limited recreational fishery was reopened in 2006 in some areas of the Strait of Georgia.

Other Management Measures

Rockfish Conservation Areas (RCAs) were established in 2002 for the protection of inshore rockfish and lingcod. Regulations prohibit fishing activities that may encounter rockfish or lingcod, such as hook and line fisheries, in these areas.[8]

Recreational catches in the Strait of Georgia are under "management caps" limiting the amount of lingcod removals and closing some sub-areas to fishing.[7]

The minimum harvest size is 65cm (25.6in).[1]

Seasonal closures are imposed from October 1 to June 1 to protect spawning lingcod.[1]

Key Recovery Uncertainties

- **Ecosystem changes in the Strait of Georgia.** Physical changes to the oceanography, including timing of freshwater influxes and changes to the trophic structure, may be placing additional pressures on the lingcod stock in the Strait and may limit the influence of management measures on the stock's recovery.
- **Data availability.** The Strait of Georgia lingcod stock is data-poor, and indices used for assessment are based on records from the commercial fishery and recreational fishery catch-per-unit effort (CPUE). Because of data limitations, the most recent stock assessment includes nine different scenarios for the state of the stock, which differ in their treatment of the historic catch data, natural mortality assumptions and the relationship between density-dependent mortality and density-dependent catchability (Fig. 2).[1]

Recovery Potential & Outlook

The lingcod population in the Strait of Georgia was assessed by Fisheries and Oceans Canada in 2015 to be recovering from historic low levels.[1] The Lingcod Management Framework Committee (formed in 2004) identified a desirable, long-term (10-year) recovery target for lingcod abundance in the Strait of Georgia as 40% of historic high biomass ($B_{40\%}$).[9] However, ***ten years after the establishment of this recovery target, the stock remains in a seriously depleted state.*** The most recent stock assessment estimates there is a 71% probability that the stock is between its lower limit reference point ($0.1B_o$) and its short-term recovery target ($0.25B_o$). Viewed from the perspective of the DFO Precautionary Approach Framework reference points, the ***stock is estimated to have a 58% chance of being in the cautious zone (between 0.4B_{MSY} and 0.8B_{MSY}), a 37% change of being in the critical zone (below 0.4B_{MSY}), and only a 5% chance of being in the healthy zone (above 0.8B_{MSY}). All indications are that the stock, although slowly increasing, is still far from being recovered.***

Moreover, in addition to the uncertainties outlined here, there are several other reasons that suggest the potential for lingcod to fully recover to B_{MSY} may be limited. First, available information suggests that protected areas (RCAs) in the Strait are not large enough to provide adequate refuge to lingcod populations.[9] Second, lingcod may be caught as bycatch in other fisheries open year-round, although these rates and the survival of released fish are unknown.[9] Third, exploitation rates of lingcod were not significantly reduced by the introduction of minimum size limits[10] (a limit restriction of 58cm was introduced in 1942 for commercial fisheries only, and a 65cm limit for the recreational fishery was introduced in 1991).[8]

Recovery Recommendations

Maximizing the potential of the Strait of Georgia lingcod stock to reach the identified recovery target ($0.4B_o$ [11]) will require several measures, including comprehensive monitoring to produce confident measures of stock status. Lingcod protection also will likely require increasing protection of spawners and spawning habitat, including lingcod habitat within marine reserves,[9] and implementing a proposed maximum size retention cap of 90cm, in addition to the lower limit, to protect larger, more fecund females that are better able to protect egg masses and avoid predation.[11] Although management of the lingcod stock in the Strait of Georgia is relatively data-limited,[2] the best available information on lingcod dispersal and movements should still be used to inform management measures such as protected area design or fishery restrictions.

Ensuring that fishing mortality rates do not impede recovery of the stock is critical. As established by the Management Framework, any harvest level decisions should be projected to maintain the population biomass increase for 10 years. Additionally, fishing mortality should not be increased at least until there is a high level of confidence that the stock has more fully recovered (i.e., reached B_{MSY}).

[1] DFO. 2015. Stock assessment for Lingcod (Ophiodon elongates) for the Strait of Georgia, British Columbia in 2014. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/014.

[2] DFO, 2005. Strait of Georgia Lingcod (Ophiodon elongates) Assessment and Advice for Fishery Management. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/42.

[3] DFO, 2001. Assessment of Lingcod in the Strait of Georgia. DFO Res. Doc. 2001/132.

[4] COSEWIC. 2016. Wildlife Species Search. Accessed February 2016. < http://www.cosewic.gc.ca/eng/sct1/index_e.cfm>

[5] SARA. 2016. Species at Risk Public Registry. Accessed February 2016. < http://www.registrelep-sararegistry.gc.ca/sar/index/default_e.cfm>

[6] DFO, 2015. Pacific Region Integrated Fisheries Management Plan – Groundfish.

[7] DFO 2012. Lingcod (Ophiodon elongates) stock assessment and yield advice for outside stocks in British Columia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/051.

[8] Martell et al. 2000. The Use of Marine Protected Areas for Conservation of Lingcod (Ophiodon elgonatus). Bulletin of Marine Science. 66(3): 729-743.

[9] DFO, 2005. Management Framework for Strait of Georgia Lingcod. CSAS Research Document 2005/048.

[10] Martell, S. J. D. 1999. Reconstructing lingcod biomass in Georgia Strait and the effect of marine reserves on lingcod populations in Howe Sound. M.Sc. Thesis, Univ. British Columbia, Vancouver. 89 p.

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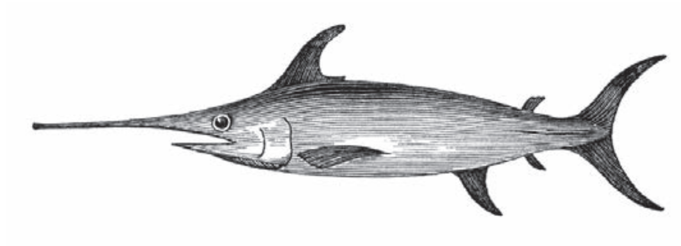
Swordfish

Xiphias gladius



Stock Area(s):	North Atlantic
Fishing Gear Used:	Longline & harpoon
Recent Assessments:	2013,[1] 2009[2]
COSEWIC Status:	Not listed[3]
SARA Status:	Not listed[4]
MSC Certified:	Canadian harpoon fishery (2010),[5] Canadian longline fishery (2012)[6]
Stock Status:	At or above B_{MSY} (90% probability)[1]
Population Trajectory:	↑
Recovery Prospects:	Stock considered recovered[2]

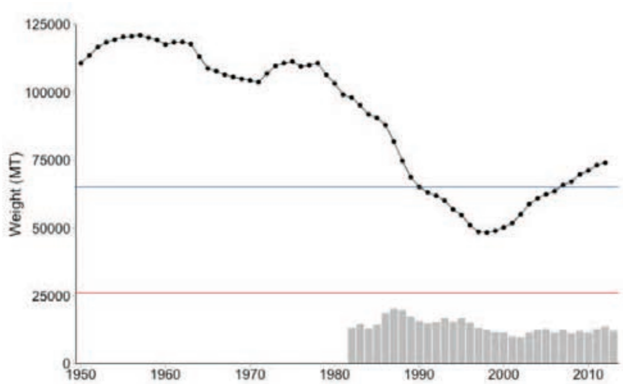


Figure 1. Total catch (grey bars, 1982-2011) and estimated starting biomass (black line, 1950-2012) for North Atlantic swordfish.[2] Lower biomass limit reference point (red line, 0.4B_{MSY}), B_{MSY} (blue line, estimated to be 65,060t for 2014/2015).[2]

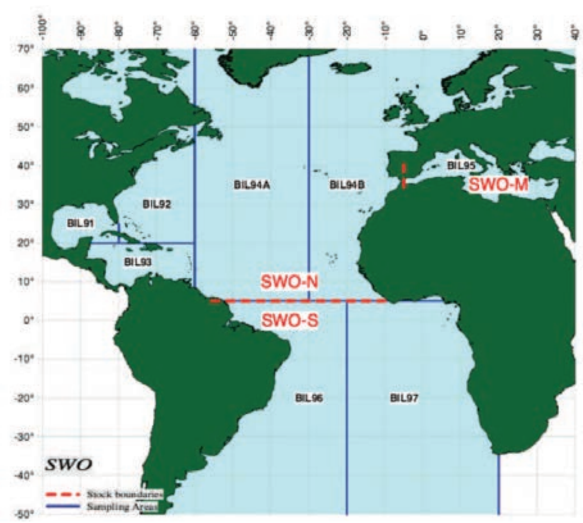


Figure 2. Stock boundaries for swordfish (red), North Atlantic stock (SWO-N), South Atlantic stock (SWO-S) and Mediterranean stock (SWO-M). Blue lines indicate sampling area boundaries. Image from ICCAT.[9]

Life History & Fishery Description

Swordfish are a highly migratory, pelagic fish and move throughout the Atlantic ocean and Mediterranean Sea (Fig. 2). Individual fish may grow up to 650kg. Swordfish are apex predators, feeding throughout the water column on a variety of prey species including groundfish, pelagics and invertebrates.

In Canada, swordfish are harvested primarily through longline fisheries and in part through harpoon fishing. The International Commission for the Conservation of Atlantic Tunas (ICCAT) is responsible for the management of the North Atlantic swordfish fishery and sets annual fishing quota allocations.

Critical Management Intervention

By 1999, the biomass of North Atlantic swordfish was estimated to have declined to just 65% of B_{MSY}, and the stock was still considered to be experiencing overfishing (F=134% of F_{MSY}).[7] In response, ICCAT adopted an international rebuilding plan for the North Atlantic swordfish stock. With the aim of achieving MSY within 10 years, the rebuilding plan involved lowered TACs, implementation of national quotas for major fleets, the elimination of dead discard allowance, and quota reassignment (unused portions and excess of annual quotas or catch limits deducted from the subsequent year's quota or catch limit).[8]

Other Management Measures

Swordfish harvesters in Canada must also abide by licence conditions including:

- areas closed to fishing to protect swordfish broodstock, to prevent bycatch of bluefin tuna and to protect sensitive areas;
- requirements to report out and in for all fishing trips; and
- dockside monitoring of all landings.[10]

Other measures include country-specific TACs[2] and 125/119cm (lower-jaw fork length) minimum size restrictions.[11]

Key Recovery Uncertainties

- **Stock boundaries.** Because boundaries between stocks for this highly migratory species are uncertain, mixing between stocks is expected.[12]
- **International cooperation.** Compliance of multiple countries is required to effectively manage fishing pressures on this stock. This includes the timely reporting of all catch and discards.[2]
- **Discard survival.** The effectiveness of minimum size limits are highly dependent on the post-release survival of undersized fish.[12]

Recovery Outlook & Potential

Biological characteristics of swordfish, including their reproduction, growth and migration behaviours, lend themselves to the resiliency of this species to fishing pressures.[8] The North Atlantic swordfish stock was considered to be rebuilt to levels supporting maximum sustainable yield (MSY) in a 2009 ICCAT assessment, which found greater than 50% probability that the stock was at or above B_{MSY}.[3] The 2013 assessment indicated that there is greater than 90% probability that the stock is at or above B_{MSY}.[2] Fishing mortality has been maintained below F_{MSY} (0.21) levels since 2000.[2]

Of the management measures contributing to the stock's rebuilding, reduction of exploitation levels through TACs appears to have been most beneficial.[8] Additionally, the recovery management process implemented by ICCAT (including transparency of scientific data, and the involvement of member countries in assessment and generation of scientific advice) was effective at reducing fishing pressure.[8]

Recovery Recommendations

Precautionary approaches to setting catch levels should be a primary objective. Assessment recommends that TACs of 13,700t over the next decade meet ICCAT objectives for stock status.[13] ICCAT has also recommended that if total catches exceed the quota, then this excess should be deducted from quotas for the following year,[14] providing incentives to remain within target quotas. Maintaining transparency of stock assessment information and decision-making for quotas will support compliance of member states.

ICCAT has requested the identification of limit reference points and development of Harvest Control Rules for the North Atlantic swordfish stock.[2] Currently ICCAT recommendations state that management measures for rebuilding should be triggered if stock biomass approaches levels which initiated the previous rebuilding plan.[14] Appropriate reference points need to be established to prompt effective management actions based on changes in stock status.

[1] ICCAT. 2013. Report of the 2013 Atlantic Swordfish Stock Assessment Session. Doc. No. SCI-036/2013.

[2] ICCAT. 2009. Report of the 2009 Atlantic Swordfish Stock Assessment Session. SCRS/2009/016 – SWO ATL Stock Assessment.

[3] COSEWIC. 2016. Wildlife Species Search. Accessed February 2016. < http://www.cosewic.gc.ca/eng/sct1/index_e.cfm>

[4] SARA. 2016. Species at Risk Public Registry. Accessed February 2016. < http://www.registrelep-sararegistry.gc.ca/sar/index/default_e.cfm>

[5] MSC. 2016. Track a Fishery: North West Atlantic Canada harpoon swordfish. Accessed February 2016. <https://www.msc.org/track-a-fishery/fisheries-in-theprogram/certified/north-west-atlantic/north-west-atlantic-canada-harpoon-swordfish >

[6] MSC. 2016. Track a Fishery: North West Atlantic Canada longline swordfish. Accessed February 2016. <https://www.msc.org/track-a-fishery/fisheries-in-theprogram/certified/north-west-atlantic/north_west_atlantic_canada_longline_swordfish>

[7] Neilson J., Arocha F., Cass-Calay S., Mejuto J., Ortiz, M., Scott G., Smith C., Travassos P., Tserpes G., Andrushchenko I. 2013. The recovery of Atlantic swordfish: The comparative roles of the Regional Fisheries Management Organization and species Biology. Reviews in Fisheries Science, 21:2, 59-97, 10.1080/10641262.2012.754842

[8] OECD. 2012. ICCAT Inventory of National and Regional approaches to fisheries rebuilding programmes. From: www.oecd.org/tad/fisheries/ICCAT.pdf

[9] ICCAT. 2011. ICCAT geographical delimitations. https://www.iccat.int/Data/ICCATMaps2011.pdf

[10] DFO. 2012. Sustainable Management of Canadian Swordfish Fishery. Accessed February 2016. <http://www.dfo-mpo.gc.ca/international/swordfish-espandon/swordfish-mgt-gestionespadon-eng.htm>

[11] ICCAT. 2014. ICCAT Report 2014-2015 Executive Summary SWO-ATL-Atlantic Swordfish.

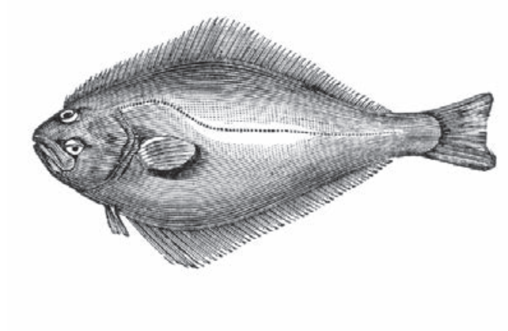
[12] SCRS, 2005. A preliminary evaluation of the effectiveness of minimum size regulations versus marine protected areas for North Atlantic swordfish stock. Col. Vol. Sci. Pap. ICCAT, 58(4): 1436-1445. SCRS/2004/128.

[13] ICCAT. 2013. Recommendation by ICCAT for the Conservation of North Atlantic Swordfish.13-02.

[14] Ibid.

Atlantic Halibut

Hippoglossus hippoglossus



Stock Area(s):	Scotian Shelf and Southern Grand Banks
Fishing Gear Used:	Longline, gillnet, bottom trawl
Recent Assessments:	2015[1]
COSEWIC Status:	None
SARA Status:	None
MSC Certified:	Yes, since May 2013[2]
Stock Status:	Above B_{MSY}[3]
Population Trajectory:	↑[4]
Recovery Prospects:	Good, provided F remains low
	Continued recovery expected, barring reduced illegal catch

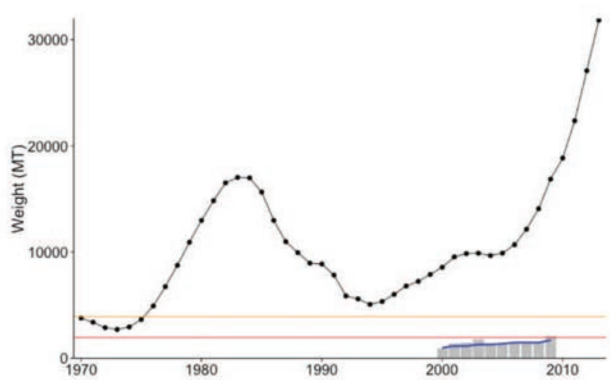


Figure 1. Atlantic halibut on the Scotian Shelf and Southern Grand Banks (3NOPs4VW5Zc) total biomass (black line), total landings (grey bars) and TAC (blue line). Upper and lower biomass limit reference points defined as 80% B_{MSY} and 40% B_{MSY}, respectively, where the biomass metric used was spawning stock biomass (SSB; as opposed to total biomass). B_{MSY}=4900t.[5]

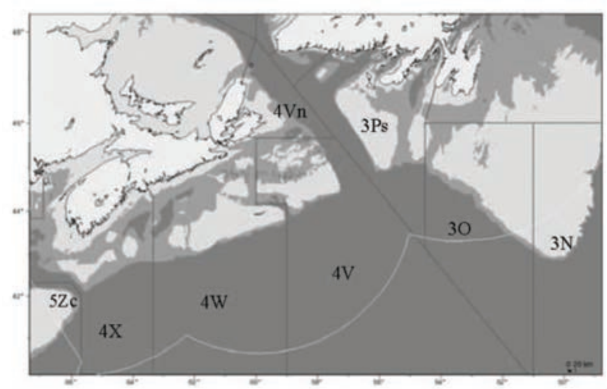


Figure 2. NAFO Divisions 3NOPs4VWX5Zc representing the Scotian Shelf Southern Grand Banks fishing areas.[6]

Life History & Fishery Description

Atlantic halibut is a demersal flatfish, living on or near the seafloor at depths between 200-500m. Its range extends from the coast of Virginia to northern Greenland. Atlantic halibut grow at rates of up to 10cm per year until they reach age of maturity (estimated 77cm at ages 5-6 for males, and 119cm at ages 9-10 for females). A total allowable catch for the Atlantic Halibut fishery was first introduced in 1988.

Critical Management Intervention

The three most significant measures that led to recovery of Atlantic halibut were the initial establishment of a TAC in 1988, implementation of the moratorium on cod fishing in 1992, which resulted in a decadal decrease in the mortality of juvenile halibut previously caught in otter trawls and, finally, the establishment of a minimum size coupled with the relatively low mortality of released fish caught in bottom longlines.

Other Management Measures

Other management measures include TAC, minimum legal size restrictions, dockside commercial catch monitoring program (100%), at-sea coverage by observers, mandatory logbooks, predetermined fishing periods, limits on size and maximum number of hooks allowed per line, by-catch protocols and vessel monitoring systems for large longliners in Quebec.

Reference points have been established, and there is a harvest control rule in place that is based on a constant F rate, a three-year average of the survey index and estimated survey biomass with a limit on TAC decrease or increase of no more than 15% per year.

Key Recovery Uncertainties

The halibut stock has a long history of overfishing, with significant declines occurring prior to the start of the data time series in 1970. As such, current recovery has not been compared to past production and shifting baselines may be occurring.

Interpretation of stock trends assume no changes in natural morality, growth or fecundity that impact population dynamics.

Recovery Outlook & Potential

The stock is considered to be recovered from a period of overexploitation in 1980s and early 1990s.[7] Despite moderate increases in TAC, the Atlantic halibut stock appears to be increasing.[8] There are concerns about illegal fishing, particularly by the demersal longline fleet, and $1 million in fines have been levied in 2015 against fishermen for illegal fishing.[9]

Seventy-four species are caught as bycatch in the Atlantic halibut fishery. Several of these are COSEWIC assessed, including Atlantic cod, white hake, cusk and winter skate.[10]

Recovery Recommendations

There is a risk of falling below the upper reference point if F increases. In the short term, harvest strategies that have higher catch rates will remain above B upper because fish from the most recent recruitment period will remain available to the fishery. Higher catch strategies reduce the long-term reproductive potential of the stock, which will lead to population decline. The relative recovery of Atlantic halibut has increased the demand for allocations and quota. Thus, adhering to the established harvest control rule is important in maintaining stock health and current increases. As well, recent Conservation and Protection fines for illegal fishing suggest that F is greater than reported landings indicate.

[1] DFO 2015. 2014 Assessment of Atlantic Halibut on the Scotian Shelf and Southern Grand Banks (NAFO Divisions 3NOPs4VWX5Zc) Canadian Science Advisory Secretariat Science Advisory Report 2015/012.

[2] Ibid.

[3] MSC Certification of Atlantic Halibut. https://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/north-westatlantic/canada_atlantic_halibut/canada_atlantic_halibut

[4] Ibid.

[5] DFO 2015 above note 1.

[6] Ibid.

[7] Trzcinski, M.K. and Bowen, W.D., 2016. The recovery of Atlantic halibut: a large, long-lived, and exploited marine predator. *ICES Journal of Marine Science: Journal du Conseil*, p.fsv266.

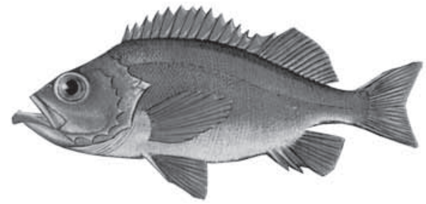
[8] DFO 2015 above note 1.

[9] DFO April 27 2015. Intelligence Led Multi-year Approach Paying Off. http://news.gc.ca/web/article-en.do?nid=967419

[10] DFO 2015 above note 1.

Atlantic Redfish

Sebastes mentella & S. fasciatus



Stock Area(s): Eastern & Northern Grand Banks (Area 3LN)
Fishing Gear Used: Bottom and mid-water trawls
Recent Assessments: 2014,[1] 2012[2]
COSEWIC Status: *S. fasciatus* Atlantic population: Threatened[3]
S. mentella Northern population: Threatened[3]
SARA Status: *S. fasciatus*: No status, *S. mentella*: No status[4]
MSC Certified: Canada 3LN Redfish under assessment[5]
Stock Status: 1.4B_{MSY}[1]
Population Trajectory: ↑[1]
Recovery Prospects: Good; caution should be exercised on fishing pressure increases

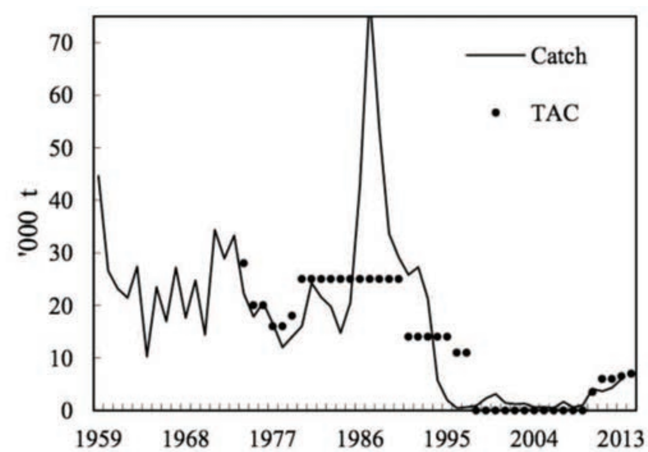


Figure 1. Redfish catch and TACs in Division 3LN. Figure from NAFO 2014.[6]

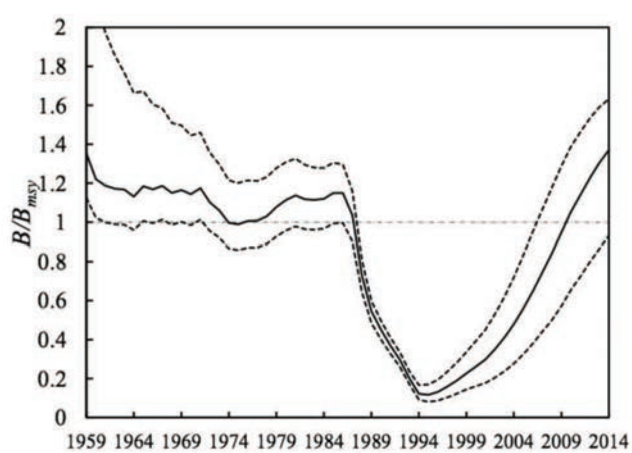


Figure 2. Redfish Biomass to B_{MSY} (B/B_{MSY}) for Division 3LN. Figure from NAFO 2014.[6]

Life History & Fishery Description

Redfish are found in deep waters (between 100-750m) of the Northwest Atlantic, where they feed primarily on pelagic species in the water column. Two species of redfish, *Sebastes mentella* (the deep sea redfish) and *Sebastes fasciatus* (the Acadian redfish), occur in NAFO Division 3LN and are managed together as a single management unit.

The TACs for fishing in Division 3LN areas within and outside Canada's EEZ are set annually by NAFO. NAFO also establishes other management measures including for those gear, area and time restrictions and bycatch.

Critical Management Intervention

Redfish catches in Division 3LN declined in the early 1990s, and stock biomass fell to 12% B_{MSY} (B_{MSY} = 191500t) in 1994-1995.[1] The fishery was placed under a moratorium from 1998 to 2009 and was reopened in 2010.

Other Management Measures

Reference points B_{lim} (30% B_{MSY}) and F_{lim} (F_{MSY}) were established during the 2004 NAFO Scientific Council meeting.[6]

Harvest control rules are in development as of 2014.[6]

Key Recovery Uncertainties

- **Unreported catches** within the directed fishery and other fisheries are difficult to estimate. Bycatch may have a significant impact on redfish populations. Furthermore, commercial fishery landings are not reported to the species level and create uncertainty in assessments of these stocks.[6]
- **Environmental factors** (including sea surface and bottom temperatures) have been found to influence trends in redfish abundances.[7]

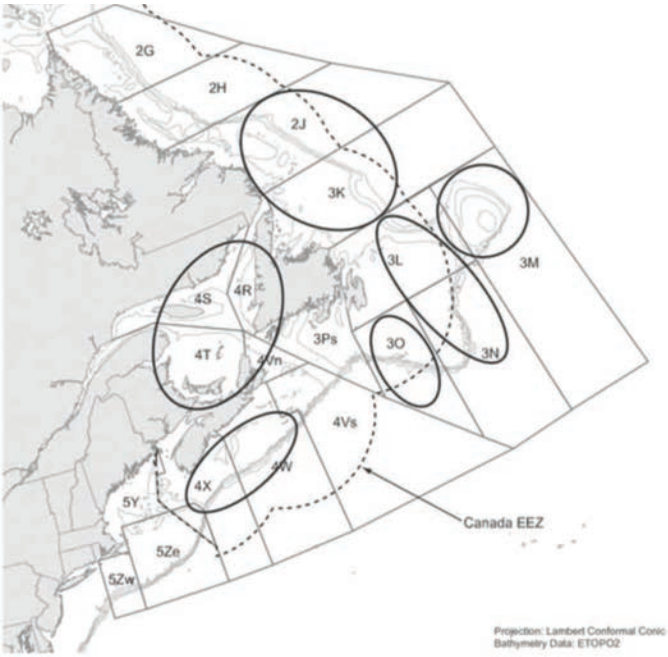


Figure 3. East coast of Canada with NAFO management areas and bathymetric contours. NAFO stocks 4RST and 3Pn4Vn (unit 1), 4WX (Unit 3), 2J3K, 3LN, 3O and 3M are illustrated. Figure from Devine and Haedrich (2011).[7]

Recovery Outlook & Potential

In 2010, COSEWIC evaluated the northern population of *S. mentella* (including the Grand Banks, Labrador Shelf, Davis Strait and Baffin Bay areas) to be "Threated" following a 98% decline in abundance.[8] The Canadian Atlantic *S. fasciatus* population (including the Gulf of St. Lawrence and Laurentian Channel, Grand Banks and Labrador Shelf, and the Scotian Shelf, Bay of Fundy and Gulf of Maine areas) was evaluated to be "endangered" due to a 99% decline in abundance but is designated as "Threatened" due to its wide distribution, a higher abundance of mature individuals and indices of abundance suggest stable or increasing trends.[8]

The longevity, slow growth and slow maturation of redfish species increase their vulnerability to fishing pressures. Low catches and fishing mortality levels since 1995 and through the moratorium period allowed biomass to rebuild. At the beginning of 2014, the stock was considered to be at or above B_{MSY} and fishing mortality below F_{MSY} (0.11) with high to very high probability.[1] Catches in 2013 were the highest recorded in the past 20 years.[6]

With the rebuilding biomass of redfish in Divisions 3LN, fishing opportunities are also expanding. The NAFO Fisheries Commission has proposed a harvest control rule to increase TAC in constant increments starting in 2015 to a maximum of 20,000t within seven years.[9] In March of 2015, the Marine Stewardship Council (MSC) began an assessment of the Canadian 3LN redfish fishery to allow products to carry MSC's ecolabel.[5]

Recovery Recommendations

Harvest control rules for Division 3LN redfish are under development.[6] Caution should be exercised with increasing pressure on redfish, which have shown to be vulnerable to exploitation. The stepwise increases in TAC are projected to maintain stock biomass above B_{MSY}.[6] Management strategies should account for life history of the species. Although time scales of several years may account for turnover in some species, the slow growth and longevity of redfish impacts its response to changes in fishing pressure or conditions.[8]

[1] NAFO. 2014. An ASPIC Based Assessment of Redfish (*S. mentella* and *S. fasciatus*) in NAFO Divisions 3LN (assuming that the highest apparently sustained historical average level of catch is a sound proxy to MSY). NAFO SCR Doc. 14/022

[2] NAFO. 2012. An ASPIC Based Assessment of Redfish (*S. mentella* and *S. fasciatus*) in NAFO Divisions 3LN (can a surplus production model cope with bumpy survey data?). NAFO SCR Doc. 12/032.

[3] COSEWIC. 2016. Wildlife Species Search. Accessed February 2016 < http://www.cosewic.gc.ca/eng/sct1/index_e.cfm>

[4] SARA. 2016. Species at Risk Public Registry Species Profile, Acadian Redfish Atlantic population. Accessed February 2016. <http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1096>

[5] MSC. 2016. Accessed February 2016 <https://www.msc.org/track-a-fishery/fisheries-in-the-program/in-assessment/northwest-atlantic/canada-3ln-redfish>

[6] NAFO. 2014. Redfish in Division 3LN Advice June 2014 for 2015-16. SC 30-May-12 Jun 2014.

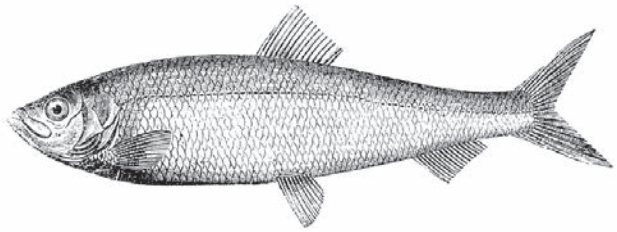
[7] Devine, J. A. and Haedrich, R. L. 2011. The role of environmental conditions and exploitation in determining dynamics of redfish (*Sebastes* species) in the Northwest Atlantic. Fisheries Oceanography, 20: 66–81. doi: 10.1111/j.1365-2419.2010.00566.x

[8] DFO. 2011. Recovery potential assessment of redfish (*Sebastes fasciatus* and *S. mentella*) in the northwest Atlantic. DFO Can. Sci. Advis. Sec., Sci. Advis. Rep. 2011/044. (Erratum: June 2013)

[9] Dauphin G., Morgan M.J., Shelton P.A. 2014. Operating Models for Management Strategy Evaluations of Div. 3LN Redfish. NAFO Scientific Council Meeting – June 2014. NAFO SCR Doc. 14/050.

Norwegian Spring Spawning Herring

Clupea harengus L.



Stock Area(s): Northeastern Atlantic
Fishing Gear Used: Purse seine, pelagic trawl
Recent Assessments: 2014,[1] 2013[2]
COSEWIC Status: N/A
SARA Status: N/A
MSC Certified: Norway Spring spawning herring (2009)[3]
Stock Status: Below MSY ($B_{trigger}$) and SSB_{mgt} target[2]
Population Trajectory: ↓ [2]
Recovery Prospects: Good, with rapid response of recovery plan

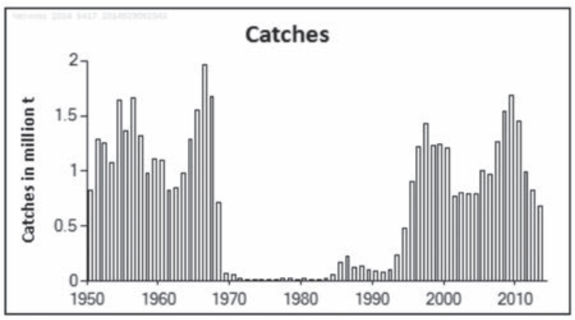


Figure 1. Catches of Norwegian spring spawning herring (Sub-areas I, II and V and in Divisions Iva and XIVa). Figure from ICES 2014.[4]

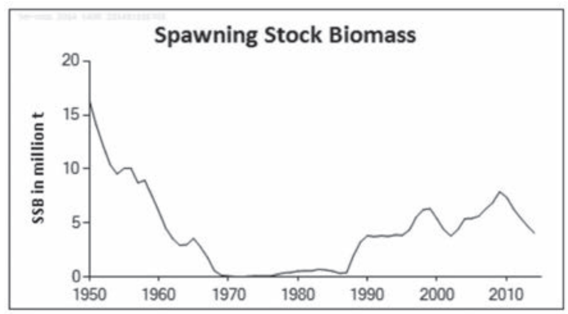


Figure 2. Spawning stock biomass (SSB) of Norwegian spring spawning herring (Sub-areas I, II and V and in Divisions IVa and XIVa). Figure from ICES 2014.[5]

Life History & Fishery Description

Atlantic herring is a pelagic species of the Clupeidae family. It occurs widely throughout the North Atlantic and feeds mainly on plankton. North Atlantic herring are divided into spring, summer and autumn spawning stocks. Herring in the Baltic and off the Norwegian coast are spring spawners. The Norwegian spring spawning herring (NSSH) stock is the largest herring stock in the world and is also the largest fish stock in the North Atlantic.[6]

The fishery of NSSH is jointly managed by the Coastal States (the E.U., Faroe Islands, Iceland, Norway and Russia), which set out TAC and allocation to national quotas.

Critical Management Intervention

Rapidly increasing fishing pressure through the 1950s and 1960s led to a decline and collapse of the NSSH in the early 1970s.[5] In the late 1970s an informal rebuilding plan was developed by Norwegian management authorities whereby fishing levels were kept at a maximum of 0.05 until the spawning stock reached the target B_{lim} for recovery (2.5 million tonnes), and a catch ceiling of 1.5 million tonnes was applied. The herring stock had rebuilt to a level surpassing the target B_{lim} in the mid-1990s and fishing levels were allowed to increase.[7] In 2001 the Coastal States agreed to a recovery plan to respond to stock declines below a precautionary reference point.[8]

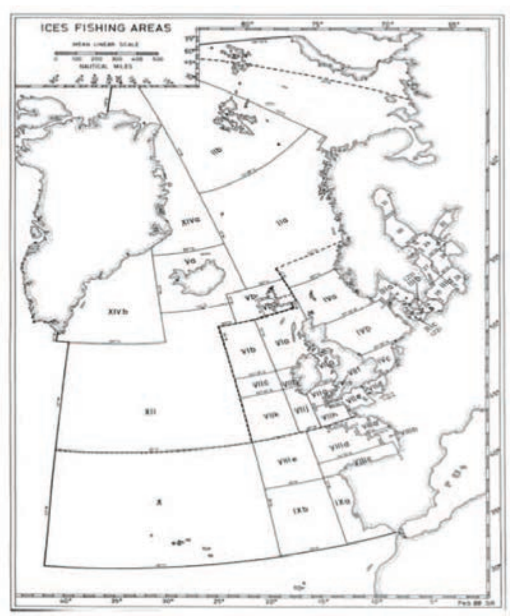


Figure 3. ICES fishing areas in the North Atlantic. Spring spawning herring are found in Divisions IIa, IVa and Vb and are fished mainly in Divisions IIa and IVa within the Norwegian EEZ. Map from MSC Public Certification Report (2009).[9]

Other Management Measures

The long-term management plan established in 2001 by the Coastal States set out several measures including:

- Establishing a B_{lim} of 2.5 million tonnes for SSB and an MSY $B_{trigger}$ reference point under the precautionary approach (BPA) of 5.0 millions tonnes[5]
- Maintaining TACs consistent with a fishing mortality rate of less than 0.125 (F_{mgt}) on appropriate age-groups unless future scientific advice recommends revision
- Adapting fishing mortality to ensure recovery if the SSB falls below B_{PA}
- Reviewing and revising management measures on the basis of advice provided by the International Council for the Exploration of the Sea (ICES)[9]

A minimum size restriction of 25cm has been set within E.U. and Norwegian waters.

Key Recovery Uncertainties

- The NSSH is a shared, straddling, high-seas stock subject to management under international cooperation of the Coastal States.
- Herring mixes with other stocks in management areas which are exploited together, potentially changing assessments or measures of relative stock abundance.[10]
- The NSSH stock is widely distributed throughout its life history, and groups spawn in different areas.[6] Changes in stock status or dynamics must also account for spatial heterogeneity of the stock.[9]
- Variable stock dynamics means that strong year classes can dominate the stock, increasing uncertainty in assessments.[10]

Recovery Outlook & Potential

Despite only moderate fishing pressure (an intended fishing mortality of 0.125) between 2007-2013,[10] the Norwegian spring spawning stock was below the MSY ($B_{trigger}$) and Management Plan (SSB_{mgt}) targets in 2014.[2] Fishing mortality was below F_{MSY} and F_{PA} ($F_{MSY} = F_{PA} = 0.15$)[5] but above the management plan F target (F_{MGT}) in 2013.[11] This higher fishing mortality is in part due to a lack of agreement between Coastal States on quota allocations in 2013 and 2014, which have resulted in separately set quotas that, when combined, are higher than the TAC recommended by the management plan.[2]

This stock has shown positive responses to reductions in fishing pressure. Due to the nature of the stocks' dynamics, the strength of recruitment of year classes determine much of the stock recovery trajectory.[10] Recommendations have been set out for decreases to fishing pressure through reduced TACs in response to stock status indicators and reference points, as set out in the Management Plan.[2] Even these reduced catches are expected to result in declines to SSB until strong recruitment occurs.

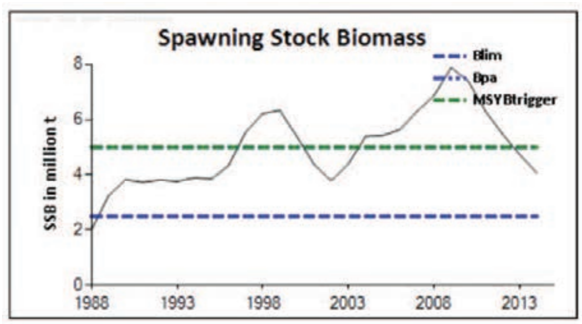


Figure 4. Spawning stock biomass (SSB) of Norwegian spring spawning herring (Sub-areas I, II, and V, and in Divisions Iva and XIVa) from 1988 to 2014 (MSY $B_{trigger} = B_{PA}$). Figure from ICES 2014.[5]

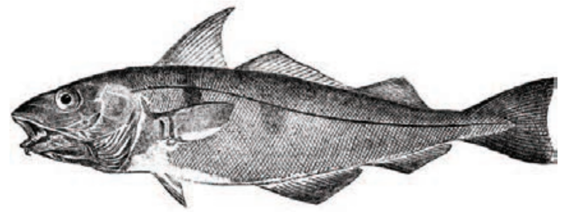
Recovery Recommendations

This stock has a clearly outlined recovery plan with trigger points for management measures that have been effective at altering stock trajectories from past declines. The current decline in stock status requires rapid response to prevent continuing decline in the stock to levels below B_{lim} and restore levels to those above the precautionary reference points (B_{PA}), including aligning catches with those set out in the management plan.[2]

1 ICES. 2014. Widely distributed and migratory stocks. Herring in Subareas I, II, and V, and in Divisions Iva and XIVa
2 ICES. 2013. Widely distributed and migratory stocks. Herring in Subareas I, II, and V, and in Divisions Iva and XIVa
3 MSC. 2016. Track a Fishery: Norway spring spawning herring. Accessed February 2016. <https://www.msc.org/track-a-fishery/fisheries-inthe-program/certified/north-east-atlantic/norway-spring-spawning-herring/norway-spring-spawning-herring>
4 ICES. 2014. ICES Advice September 2014. Widely distributed and migratory stocks; Herring in Subareas I, II, and V, and in Divisions Iva and XIVa (Norwegian spring-spawning herring). ICES Advice 2014, Book 9.
5 ICES. 2014. Above note 1.
6 MSC. 2014. Public certification report. Reassessment of the Norway Spring Spawning herring fishery. MSC Fishery Assessment Report No. 2013-009.
7 Tjelmeland S. and Røttingen I. 2009. Objectives and harvest control rules in the management of the fishery of Norwegian spring-spawning herring. – ICES Journal of Marine Science, 66: 1793–1799.
8 Røttingen I. 2003. The agreed recovery plan in the management of Norwegian spring-spawning herring. ICES CM 2003/U:01.
9 MSC.. 2016. Above note 3.
10 Dickey-Collas, M., Nash, R. D. M., Brunel, T., van Damme, C. J. G., Marshall, C. T., Payne, M. R., Corten, A., Geffen, A. J., Peck, M. A., Hatfield, E. M. C., Hintzen, N. T., Enberg, K., Kell, L. T., and Simmonds, E. J. 2010. Lessons learned from stock collapse and recovery of North Sea herring: a review. – ICES Journal of Marine Science, 67: 1875–1886.
11 ICES. 2013. Report of the Working Group on Widely Distributed Stocks (WGWIDE). ICES Advisory Committee, ICES CM 2013/ACOM: 15

Haddock

Melanogrammus aeglefinus



Stock Area(s): Eastern Georges Bank (NAFO Area 5Zjm
Fishing Gear Used: Otter trawls, longlines, handlines, gillnets
Recent Assessments: 2014,[1] 2013,[2] 2012[3]
COSEWIC Status: Not Listed[4]
SARA Status: Not Listed[5]
MSC Certified: Yes (Canadian), No (U.S.)[6]
Stock Status: Not overfished, overfishing not occurring[7]
Population Trajectory: ↑ [8]
Recovery Prospects: Continued recovery expected provided recruitment remains high

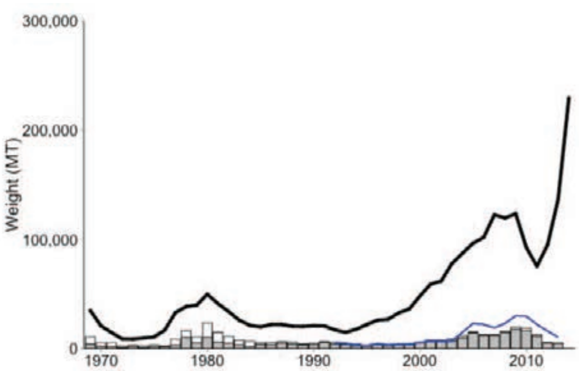


Figure 1. Total landings for 5Zjm haddock for Canada (grey bars) and the USA (white bars), total stock biomass (black line) and Total Allowable Catch (blue line).

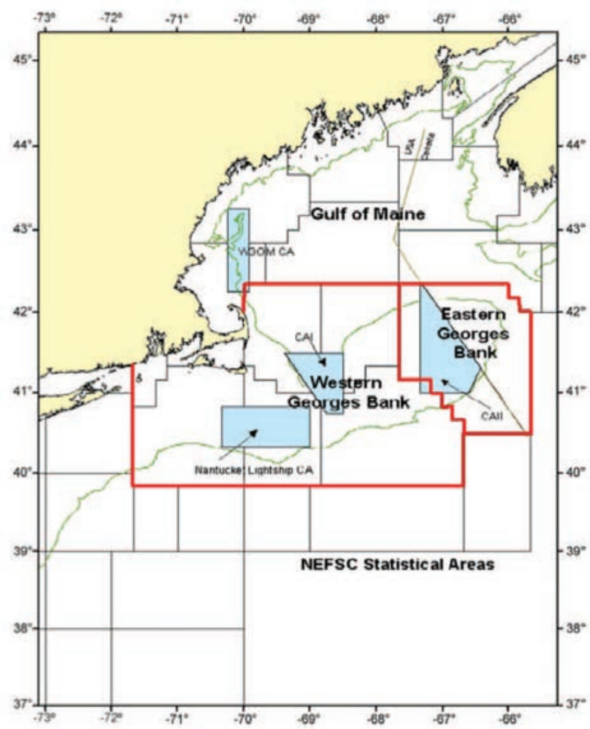


Figure 2. From Brodziak et al. 2008[6]. The geographic range of the Georges Bank haddock stock off New England (red lines), showing the western and eastern management units with the Hague Line demarcating the boundary between U.S. and Canadian waters and four year-round groundfish closed areas (CA): CA I, CAII, the Nantucket Lightship CA and the Western Gulf of Maine (WGOM) CA.

Life History & Fishery Description

Haddock are a groundfish species occurring on both sides of the Atlantic, spending most of their life in deep water between 40-300m deep. Haddock feed on smaller invertebrates, including shellfish, urchins, worms and small fish.

Commercial fishing for haddock on the Georges Bank began in the early 1920s. Maximum catches are estimated to have occurred in the early 1960s. Canada and the United States conduct joint assessments and management of the Georges Bank Haddock stock through the Canada-United States Transboundary Management Guidance Committee (TMGC), established in 2000. The haddock stock is managed as western and eastern stock units to reflect the harvest-sharing agreement (2003) between the two countries (Fig. 2).

Critical Management Intervention

Spawning biomass of Georges Bank Haddock declined by almost 80% during the 1980s, eventually collapsing and reaching a historical low of 5% of B_{MSY} in 1993.[9] Restrictive management measures were imposed in the mid-1990s to reduce fishing mortality on groundfish stocks (Atlantic cod, haddock and yellowtail flounder) through areas closed to all fishing gears capable of catching groundfish, days-at-sea restrictions and increased trawl mesh sizes. Canada introduced Individual Transferable Quotas (ITQs) and dockside monitoring (DSM) of all Canadian landings in 1992.[3]

Other Management Measures

Haddock have been managed using quotas since the 1970s.

There are seasonal and area fishing closures during haddock spawning, including Haddock Box on Scotian Shelf.[10]

The TMGC adopted a fishing mortality reference limit point (F_{ref} = 0.26) in 2002 and an F strategy to maintain low-to-neutral risk of exceeding this limit.[3]

There are restrictions on catching haddock under 43cm (small fish protocol).[3]

Key Recovery Uncertainties

Joint management of a transboundary stock. Challenges exist in coordination and cooperation of fishing efforts between Canadian and American fisheries to rebuild the stock.[6]

Density-dependence growth. Georges Bank haddock stock appears to have a threshold of productivity around 75,000-85,000kt of spawning biomass.[6,8]

Declining condition. Size at age of the Georges Bank haddock stock has been declining. Increased levels of catch below the minimum size regulation could lead to higher rates of discard.

Recovery Outlook & Potential

The Georges Bank haddock stock responded rapidly and positively to lowered fishing pressure between 1995 and 2004[11] but was still considered to be overfished by 2004 since spawning biomass was less than one-half of the rebuilding target (BMSY = 250.3kt).[6] Stock productivity remains uncertain. Although stock biomass is increasing (reaching a historical high of 160,300 mt in 2014 and is projected to be at 568,200mt in 2016),[2] fish condition and size-at-age have been continually declining.[2] Density-dependent growth needs to be accounted for in reference points, fishing mortality and spawning biomass targets.[8]

Recovery Recommendations

Larger-than-normal recruitment and year classes have led to a considerable recovery of Georges Bank haddock. There remains concern regarding reduced length and weight at age. The fact that the majority of the haddock stock is harvested by otter trawl results in potential discarding of smaller fish.

[1] TRAC. 2014. Eastern Georges Bank Haddock [5Zjm; 51,552,561,562] Status Report 2014/02.

[2] TRAC. 2013. Assessment of Eastern Georges Bank Haddock for 2013. Transboundary Resources Assessment Committee Reference Document 2013/03.

[3] TRAC. 2012. Assessment of Eastern Georges Bank Haddock for 2012. Transboundary Resources Assessment Committee Reference Document 2012/01.

[4] COSEWIC. 2016. Wildlife Species Search. Accessed February 2016. < http://www.cosewic.gc.ca/eng/sct1/index_e.cfm>

[5] SARA. 2016. Species at Risk Public Registry. Accessed February 2016. < http://www.registrelepsararegistry.gc.ca/sar/index/default_e.cfm>

[6] MSC. 2016. MSC Certified Fisheries North-west Atlantic. Accessed February 2016. < https://www.msc.org/track-a-fishery/fisheries-in-theprogram/certified/north-west-atlantic>

[7] NOAA 2015. Georges Bank Haddock. 2015 Assessment Update Report. http://www.nefsc.noaa.gov/groundfish/operational-assessments-2015/Reports/Georges_Bank_haddock_Update_2015_09_02_101218.pdf

[8] Brodziak J., Traver M.L., Col L.A. 2008. The nascent recovery of the Georges Bank haddock stock. Fisheries Research 94: 123-132. doi:10.1016/j.fishres.2008.03.009

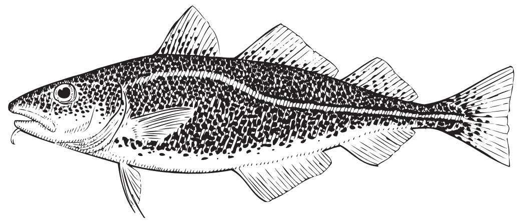
[9] Ibid.

[10] DFO. 2015. Haddock. Accessed February 2016. < http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/fisheries-peches/haddock-aiglefin-eng.htm>

[11] Brodziak, J.K.T. and J.S. Link. 2008. The Incredible Shrinking Georges Bank Haddock (*Melanogrammus aeglefinus*). In: G.H. Kruse, K. Drinkwater, J.N. Ianelli, J.S. Link, D.L. Stram, V. Wespestad, and D. Woodby (eds.), Resiliency of Gadid Stocks to Fishing and Climate Change. Alaska Sea Grant College Program, Fairbanks, pp. 141-160. doi:10.4027/rgsfcc.2008.08

Atlantic Cod

Gadus morhua



Stock Area(s):	Flemish Cap (NAFO Div. 3M)
Fishing Gear Used:	Bottom trawls
Recent Assessments:	2015,[1] 2014[2]
COSEWIC Status:	Not applicable
SARA Status:	Not applicable
MSC Certified:	No
Stock Status:	SSB well above B_{lim}[2]
Population Trajectory:	↑ [2]
Recovery Prospects:	Lowered fishing mortality required[2]

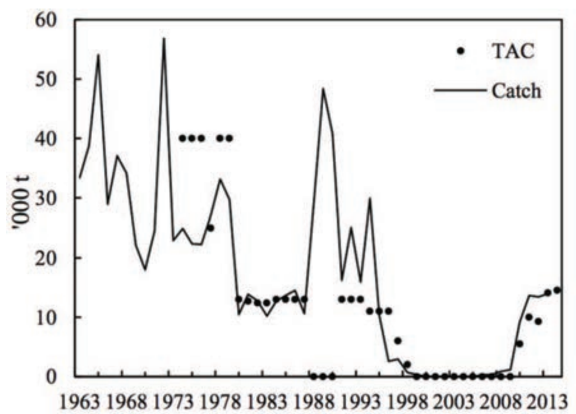


Figure 1. Total catch and TAC for cod in the Flemish Cap (NAFO Div. 3M). Figure from NAFO 2014.[3]

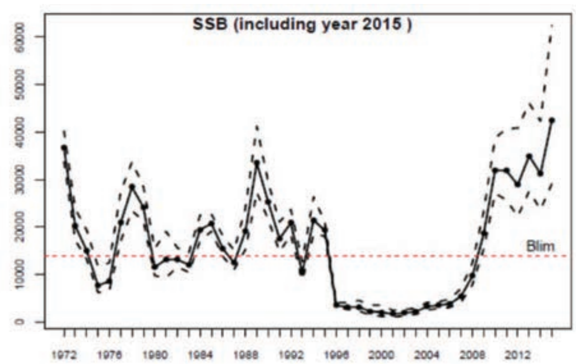


Figure 2. Estimated trends in Spawning Stock Biomass (SSB); solid line is the calculated posterior median, and the dashed line show limits of 90% posterior credible intervals. Red line represents B_{lim} = 14 000t. From NAFO 2015.[2]

Life History & Fishery Description

Atlantic cod are a species of groundfish widely distributed in the North Atlantic, Arctic Ocean, Labrador Sea and Barents Sea. In the Northwest Atlantic, Atlantic cod inhabit a wide range of depths, from inshore shallow water to the edge of the continental shelf. Capelin is a key prey species of cod.

Atlantic cod have been fished in the North Atlantic for over 500 years. Fishing pressure on cod stocks increased to a peak in the late 1970s and early 1980s. Cod stocks in NAFO regions, including in the Flemish Cap (Div. 3M), declined to collapse in the 1990s due to overfishing, increased catchability due to aggregation at low abundances and poor recruitments, leading to the implementation of a moratorium on many cod stocks. The stock within the Flemish Cap is assessed and managed by the Northwest Atlantic Fisheries Organization (NAFO).

Critical Management Intervention

A fishing moratorium was imposed from 1999 to 2009, and spawning stock biomass began to rebuild from 2004. Higher levels of recruitment in recent years have contributed to recovery of the stock's biomass.

Figure 3. NAFO Divisions on Canada's east coast. Image from DFO 2012.[4]

Other Management Measures

Bycatch and gear restrictions have been imposed (minimum mesh size regulations for bottom trawl gear (130mm)).

A Minimum Landing Size (MLS) of 41cm has been established.

A large area of Division 3M is under closure to protect benthic species including sponges, seapens and coral.

Key Recovery Uncertainties

The mesh size used makes it possible to catch immature individuals with a length below the minimum size that need to be discarded.

The recent TAC level has been set higher than scientific advice calls for.

Recovery Outlook & Potential

The cod fishery on the Flemish cap was re-opened in 2010. Although stock biomass is increasing and is well above the limit reference point B_{lim} (14,000t of spawning biomass) developed by the scientific council in 2008, current fishing mortality levels are considered to be unsustainable at twice the long-term management target of F_{max} (0.145).[2,5] Catches are estimated to have exceeded the TAC in the majority of recent years (e.g., the catch estimated by the Scientific Council in 2010 was 9,291t, far surpassing the TAC of 5,500t).[2] Between 2012 and 2014, there was a 97% probability that F exceeded F_{lim} (0.13 = F_{MSY}).[4]

Catch information indicates that a higher proportion of the catch falls close to the minimum landing size, resulting in a larger number of individuals being removed to fulfill the same TAC and a higher number of discards.[6] The Scientific Council recommends TAC be less than catches corresponding to those predicted under F_{lim}.[7]

Recovery Recommendations

Current recommendations from the NAFO Scientific Council is to regulate fishing to a sustainable level, and bring F below FMSY.[4] A harvest control rule is being developed by the Fisheries Commission and Scientific Council.

[1] NAFO. 2015. Assessment of the Cod Stock in NAFO Division 3M. Scientific Council Meeting June 2015. NAFO SCR Doc. 15/033.

[2] NAFO. 2014. Assessment of the Cod Stock in NAFO Division 3M. Scientific Council Meeting June 2014. NAFO SCR Doc. 14/035.

[3] NAFO. 2014. Cod in Division 3M Advice June 2014 for 2015.

[4] DFO 2012. The Grand Banks and the Flemish Cap. Accessed February 2016. http://www.dfompo.gc.ca/international/media/bk_grandbanks-eng.htm

[5] SEAFISH. 2015. Atlantic cod on the Flemish Cap, Demersal otter trawl. www.seafish.org/rass/do_pdf.php?id=2422&section=all

[6] NAFO. 2015. Above note 1.

[7] Ibid.

Atlantic Sea Scallops

Placopecten magellanicus

Stock Area(s): Gulf of Maine, U.S.
Fishing Gear Used: Dredge
Recent Assessments: 2014,[1] 2010[2]
COSEWIC Status: N/A
SARA Status: N/A
MSC Certified: U.S. Atlantic sea scallop (2013)[3]
Stock Status: $B > B_{target}$
Population Trajectory: Stable[2]
Recovery Prospects: Good, with development of regional reference points

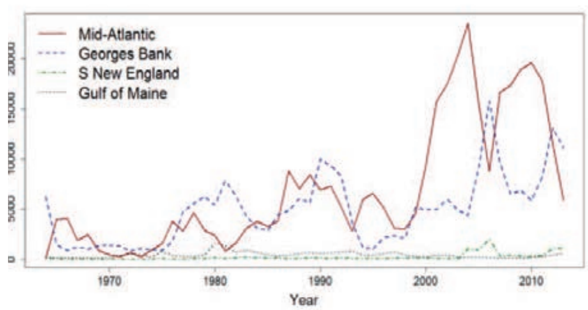


Figure 1. Sea scallop landings by region for 1965-2013. Figure from NOAA 2014.[2]

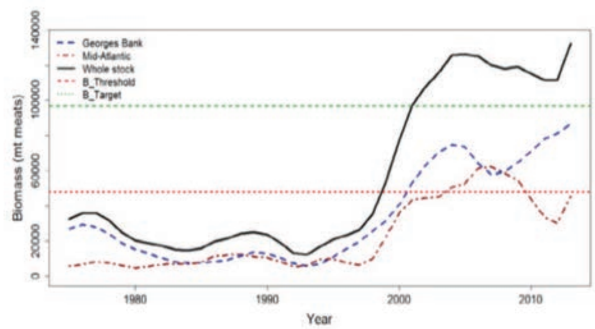


Figure 2. Total biomass for Georges Bank, Mid-Atlantic and whole scallop stock for scallops larger than 40mm from 1975-2013 with whole stock reference points ($B_{threshold}$ and B_{target}). Figure from NOAA 2014.[2]

Life History & Fishery Description

Sea scallops are benthic filter-feeding bivalve molluscs. Scallops typically occur in large aggregations, called beds, at depths between 18-110m. The Atlantic sea scallop is distributed from Newfoundland to North Carolina. Under the Atlantic Sea Scallop Fishery Management Plan, all sea scallops within the EEZ of the United States belong to a single stock with two stock assessment regions – the Mid-Atlantic and Georges Bank.

The sea scallop fishery is the most important commercial bivalve fishery in North America.[4] This stock is managed by the New England Fishery Management Council (NEFMC) and by the National Marine Fisheries Service (NMFS). With the aim of restoring scallop stocks and reducing fluctuations in stock abundances, the Atlantic Sea Scallop Fishery Management Plan was implemented in 1982, setting minimum weight requirement for harvestable scallops. [5]

Critical Management Intervention

Stock biomass declined from the 1960s to the mid-1990s with increasing fishing mortality.[6] An amendment to the plan in 1994 replaced minimum weight requirements with a limited access program with effort and gear controls, including a moratorium on permits and limits to days at sea and crew sizes. In 1997 sea scallops were declared overfished, and a further amendment to the management plan lowered mortality levels with the goal of rebuilding the stock within 10 years. Using a combination of area closures, effort reduction, and gear restrictions, scallop biomass was considered rebuilt by 2001.

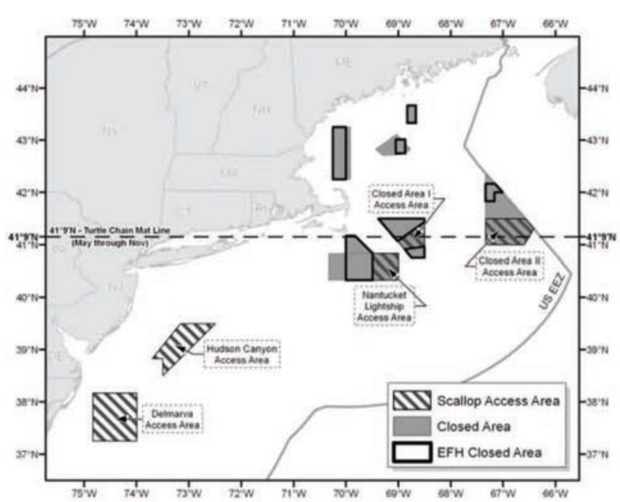


Figure 3. Sea scallop management areas, closed areas and Essential Fish Habitat (EFH) Closed Areas on the U.S. Atlantic coast under rotational management system introduced in 2004. Figure from NOAA.[7]

Other Management Measures

Stock reference points were revised in the 2010 assessment, raising F_{MSY} from 0.38 to 0.48, lowering BMSY from 125,358 to 96,480 mt (meats) and lowering MSY from 24,975 to 23,798 mt (meats). Sea scallops are considered overfished when the survey biomass index for the whole stock falls below $1/2B_{target}$ (=B_{MSY}).

An area rotation management program was implemented in 2004.[8]

Vessel monitoring systems have been required since 2005.[8]

Dredge ring size requirements (increased to 4 inches in 2004) are in place to target older scallops.[7]

Industry-funded observer program was established in 2007, with the costs to vessel owners of carrying observers mitigated through a total allowable catch and days-at-sea set-aside program.[8]

Several categories of limited access permit replaced open-access scallop permits in 2008.[8]

Key Recovery Uncertainties

Fleet overcapacity. The scallop fleet is still considered to be in a state of overcapacity,[6] and changes in fishing effort introduce uncertainty into the future of the stock.

Reported whole-stock fishing mortality underestimates mortalities in open fishing areas due to long-term and rotational closure areas. Open areas might be depleted even if overfishing was not indicated for the overall stock.[2]

Because assessments have overestimated stock biomass by an average of 24% in the last seven years, uncertainty in biomass dynamics should be accounted for in management of stock trends.[2]

Recovery Outlook & Potential

Sea scallops exhibited a rapid rebuilding after a period of severe overfishing. While reductions in effort through the implementation of limited access was among the most important factors contributing to alleviating overfishing of the scallop stock, area closures have been shown to have had the greatest influence on sea scallop abundance and biomass.[6]

After a rapid increase in stock biomass between 1995 and 2003, the stock has been relatively stable. In 2013, the estimated stock biomass (132,561mt) was above the target BMSY reference point.

In 2013, the U.S. scallop fishery was reviewed by the Marine Stewardship Council (MSC) which dismissed objections to its certification that raised concerns over the Harvest Control Rule (HCR) for the stock.

At the time of certification, fishing mortality (F=0.32) was below the target FMSY reference point. It has been noted, however, that F_{MSY} estimates for the two stock assessment regions are very different (0.3 for Georges Bank and 0.74 for the Mid Atlantic) and that the use of a combined reference point could result in higher fishing rates on the Georges Bank than would be advisable.[8]

Recovery Recommendations

Fleet consolidation, as has occurred in Canada, and further days-at-sea reductions may be needed to proactively avoid another period of overfishing scallop populations.[6] Region-specific reference points may be required to appropriately manage the stock, given the differing regional fishing mortality rates, noted above.

[1] Northeast Fisheries Science Center. 2014. 59th Northeast Regional Stock Assessment Workshop (59th SAW) Assessment Summary Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 14-07; 39 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://nefsc.noaa.gov/publications/

[2] Northeast Fisheries Science Center. 2010. 50th Northeast Regional Stock Assessment Workshop (50th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 10-09; 57 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at: http://nefsc.noaa.gov/publications/

[3] MSC. 2016. Track a fishery Northwest Atlantic US Atlantic Sea Scallop. Accessed February 2016 at https://www.msc.org/track-a-fishery/fisheries-in-theprogram/certified/north-west-atlantic/us-atlantic-sea-scallop/

[4] MSC. 2013. MSC Assessment Report for USA Sea Scallop Fishery. Intertek Moody Marine Ltd. FN 82517 v5 December 2013.

[5] NEFMC. 1982. Fishery Management Plan Final Environmental Impact Statement Regulatory Impact Review for Atlantic Sea Scallops (Placopecten maellanicus). New England Management Council.

[6] Hart D.R. and Rago P.J. 2006. Long-term dynamics of U.S. Atlantic Sea Scallop *Palcopecten magellanicus* populations. *North American Journal of Fisheries Management*. 26:490-501. DOI: 10.1577/M04-116.1

[7] NOAA fisheries services. Scallop Access Areas, Closed Areas and EFH Closed Areas. Accessed February 2016. http://www.greateratlantic.fisheries.noaa.gov/nero/fishermen/charts/scal4.html

[8] NOAA. 2016. NOAA Fisheries Atlantic Sea Scallop. Accessed February 2016. http://www.greateratlantic.fisheries.noaa.gov/sustainable/species/scallop/

APPENDIX B. OVERVIEW OF CANADIAN STOCKS AND MAPS

Table B1: Full list of Canadian marine fish and invertebrate stocks included in report
RAM Stock Code refers to the corresponding code for individual stocks within the RAM Legacy Database. Stocks are classified by broad taxonomic group as in the RAM database. Management bodies are DFO, International Commission for the Conservation of Atlantic Tuna (ICCAT), International Pacific Halibut Commission (IPHC), Pacific Fisheries Management Council (PFMC), Transboundary Resource Assessment Committee (DFO, National Oceanic and Atmospheric Administration (TRAC (DFO, NOAA)), Northwest Atlantic Fisheries Organization (NAFO).

#	Species	Scientific Name	Individual Stock Region/Area	Stock Code	Taxa	Management Body
ATLANTIC SPECIES						
1	**American plaice**	*Hippoglossoides platessoides*	Labrador NE Newfoundland (NAFO 23K)	AMPL23K	Flatfish	DFO
2			Grand Banks (NAFO 3LNO)	AMPL3LNO	Flatfish	DFO
3			St. Pierre Bank (NAFO 3Ps)	AMPL3Ps	Flatfish	DFO
4			Southern Gulf of St. Lawrence (NAFO 4T)	AMPL4T	Flatfish	DFO
5			Scotian Shelf (NAFO 4VWX)	AMPL4VWX	Flatfish	DFO
6	**Atlantic halibut**	*Hippoglossus hippoglossus*	Scotian Shelf and Grand Banks (3NOPs4VWX5Zc)	ATHAL3NOPs4VWX5Zc	Flatfish	DFO
7	**Greenland halibut**	*Reinhardtius hippoglossoides*	Labrador Shelf - Grand Banks (NAFO 23KLMNO)	GHAL23KLMNO	Flatfish	DFO
8			Gulf of St. Lawrence	GHAL4RST	Flatfish	DFO
9	**Winter flounder**	*Pseudopleuronectes americanus*	Southern Gulf of St. Lawrence (NAFO 4T)	WINFLOUN4T	Flatfish	DFO
10	**Witch flounder**	*Glyptocephalus cynoglossus*	St. Pierre Banks (NAFO 3Ps)	WITFLOUN3Ps	Flatfish	DFO
11			Gulf of St. Lawrence (NAFO 4RST)	WITFLOUN4RST	Flatfish	DFO
12	**Yellowtail flounder**	*Limanda ferruginea*	Grand Banks (NAFO 3LNO)	YELL3LNO	Flatfish	DFO
13			5Zhjmn Georges Bank	YELLGB	Flatfish	TRAC (NOAA/DFO)
14	**Capelin**	*Mallotus villosus*	East Coast, Gulf of St. Lawrence	CAPE4RST	Forage Fish	DFO
15	**Herring**	*Clupea harengus*	NAFO Div 4R (fall spawners)	HERR4RFA	Forage Fish	DFO
16			NAFO Div 4R (spring spawners)	HERR4RSP	Forage Fish	DFO
17			Quebec North Shore (4S)	HERR4S	Forage Fish	DFO
18			Southern Gulf of St. Lawrence (fall spawners)	HERR4TFA	Forage Fish	DFO

#	Species	Scientific Name	Individual Stock Region/Area	Stock Code	Taxa	Management Body
19			Southern Gulf of St. Lawrence (spring spawners)	HERR4TSP	Forage Fish	DFO
20			Scotian Shelf and Bay of Fundy (4VWX)	HERR4VWX	Forage Fish	DFO
21			Newfoundland east and south coast	HERRNFLDESC	Forage Fish	DFO
22	**Mackerel**	*Scomber scombrus*	NAFO subareas 3 and 4	MACKNWATLSA3-4	Forage Fish	DFO
23	**Atlantic cod**	*Gadus morhua*	Southern Labrador, eastern Newfoundland (NAFO 2J3KL)	COD2J3KL	Groundfish	DFO
24			Southern Grand Banks (3NO)	COD3NO	Groundfish	DFO
25			Northern Gulf of St. Lawrence (3Pn4RS)	COD3Pn4RS	Groundfish	DFO
26			St. Pierre Bank (3Ps)	COD3Ps	Groundfish	DFO
27			Southern Gulf of St. Lawrence (4TVn)	COD4TVn	Groundfish	DFO
28			Eastern Scotian Shelf (4VsW)	COD4VsW	Groundfish	DFO
29			Scotian Shelf and Bay of Fundy (4X5Yb)	COD4X5Yb	Groundfish	DFO
30			Eastern Georges Bank (5Zjm)	COD5Zjm	Groundfish	DFO
31	**Haddock**	*Melanogrammus aeglefinus*	NAFO 3LNO	HAD3LNO	Groundfish	DFO
32			Western Scotian Shelf, Bay of Fundy and Gulf of Maine (4XY)	HAD4X5Y	Groundfish	DFO
33			5Zjm	HADGB	Groundfish	TRAC (NOAA/ DFO)
34	**Pollock**	*Pollachius virens*	St. Pierre Banks (NAFO 3Ps)	POLL3Ps	Groundfish	DFO
35			Scotian Shelf (NAFO 4WVX)	POLL4VWX	Groundfish	DFO
36	**Silver hake**	*Merluccius bilinearis*	Atlantic Ocean	SHAKE4VWX	Groundfish	DFO
37	**White hake**	*Urophycis tenuis*	Newfoundland (NAFO 3NOPs)	WHAKE3NOPs	Groundfish	NAFO
38			Northern Gulf of St. Lawrence (NAFO 4RS)	WHAKE4RS	Groundfish	DFO
39			Southern Gulf of St. Lawrence (NAFO 4T)	WHAKE4T	Groundfish	DFO
40	**American lobster**	*Homarus americanus*	Quebec north shore and Anticosti island (LFA 15-18)	LOBSTERLFA15-18	Invertebrate	DFO
41			Gaspe (LFA 19-21)	LOBSTERLFA19-21	Invertebrate	DFO
42			Magdalen Islands (LFA 22)	LOBSTERLFA22	Invertebrate	DFO
43			Southern Gulf of St. Lawrence	LOBSTERLFA23-26AB	Invertebrate	DFO
44			Atlantic coast of Nova Scotia (LFA 27-33)	LOBSTERLFA27-33	Invertebrate	DFO

#	Species	Scientific Name	Individual Stock Region/Area	Stock Code	Taxa	Management Body
45			LFAs 3-14	LOBSTERLFA3-14	Invertebrate	DFO
46			LFA 34	LOBSTERLFA34	Invertebrate	DFO
47			LFA 35-38	LOBSTERLFA35-38	Invertebrate	DFO
48			LFA 41	LOBSTERLFA41	Invertebrate	DFO
49	**Arctic surfclam**	*Mactromeris polynyma*	Gulf of St. Lawrence NAFO 4RST	ARCSURF4RST	Invertebrate	DFO
50			Banquereau	ARCSURFBANQ	Invertebrate	DFO
51			Grand Bank	ARCSURFGB	Invertebrate	DFO
52	**Northern shrimp**	*Pandalus borealis*	Gulf of St. Lawrence (SFA 8, 9,10,12) 4RST	PANDAL4RST	Invertebrate	DFO
53			Western and eastern assessment zones, SFAs Nunavut, Nunavik and Davis Strait	PANDALSFA2-3	Invertebrate	DFO
54			SFA 4	PANDALSFA4	Invertebrate	DFO
55			SFA 5	PANDALSFA5	Invertebrate	DFO
56			SFA 6	PANDALSFA6	Invertebrate	DFO
57	**Rock crab**	*Cancer irroratus*	Southern Gulf of St. Lawrence (LFA 23-26)	ROCKCRABLFA23-26	Invertebrate	DFO
58			Quebec coastal waters	ROCKCRABQCW	Invertebrate	DFO
59	**Sea scallop**	*Placopecten magellanicus*	Southern Gulf of St. Lawrence SFA 21-24	SCALL4T	Invertebrate	DFO
60			Inshore waters of Quebec SFA 16-20	SCALLSFA16-20	Invertebrate	DFO
61	**Snow crab**	*Chionoecetes opilio*	Division 2HJ	SNOWCRAB2HJ	Invertebrate	DFO
62			Division 3K	SNOWCRAB3K	Invertebrate	DFO
63			Division 3LNO	SNOWCRAB3LNO	Invertebrate	DFO
64			St. Pierre Bank (Division 3Ps)	SNOWCRAB3Ps	Invertebrate	DFO
65			Division 4R3Pn	SNOWCRAB4R3Pn	Invertebrate	DFO
66			Northern Gulf of St. Lawrence	SNOWCRABSCMA 12-17	Invertebrate	DFO
67			Southern Gulf of St. Lawrence	SNOWCRABSGSL	Invertebrate	DFO
68	**Redfish species**	*Sebastes fasciatus*	2+3K	ACADRED2J3K	Redfish	DFO
69		*S. fasciatus*	Unit 1 + Unit 2 + 3LNO	ACADRED3LNO-UT12	Redfish	DFO
70		*S. fasciatus*	Unit 3	ACADREDUT3	Redfish	DFO
71		*S. mentella*	2+3K *S. mentella*	REDDEEP2J3K-3LNO	Redfish	DFO
72		*S. mentella*	Unit 1+2	REDDEEPUT12	Redfish	DFO
73		*S. fasciatus (Acadian redfish) & S. mentella (Deepwater redfish)*	North and southwest Grand Banks (NAFO 3LN)	REDFISHSPP3LN	Redfish	NAFO
74			Gulf of St. Lawrence and Cabot Strait (3Pn4RSTVn)	REDFISHSPP3Pn4RS TVn	Redfish	DFO

#	Species	Scientific Name	Individual Stock Region/Area	Stock Code	Taxa	Management Body
75	**Porbeagle shark**	*Lamna nasus*	Atlantic Ocean	PORSHARATL	SharksSkates	DFO
76	**Smooth skate**	*Malacoraja senta*	Northeastern Newfoundland and Labrador (NAFO 2J3K)	SMOOTHSKA2J3K	SharksSkates	DFO
77			Southern Gulf of St. Lawrence (NAFO 4T)	SMOOTHSKA4T	SharksSkates	DFO
78	**Spiny dogfish**	*Squalus acanthias*	Atlantic Ocean	SDOG4VWX5	SharksSkates	DFO
79	**Thorny skate**	*Amblyraja radiata*	Grand Banks and St. Pierre Banks (NAFO 3LNOPs)	TSKA3LNOPs	SharksSkates	NAFO
80			Southern Gulf of St. Lawrence (NAFO 4T)	TSKA4T	SharksSkates	DFO
81	**Atlantic bluefin tuna**	*Thunnus thynnus*	Western Atlantic stock	ATBTUNAWATL	TunaSword-fish	ICCAT
82	**Swordfish**	*Xiphias gladius*	North Atlantic	SWORDNATL	TunaSword-fish	ICCAT
PACIFIC SPECIES						
83	**Pacific halibut**	*Hippoglossus stenolepis*	British Columbia coast	PHALNPAC	Flatfish	IPHC
84	**Rock sole**	*Lepidopsetta bilineata*	Queen Charlotte Sound (DFO 5AB)	RSOLE5AB	Flatfish	DFO
85			Hecate Strait NAFO (DFO 5CD)	RSOLEHSTR	Flatfish	DFO
86	**Eulachon**	*Thaleichthys pacificus*	Central Coast	EULAPCOASTCCDU	Forage Fish	DFO
87			Fraser River	EULAPCOASTFRDU	Forage Fish	DFO
88			Nass/Skeena	EULAPCOASTNSDU	Forage Fish	DFO
89	**Pacific herring**	*Clupea pallasii*	Central Coast	HERRCC	Forage Fish	DFO
90			Prince Rupert District	HERRPRD	Forage Fish	DFO
91			Haida Gwaii	HERRQCI	Forage Fish	DFO
92			Strait of Georgia	HERRSOG	Forage Fish	DFO
93			West coast of Vancouver Island	HERRWCVANI	Forage Fish	DFO
94	**Pacific sardine**	*Sardinops sagax*	British Columbia	SARDBC	Forage Fish	DFO
95	**Pacific cod**	*Gadus macrocephalus*	Queen Charlotte Sound (DFO 5AB)	PCOD5AB	Groundfish	DFO
96			Hecate Strait NAFO (DFO 5CD)	PCODHS	Groundfish	DFO
97	**Pacific hake**	*Merluccius productus*	Pacific Coast, U.S. and Canadian waters	PHAKEPCOAST	Groundfish	PFMC
98	**Northern shrimp (Pink shrimp)**	*Pandalus borealis and P. jordani*	Shrimp Management Area (SMA) 14	PANDALICSMA14	Invertebrate	DFO
99			SMA 16	PANDALICSMA16	Invertebrate	DFO
100			SMA 18-19	PANDALICSMA18-19	Invertebrate	DFO
101			Fraser River SMA	PANDALICSMAFR	Invertebrate	DFO
102			SMA Georgia Strait East	PANDALICSMAGTSE	Invertebrate	DFO

#	Species	Scientific Name	Individual Stock Region/Area	Stock Code	Taxa	Management Body
103			SMA Prince Rupert District	PANDALICSMAPRD	Invertebrate	DFO
104	**Sidestripe shrimp**	*Pandalopsis dispar*	SMA 14	SSSHRIMPSMA14	Invertebrate	DFO
105			SMA 16	SSSHRIMPSMA16	Invertebrate	DFO
106			SMA 18-19	SSSHRIMPSMA18-19	Invertebrate	DFO
107			Fraser River SMA	SSSHRIMPSMAFR	Invertebrate	DFO
108			SMA Georgia Strait East	SSSHRIMPSMAGTSE	Invertebrate	DFO
109			SMA Prince Rupert District	SSSHRIMPSMAPRD	Invertebrate	DFO
110	**Lingcod**	*Ophiodon elongatus*	Strait of Georgia 4B	LINGCODSOG	Rockfish	DFO
111	**Rockfish**	*Sebastes paucispinis*	Bocaccio	BOCACCBCW	Rockfish	DFO
112		*S. pinniger*	Canary rockfish (west coast Vancouver Island, Strait of Georgia, Queen Charlotte Islands)	CROCKWCVANISO GQCI	Rockfish	DFO
113		*S. alutus*	Pacific Ocean perch, north and west coasts of Haida Gwaii	PERCHQCI	Rockfish	DFO
114		*S. alutus*	Pacific Ocean perch, west coast Vancouver Island	PERCHWCVANI	Rockfish	DFO
115		*S. maliger*	Quillback (inside management unit)	QROCKPCOASTIN	Rockfish	DFO
116		*S. maliger*	Quillback (outside management unit)	QROCKPCOASTOUT	Rockfish	DFO
117		*S. ruberrimus*	Yelloweye rockfish Pacific Coast inside management unit	YEYEROCKPCOASTIN	Rockfish	DFO
118	**Big skate**	*Raja binoculata*	West coast Vancouver Island (DFO 3CD)	BIGSKA3CD	SharksSkates	DFO
119			Strait of Georgia (DFO 4B)	BIGSKA4B	SharksSkates	DFO
120			Queen Charlotte Sound (DFO 5AB)	BIGSKA5AB	SharksSkates	DFO
121			Hecate Strait NAFO (DFO 5CDE)	BIGSKA5CDE	SharksSkates	DFO
122	**Longnose skate**	*Raja rhina*	West coast Vancouver Island (DFO 3CD)	LNOSESKA3CD	SharksSkates	DFO
123			Strait of Georgia (DFO 4B)	LNOSESKA4B	SharksSkates	DFO
124			Queen Charlotte Sound (DFO 5AB)	LNOSESKA5AB	SharksSkates	DFO
125			Hecate Strait (DFO 5CDE)	LNOSESKA5CDE	SharksSkates	DFO

Table B2: Reference points determined for Canadian fishery stocks

BMSY, LRP (Lower Reference Point), USR (Upper Stock Reference Point), FMSY, and any other FREF (Fishing mortality reference point)

#	Species	Stock Code	Taxa	BMSY	LRP	USR	FMSY	Fref
ATLANTIC SPECIES								
1	**American plaice**	AMPL23K	Flatfish	-	✓	-	-	-
2		AMPL3LNO	Flatfish	✓	✓	-	-	-
3		AMPL3Ps	Flatfish	-	✓	✓	-	-
4		AMPL4T	Flatfish	-	✓	-	-	-
5		AMPL4VWX	Flatfish	✓	✓	✓	✓	✓
6	**Atlantic halibut**	ATHAL3NOPs4V WX5Zc	Flatfish	-	✓	✓	-	✓
7	**Greenland halibut**	GHAL23KLMNO	Flatfish	-	-	-	-	-
8		GHAL4RST	Flatfish	-	✓	-	-	-
9	**Winter flounder**	WINFLOUN4T	Flatfish	-	-	-	-	-
10		WITFLOUN3Ps	Flatfish	-	-	-	-	-
11		WITFLOUN4RST	Flatfish	✓	✓	-	✓	-
12	**Yellowtail flounder**	YELL3LNO	Flatfish	✓	✓	-	✓	-
13		YELLGB	Flatfish	-	-	-	-	✓
14	**Capelin**	CAPE4RST	Forage Fish	-	-	-	-	-
15	**Herring**	HERR4RFA	Forage Fish	-	✓	✓	-	✓
16		HERR4RSP	Forage Fish	-	✓	✓	-	✓
17		HERR4S	Forage Fish	-	-	-	-	-
18		HERR4TFA	Forage Fish	-	✓	✓	-	✓
19		HERR4TSP	Forage Fish	-	✓	✓	-	✓
20		HERR4VWX	Forage Fish	-	✓	-	-	-
21		HERRNFLDESC	Forage Fish	-	-	-	-	-
22	**Mackerel**	MACKNWATLSA3-4	Forage Fish	-	-	-	-	-
23	**Atlantic cod**	COD2J3KL	Groundfish	-	✓	-	-	-
24		COD3NO	Groundfish	✓	✓	-	-	✓
25		COD3Pn4RS	Groundfish	-	✓	-	-	-
26		COD3Ps	Groundfish	-	✓	✓	-	-
27		COD4TVn	Groundfish	-	✓	-	-	-
28		COD4VsW	Groundfish	-	✓	✓	-	-
29		COD4X5Yb	Groundfish	-	✓	-	-	-
30		COD5Zjm	Groundfish	-	✓	✓	-	✓
31	**Haddock**	HAD3LNO	Groundfish	-	-	-	-	-
32		HAD4X5Y	Groundfish	-	✓	✓	-	✓
33		HADGB	Groundfish	✓	✓	✓	-	✓

#	Species	Stock Code	Taxa	BMSY	LRP	USR	FMSY	Fref
34	**Pollock**	POLL3Ps	Groundfish	-	-	-	-	-
35		POLL4VWX	Groundfish	✓	✓	✓	-	-
36	**Silver hake**	SHAKE4VWX	Groundfish	✓	✓	✓	✓	-
37	**White hake**	WHAKE3NOPs*	Gadids	✓	✓	-	-	-
38		WHAKE4RS*	Gadids	✓	-	✓	-	-
39		WHAKE4T	Gadids	-	-	-	-	-
40	**American lobster**	LOBSTERLFA15-18	Invertebrate	-	-	-	-	-
41		LOBSTERLFA19-21	Invertebrate	-	-	-	-	-
42		LOBSTERLFA22	Invertebrate	-	✓	✓	-	-
43		LOBSTERLFA23-26 AB	Invertebrate	-	-	-	-	-
44		LOBSTERLFA27-33	Invertebrate	-	✓	✓	-	-
45		LOBSTERLFA3-14	Invertebrate	-	-	-	-	-
46		LOBSTERLFA34	Invertebrate	-	✓	✓	-	-
47		LOBSTERLFA35-38	Invertebrate	-	✓	✓	-	-
48		LOBSTERLFA41	Invertebrate	-	-	-	-	-
49	**Arctic surfclam**	ARCSURF4RST	Invertebrate	-	-	-	-	✓
50		ARCSURFBANQ	Invertebrate	✓	✓	✓	✓	✓
51		ARCSURFGB	Invertebrate	✓	✓	✓	✓	-
52	**Northern shrimp**	PANDAL4RST	Invertebrate	-	✓	✓	-	-
53		PANDALSFA2-3	Invertebrate	-	✓	✓	-	-
54		PANDALSFA4	Invertebrate	✓	✓	✓	-	-
55		PANDALSFA5	Invertebrate	✓	✓	✓	-	-
56		PANDALSFA6	Invertebrate	✓	✓	✓	-	-
57	**Rock crab**	ROCKCRABLFA 23-26	Invertebrate	-	-	-	-	-
58		ROCKCRABQCW	Invertebrate	-	-	-	-	-
59	**Sea scallop**	SCALL4T	Invertebrate	-	-	-	-	-
60		SCALLSFA16-20	Invertebrate	-	-	-	-	-
61	**Snow crab**	SNOWCRAB2HJ	Invertebrate	-	-	-	-	-
62		SNOWCRAB3K	Invertebrate	-	-	-	-	-
63		SNOWCRAB3LNO	Invertebrate	-	-	-	-	-
64		SNOWCRAB3Ps	Invertebrate	-	-	-	-	-
65		SNOWCRAB4R3Pn	Invertebrate	-	-	-	-	-
66		SNOWCRABSCMA 12-17	Invertebrate	-	-	-	-	-
67		SNOWCRABSGSL	Invertebrate	✓	✓	✓	-	✓
68	**Redfish species**	ACADRED2J3K	Redfish	✓	✓	✓	✓	-
69		ACADRED3LNO-UT12	Redfish	✓	✓	✓	✓	-

#	Species	Stock Code	Taxa	BMSY	LRP	USR	FMSY	Fref
70		ACADREDUT3	Redfish	✓	✓	✓	-	-
71		REDDEEP2J3K-3LNO	Redfish	✓	✓	✓	✓	-
72		REDDEEPUT12	Redfish	✓	✓	✓	✓	-
73		REDFISHSPP3LN	Redfish	✓	-	-	✓	-
74		REDFISHSPP3Pn4RSTVn	Redfish	-	-	-	-	-
75	**Porbeagle shark**	PORSHARATL	Sharks and Skates	✓	-	✓	✓	-
76	**Smooth skate**	SMOOTHSKA2J3K	Sharks Skates	-	-	-	-	-
77		SMOOTHSKA4T	Sharks and Skates	-	-	-	-	-
78	**Spiny dogfish**	SDOG4VWX5*	Sharks and Skates	✓	✓	✓	✓	✓
79	**Thorny skate**	TSKA3LNOPs*	Sharks and Skates	✓	✓	-	✓	-
80		TSKA4T	Sharks and Skates	-	-	-	-	-
81	**Bluefin tuna**	ATBTUNAWATL	Tuna and Swordfish	✓	-	-	-	-
82	**Swordfish**	SWORDNATL	Tuna and Swordfish	✓	✓	-	✓	✓
PACIFIC SPECIES								
83	**Pacific halibut**	PHALNPAC	Flatfish	-	-	-	-	-
84	**Rock sole**	RSOLE5AB	Flatfish	✓	✓	✓	✓	-
85		RSOLEHSTR	Flatfish	✓	✓	✓	✓	-
86	**Eulachon**	EULAPCOASTCCDU	Forage Fish	-	-	-	-	-
87		EULAPCOASTFRDU*	Forage Fish	✓	✓	-	✓	-
88		EULAPCOASTNSDU	Forage Fish	-	-	-	-	-
89	**Pacific herring**	HERRCC*	Forage Fish	✓	✓	-	✓	-
90		HERRPRD	Forage Fish	✓	✓	-	✓	-
91		HERRQCI*	Forage Fish	✓	✓	-	✓	-
92		HERRSOG*	Forage Fish	✓	✓	-	✓	-
93		HERRWCVANI*	Forage Fish	✓	✓	-	✓	-
94	**Pacific sardine**	SARDBC	Forage Fish	-	-	-	-	-
95	**Pacific cod**	PCOD5AB	Groundfish	✓	-	-	-	✓
96		PCODHS	Groundfish	✓	✓	✓	-	✓
97	**Pacific hake**	PHAKEPCOAST*	Groundfish	✓	✓	-	✓	✓
98	**Northern shrimp**	PANDALICSMA14	Invertebrate	✓	✓	✓	-	✓
99		PANDALICSMA16	Invertebrate	✓	✓	✓	-	✓
100		PANDALICSMA 18-19	Invertebrate	✓	✓	✓	-	✓
101		PANDALICSMAFR	Invertebrate	✓	✓	✓	-	✓
102		PANDALICSMAGTSE	Invertebrate	✓	✓	✓	-	✓
103		PANDALICSMAPRD	Invertebrate	✓	✓	✓	-	✓

#	Species	Stock Code	Taxa	B_{MSY}	LRP	USR	F_{MSY}	F_{ref}
104	**Sidestripe shrimp**	SSSHRIMPSMA14	Invertebrate	✓	✓	✓	-	✓
105		SSSHRIMPSMA16	Invertebrate	✓	✓	✓	-	✓
106		SSSHRIMPSMA 18-19	Invertebrate	✓	✓	✓	-	✓
107		SSSHRIMPSMAFR	Invertebrate	✓	✓	✓	-	✓
108		SSSHRIMPSMAG TSE	Invertebrate	✓	✓	✓	-	✓
109		SSSHRIMPSMAPRD	Invertebrate	✓	✓	✓	-	✓
110	**Lingcod**	LINGCODSOG*	Rockfish	✓	✓	✓	-	-
111	**Rockfish**	BOCACCBCW*	Rockfish	✓	✓	✓	✓	-
112		CROCKWCVANISO GQCI*	Rockfish	✓	✓	✓	-	-
113		PERCHQCI*	Rockfish	✓	✓	✓	✓	-
114		PERCHWCVANI*	Rockfish	✓	✓	✓	✓	-
115		QROCKPCOASTIN	Rockfish	✓	✓	✓	✓	-
116		QROCKPCOASTO UT	Rockfish	✓	✓	✓	✓	-
117		YEYEROCKPCOAS TIN	Rockfish	✓	✓	✓	✓	-
118	**Big skate**	BIGSKA3CD	Sharks and Skates	-	-	-	-	-
119		BIGSKA4B	Sharks and Skates	-	-	-	-	-
120		BIGSKA5AB	Sharks and Skates	-	-	-	-	-
121		BIGSKA5CDE	Sharks and Skates	-	-	-	-	-
122	**Longnose skate**	LNOSESKA3CD	Sharks and Skates	-	-	-	-	-
123		LNOSESKA4B	Sharks and Skates	-	-	-	-	-
124		LNOSESKA5AB	Sharks and Skates	-	-	-	-	-
125		LNOSESKA5CDE	Sharks and Skates	-	-	-	-	-
		Total		**58**	**77**	**57**	**30**	**31**

* Stocks have other reference points determined including B0 (unfished biomass), SB0 (unfished spawning biomass), V0 (unfished vulnerable biomass) and Vmsy (vulnerable biomass at MSY).

Table B3: The biomass at MSY (B_{MSY}), lower (LRP) and upper (USR) stock reference points and reference fishing mortality rate (F_{MSY}) for each stock, if known

The value for F_{MSY} is estimated F at MSY unless otherwise stated in brackets. Units of B_{Msy}, LRP and USR are metric tonnes unless otherwise stated. Taxonomic codes: F=Flatfish, FF=Forage fish, G=Groundfish, I=Invertebrate, R=Redfish/rockfish, SS=Sharks and skates, TS=Tuna and swordfish. Precautionary Framework status codes: U=Unknown, C=Cautious, CR=Critical, H=Healthy, NA=Assessed by NAFO and not DFO and so status is not designated this way.

#	Species	Stock Code	Taxa	B_{MSY}	LRP	USR	F_{MSY}	Status
ATLANTIC SPECIES								
1	**American plaice**	AMPL23K	F		70,000			CR
2		AMPL3LNO	F	24,200	50,000		0.31 (F_{lim})	NA
3		AMPL3Ps	F					CR
4		AMPL4T	F		64,000			CR
5		AMPL4VWX	F	32,381	12,952	25,905	0.16	C
6	**Atlantic halibut**	ATHAL3NOPs4V WX5Zc	F		1,960	3,920	0.36 (F_{lim})	C
7	**Greenland halibut**	GHAL23KLMNO	F					U
8		GHAL4RST	F		10,056			H
9	**Winter flounder**	WINFLOUN4T	F					U
10	**Witch flounder**	WITFLOUN3Ps	F					U
11		WITFLOUN4RST	F	26,7000	10,700		0.072	CR
12	**Yellowtail flounder**	YELL3LNO	F	72,500			0.26	NA
13		YELLGB	F				0.25 (F0.1)	NA
14	**Capelin**	CAPE4RST	FF					U
15	**Herring**	HERR4RFA	FF		47,953	61,074	0.22 (F0.1)	U
16		HERR4RSP	FF		37,384	57,468	0.16 (F0.1)	U
17		HERR4S	FF					U
18		HERR4TFA	FF		51,000	172,000	0.32 (F0.1)	C
19		HERR4TSP	FF		22,000	54,000	0.35 (F0.1)	C
20		HERR4VWX	FF		371,067			C
21		HERRNFLDESC	FF					U
22	**Mackerel**	MACKNWATLS A3-4	FF					CR
23	**Atlantic cod**	COD2J3KL	G					CR
24		COD3NO	G	24,800	60,000	NA	0.3 (F_{lim})	NA
25		COD3Pn4RS	G		11,600			CR
26		COD3Ps	G		10,700	21,000		C
27		COD4TVn	G		80,000			CR
28		COD4VsW	G		50,000	10,000		C
29		COD4X5Yb	G		24,000			CR
30		COD5Zjm	G		21,000	48,000	0.2 (F_{lim})	CR

#	Species	Stock Code	Taxa	B_{MSY}	LRP	USR	F_{MSY}	Status
31	**Haddock**	HAD3LNO	G					U
32		HAD4X5Y	G		20,800	41,600	0.25 (F_{ref})	C
33		HADGB	G	78,000	10,340	40,000	0.26 (F_{ref})	NA
34	**Pollock**	POLL3Ps	G					U
35		POLL4VWX	G	50,184	20,074	40,147		H
36	**Silver hake**	SHAKE4VWX	G	59,000	23,600	47,200	0.32	H
37	**White hake**	WHAKE3NOPs*	G	42,300	12,700			U
38		WHAKE4RS*	G	9,016	3,606	7,213		CR
39		WHAKE4T	G					U
40	**American lobster**	LOBSTERLFA15-18	I					U
41		LOBSTERLFA19-21	I					U
42		LOBSTERLFA22	I		875	1,750		H
43		LOBSTERLFA23-26AB	I					U
44		LOBSTERLFA27-33	I		27: 814, 28-29: 60, 30: 40, 31: 125, 32: 121, 33: 919	27: 1629, 28-29: 120, 30: 79, 31: 250, 32: 242, 33: 1838		U
45		LOBSTERLFA3-14	I					U
46		LOBSTERLFA34	I		4,434	8,867		H
47		LOBSTERLFA35-38	I		788	1,575		H
48		LOBSTERLFA41	I					H
49	**Arctic surfclam**	ARCSURF4RST	I					U
50		ARCSURFBANQ	I	1,015,058	406,024	812,047	0.0264	H
51		ARCSURFGB	I	703,065	281,226	562,452	0.0264	H
52	**Northern shrimp**	PANDAL4RST	I					U
53		PANDALSFA2-3	I		6,800	18,200		H
54		PANDALSFA4	I		21,100	56,300		H
55		PANDALSFA5	I		14,300	38,000		H
56		PANDALSFA6	I		79,600	212,200		C
57	**Rock crab**	ROCKCRABLFA 23-26	I					U
58		ROCKCRABQCW	I					U
59	**Sea scallop**	SCALL4T	I					U
60		SCALLSFA16-20	I					U
61	**Snow crab**	SNOWCRAB2HJ	I					U
62		SNOWCRAB3K	I					U
63		SNOWCRAB3LNO	I					U
64		SNOWCRAB3Ps	I					U
65		SNOWCRAB4R3Pn	I					U

#	Species	Stock Code	Taxa	B_{MSY}	LRP	USR	F_{MSY}	Status
66		SNOWCRABSCMA 12-17	I					U
67		SNOWCRABSGSL	I		10,000	41,400	0.346 (F_{lim})	H
68	**Redfish species**	ACADRED2J3K	R	73,000	29,000	58,000	0.04	CR
69		ACADRED3LNO-UT12	R	370,000	148,000	296,000	0.06	CR
70		ACADREDUT3	R	73,000	29,000	58,000		H
71		REDDEEP2J3K-3LNO	R	29,0000	166,000	232,000	0.06	CR
72		REDDEEPUT12	R	583,000	233,000	266,000	0.03	CR
73		REDFISHSPP3LN	R	225,100			0.11	NA
74		REDFISHSPP3Pn4R STVn	R					NA
75	**Porbeagle shark**	PORSHARATL	SS	34,573 individuals		27,658 individuals	0.051	U
76	**Smooth skate**	SMOOTHSKA2J3K	SS					U
77		SMOOTHSKA4T	SS					U
78	**Spiny dogfish**	SDOG4VWX5*	SS	252,000 individuals				H
79	**Thorny skate**	TSKA3LNOPs*	SS	83,160	24,948		0.08	U
80		TSKA4T	SS					U
81	**Bluefin tuna**	ATBTUNAWATL	TS	12,722				NA
82	**Swordfish**	SWORDNATL	TS	65,060	26,204		0.2	NA
PACIFIC SPECIES								
83	**Pacific halibut**	PHALNPAC	F					NA
84	**Rock sole**	RSOLE5AB	F	1,833	733	1,467	0.239	H
85		RSOLEHSTR	F	4,853	1,941	3,883	0.507	H
86	**Eulachon**	EULAPCOASTCCDU	FF					U
87		EULAPCOASTFR DU*	FF	1,220	382		0.1	U
88		EULAPCOASTNSDU	FF					U
89	**Pacific herring**	HERRCC*	FF	11,514	14,841		1.31	U
90		HERRPRD	FF	18,600	17,190		0.54	U
91		HERRQCI*	FF	8,708	10,171		2.36	U
92		HERRSOG*	FF	28,211	33,881		1.4	U
93		HERRWCVANI*	FF	11,281	14,366		0.98	U
94	**Pacific sardine**	SARDBC	FF					U
95	**Pacific cod**	PCOD5AB	G				0.305 (F_{avg})	U
96		PCODHS	G		12,182	19,258	0.22 (F_{avg})	C
97	**Pacific hake**	PHAKEPCOAST*	G	586	959		0.332 (ER_{MSY})	H
98	**Northern shrimp**	PANDALICSMA14	I	222.5	89	178	0.35 (F_{max})	H
99		PANDALICSMA16	I	312.5	125	251	0.35 (F_{max})	C

#	Species	Stock Code	Taxa	B_{MSY}	LRP	USR	F_{MSY}	Status
100		PANDALICSMA 18-19	I	SMA 18: 95, SMA 19: 75	SMA 18: 38, SMA 19: 30	SMA 18: 76, SMA 19: 61	0.35 (F_{max})	CR
101		PANDALICSMAFR	I	367.5	147	294	0.35 (F_{max})	C
102		PANDALICSMAGS TE	I	115	46	92	0.35 (F_{max})	H
103		PANDALICSMAPRD	I	977.5	391	782	0.35 (F_{max})	H
104	**Sidestripe shrimp**	SSSHRIMPSMA14	I	70	28	56	0.35 (F_{max})	H
105		SSSHRIMPSMA16	I	87.5	11	22	0.35 (F_{max})	H
106		SSSHRIMPSMA 18-19	I	SMA 18: 25, SMA 19: 10	SMA 18: 10, SMA 19: 4	SMA 18: 19, SMA 19: 8	0.35 (F_{max})	C
107		SSSHRIMPSMAFR	I	170	68	137	0.35 (F_{max})	H
108		SSSHRIMPSMAG TSE	I	77.5	31	63	0.35 (F_{max})	H
109		SSSHRIMPSMAPRD	I	587.5	235	470	0.35 (F_{max})	H
110	**Lingcod**	LINGCODSOG*	R	15,924	6,370	12,739		C
111	**Rockfish**	BOCACCBCW*	R	31,620	12,648	25,296	0.0422	CR
112		CROCKWCVANISO GQCI*	R	542	216.8	433.6		C
113		PERCHQCI*	R	7,304	2,921	5,843	0.109	H
114		PERCHWCVANI*	R	5,809	2,324	4,647	0.091	H
115		QROCKPCOASTIN	R	5,742	2,296.8	4,593.6	0.025	C
116		QROCKPCOASTO UT	R	11,718	4,687.2	9,374.4	0.035	C
117		YEYEROCKPCOAS TIN	R	1,0772	4,308.8	8,617.6		CR
118	**Big skate**	BIGSKA3CD	SS					U
119		BIGSKA4B	SS					U
120		BIGSKA5AB	SS					U
121		BIGSKA5CDE	SS					U
122	**Longnose skate**	LNOSESKA3CD	SS					U
123		LNOSESKA4B	SS					U
124		LNOSESKA5AB	SS					U
125		LNOSESKA5CDE	SS					U

Table B4: Integrated Fisheries Management Plans (IFMP) for Canadian stocks

Name of specific plan and date of most recent plan (Year). Taxonomic codes: F=Flatfish, FF=Forage fish, G=Groundfish, I=Invertebrate, O=Other, R=Redfish/rockfish, SS=Sharks and skates, TS=Tuna and swordfish.

#	Species	Stock Code	Taxa	IFMP	Year
ATLANTIC SPECIES					
1	**American plaice**	AMPL23K	F	NL Groundfish 2+3KL	2013
2		AMPL3LNO	F	NL Groundfish 2+3KL	2013
3		AMPL3Ps	F	NL Groundfish 3Ps	2013
4		AMPL4T	F	-	-
5		AMPL4VWX	F	-	-
6	**Atlantic halibut**	ATHAL3NOPs4VWX5Zc	F	-	-
7	**Greenland halibut**	GHAL23KLMNO	F	NL Groundfish 2+3KL	2013
8		GHAL4RST	F	-	-
9	**Winter flounder**	WINFLOUN4T	F	-	-
10		WITFLOUN3Ps	F	NL Groundfish 3Ps	2013
11		WITFLOUN4RST	F	-	-
12	**Yellowtail flounder**	YELL3LNO	F	Yellowtail Flounder 3LNO	2012
13		YELLGB	F	-	-
14	**Capelin**	CAPE4RST	FF	-	-
15	**Herring**	HERR4RFA	FF	-	-
16		HERR4RSP	FF	-	-
17		HERR4S	FF	-	-
18		HERR4TFA	FF	-	-
19		HERR4TSP	FF	-	-
20		HERR4VWX	FF	Atlantic Herring SWNS BoF	2013
21		HERRNFLDESC	FF	-	-
22	**Mackerel**	MACKNWATLSA3-4	FF	Atlantic Mackerel	2007
23	**Atlantic cod**	COD2J3KL	G	NL Groundfish 2+3KL	2013
24		COD3NO	G	-	-
25		COD3Pn4RS	G	NL Groundfish 3Ps	2013
26		COD3Ps	G	NL Groundfish 3Ps	2013
27		COD4TVn	G	-	-
28		COD4VsW	G	-	-
29		COD4X5Yb	G	-	-
30		COD5Zjm	G	-	-
31	**Haddock**	HAD3LNO	G	NL Groundfish 2+3KL	2013
32		HAD4X5Y	G	-	-
33		HADGB	G	-	-

#	Species	Stock Code	Taxa	IFMP	Year
34	**Pollock**	POLL3Ps	G	NL Groundfish 3Ps	2013
3 35		POLL4VWX	G	-	-
36	**Silver hake**	SHAKE4VWX	G	-	-
37	**White hake**	WHAKE3NOPs*	G	NL Groundfish 3Ps	-
38		WHAKE4RS*	G	-	-
39		WHAKE4T	G	-	-
40	**American lobster**	LOBSTERLFA15-18	I	-	-
41		LOBSTERLFA19-21	I	-	-
42		LOBSTERLFA22	I	-	-
43		LOBSTERLFA23-26AB	I	SGSL LFA 23-26B	2014
44		LOBSTERLFA27-33	I	LFA 27-38	2011
45		LOBSTERLFA3-14	I	LFA 27-38	2011
46		LOBSTERLFA34	I	LFA 27-38	2011
47		LOBSTERLFA35-38	I	LFA 27-38	2011
48		LOBSTERLFA41	I	-	-
49	**Arctic surfclam**	ARCSURF4RST	I	-	-
50		ARCSURFBANQ	I	-	-
51		ARCSURFGB	I	-	-
52	**Northern shrimp**	PANDAL4RST	I	-	-
53		PANDALSFA2-3	I	Northern Shrimp SFA 1-7	2007
54		PANDALSFA4	I	Northern Shrimp SFA 1-7	2007
55		PANDALSFA5	I	Northern Shrimp SFA 1-7	2007
56		PANDALSFA6	I	Northern Shrimp SFA 1-7	2007
57	**Rock crab**	ROCKCRABLFA23-26	I	-	-
58		ROCKCRABQCW	I	-	-
59	**Sea scallop**	SCALL4T	I	-	-
60		SCALLSFA16-20	I	-	-
61	**Snow crab**	SNOWCRAB2HJ	I	Snow Crab - NL & Lab	2009-2011
62		SNOWCRAB3K	I	Snow Crab - NL & Lab	2009-2011
63		SNOWCRAB3LNO	I	Snow Crab - NL & Lab	2009-2011
64		SNOWCRAB3Ps	I	Snow Crab - NL & Lab	2009-2011
65		SNOWCRAB4R3Pn	I	Snow Crab - NL & Lab	2009-2011
66		SNOWCRABSCMA12-17	I	-	-
67		SNOWCRABSGSL	I	Snow Crab Area 12,12E,12F,19	2014
68	**Redfish species**	ACADRED2J3K	R	NL Groundfish 2+3KL	2013
69		ACADRED3LNO-UT12	R	NL Groundfish 2+3KL	2013
70		ACADREDUT3	R	NL Groundfish 2+3KL	2013

#	Species	Stock Code	Taxa	IFMP	Year
71		REDDEEP2J3K-3LNO	R	NL Groundfish 2+3KL	2013
72		REDDEEPUT12	R	NL Groundfish 3PS	2013
73		REDFISHSPP3LN	R	NL Groundfish 2+3KL	2013
74		REDFISHSPP3Pn4RSTVn	R	NL Groundfish 3Ps	2013
75	**Porbeagle shark**	PORSHARATL	SS	-	-
76	**Smooth skate**	SMOOTHSKA2J3K	SS	NL Groundfish 2+3KL	2013
77		SMOOTHSKA4T	SS	-	-
78	**Spiny dogfish**	SDOG4VWX5*	SS	-	-
79	**Thorny skate**	TSKA3LNOPs*	SS	-	-
80		TSKA4T	SS	-	-
81	**Bluefin tuna**	ATBTUNAWATL	TS	Atlantic Bluefin Tuna	2008
82	**Swordfish**	SWORDNATL	TS	Canadian Atlantic Swordfish and Other Tunas	2004-2006
PACIFIC SPECIES					
83	**Pacific halibut**	PHALNPAC	F	BC Groundfish	2016
84	**Rock Sole**	RSOLE5AB	F	BC Groundfish	2016
85		RSOLEHSTR	F	BC Groundfish	2016
86	**Eulachon**	EULAPCOASTCCDU	FF	-	-
87		EULAPCOASTFRDU*	FF	Fraser River Eulachon	2013-2014
88		EULAPCOASTNSDU	FF	-	-
89	**Pacific herring**	HERRCC*	FF	Pacific Herring	2013-2014
90		HERRPRD	FF	Pacific Herring	2013-2014
91		HERRQCI*	FF	Pacific Herring	2013-2014
92		HERRSOG*	FF	Pacific Herring	2013-2014
93		HERRWCVANI*	FF	Pacific Herring	2013-2014
94	**Pacific sardine**	SARDBC	FF	Pacific Sardine	2015-2018
95	**Pacific cod**	PCOD5AB	G	BC Groundfish	2016
96		PCODHS	G	BC Groundfish	2016
97	**Pacific hake**	PHAKEPCOAST*	G	BC Groundfish	2016
98	**Northern shrimp**	PANDALICSMA14	I	Shrimp Trawl	2016-2017
99		PANDALICSMA16	I	Shrimp Trawl	2016-2017
100		PANDALICSMA18-19	I	Shrimp Trawl	2016-2017
101		PANDALICSMAFR	I	Shrimp Trawl	2016-2017
102		PANDALICSMAGSTE	I	Shrimp Trawl	2016-2017
103		PANDALICSMAPRD	I	Shrimp Trawl	2016-2017
104	**Sidestripe shrimp**	SSSHRIMPSMA14	I	Shrimp Trawl	2016-2017
105		SSSHRIMPSMA16	I	Shrimp Trawl	2016-2017
106		SSSHRIMPSMA18-19	I	Shrimp Trawl	2016-2017

#	Species	Stock Code	Taxa	IFMP	Year
107		SSSHRIMPSMAFR	I	Shrimp Trawl	2016-2017
108		SSSHRIMPSMAGSTE	I	Shrimp Trawl	2016-2017
109		SSSHRIMPSMAPRD	I	Shrimp Trawl	2016-2017
110	**Lingcod**	LINGCODSOG*	R	BC Groundfish	2016
111	**Rockfish**	BOCACCBCW*	R	BC Groundfish	2016
112		CROCKWCVANISOGQCI*	R	BC Groundfish	2016
113		PERCHQCI*	R	BC Groundfish	2016
114		PERCHWCVANI*	R	BC Groundfish	2016
115		QROCKPCOASTIN	R	BC Groundfish	2016
116		QROCKPCOASTOUT	R	BC Groundfish	2016
117		YEYEROCKPCOASTIN	R	BC Groundfish	2016
118	**Big skate**	BIGSKA3CD	SS	BC Groundfish	2016
119		BIGSKA4B	SS	BC Groundfish	2016
120		BIGSKA5AB	SS	BC Groundfish	2016
121		BIGSKA5CDE	SS	BC Groundfish	2016
122	**Longnose skate**	LNOSESKA3CD	SS	BC Groundfish	2016
123		LNOSESKA4B	SS	BC Groundfish	2016
124		LNOSESKA5AB	SS	BC Groundfish	2016
125		LNOSESKA5CDE	SS	BC Groundfish	2016

Figure B1: Map of fishing regions within the NAFO
Northwest Atlantic Fisheries Organization. Source: www.nafo.int

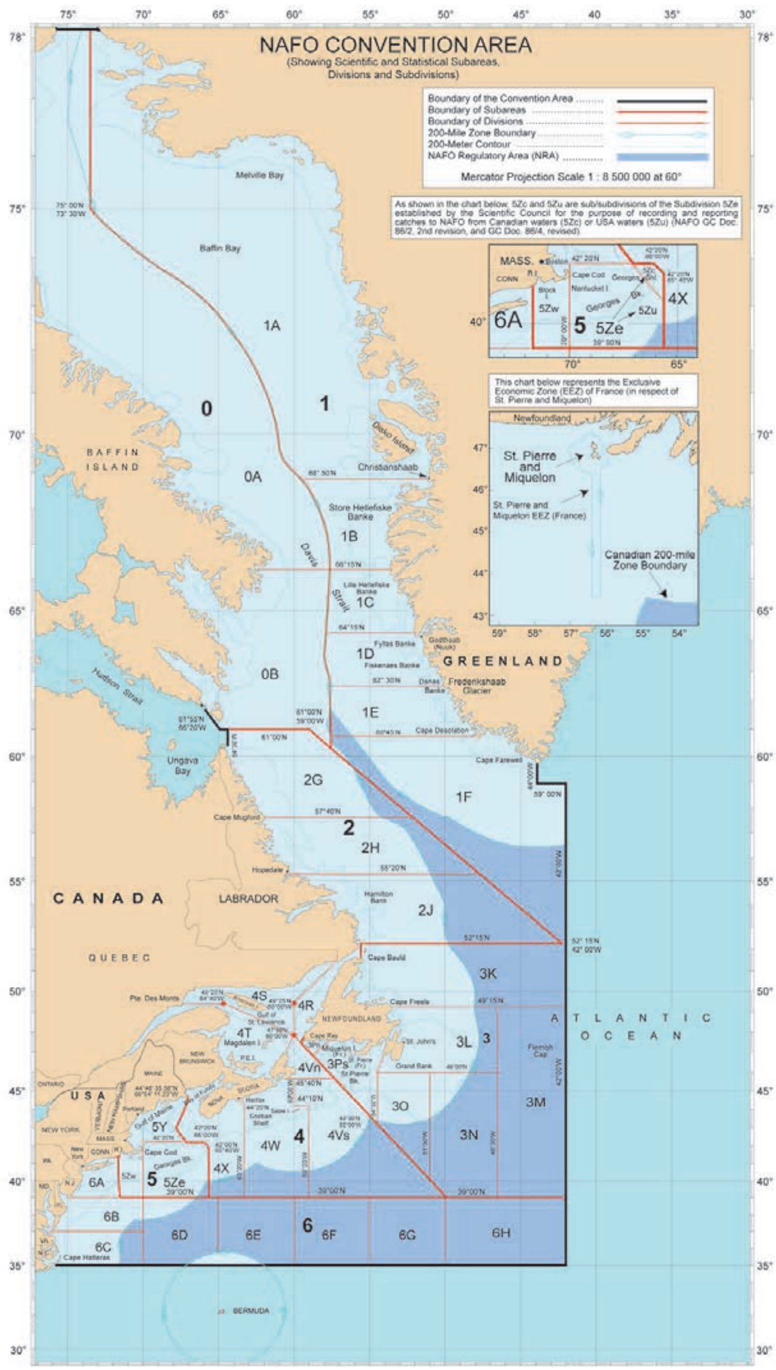


Figure B2: Map of fishing regions on Canada's West Coast

Source: http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/ground-fond/ground-fond-eng.html

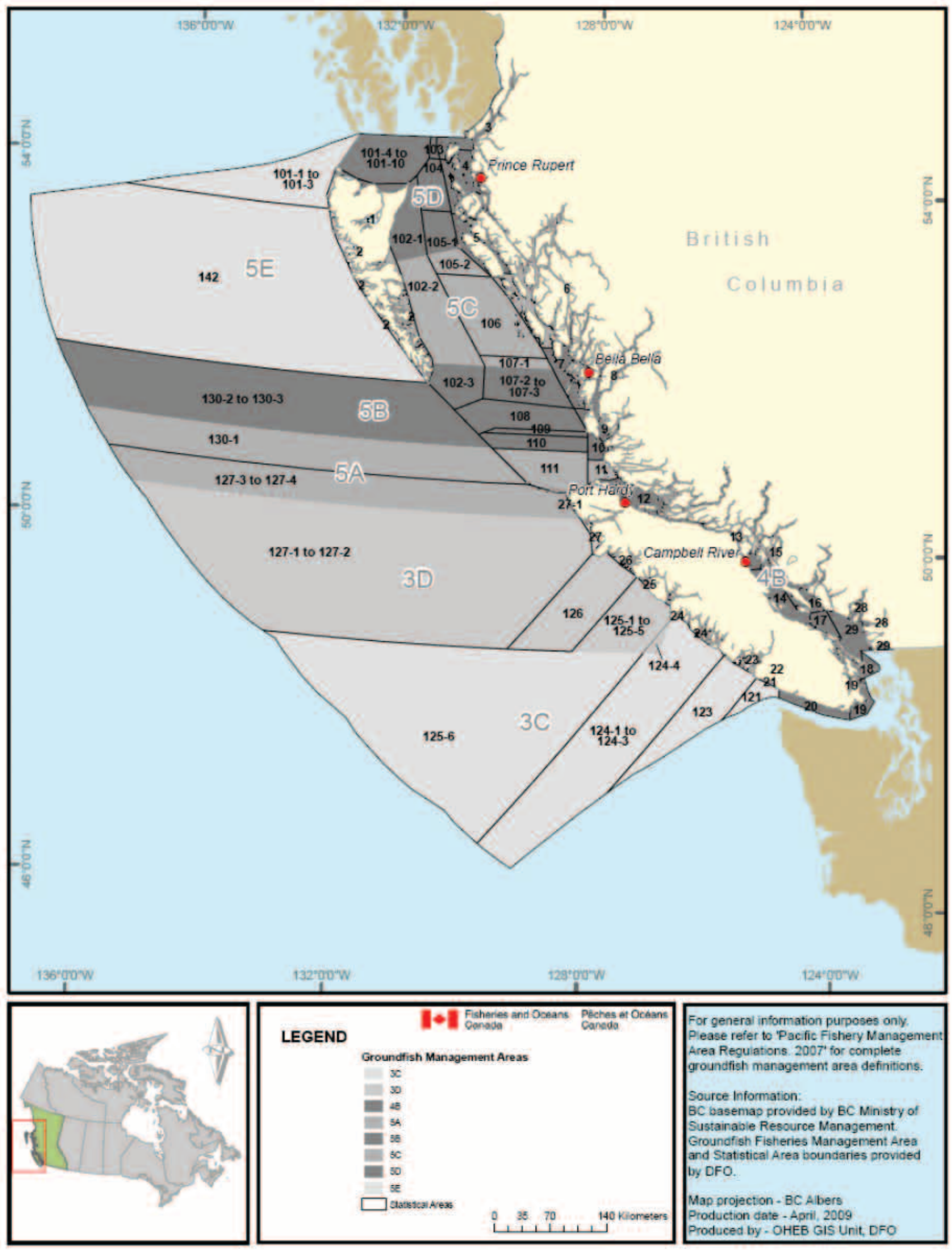


Figure B3: Map of lobster fishing areas (LFAs) on Canada's Atlantic coast

Source: http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/fisheries-peches/lobster-homard-eng.htm

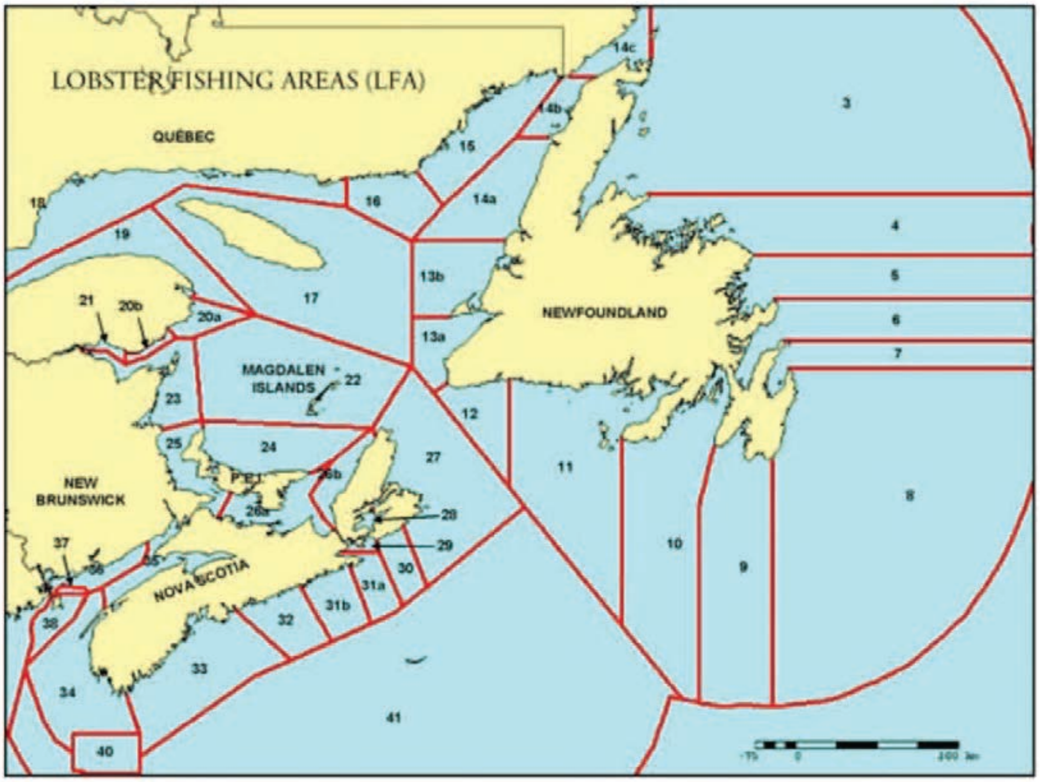
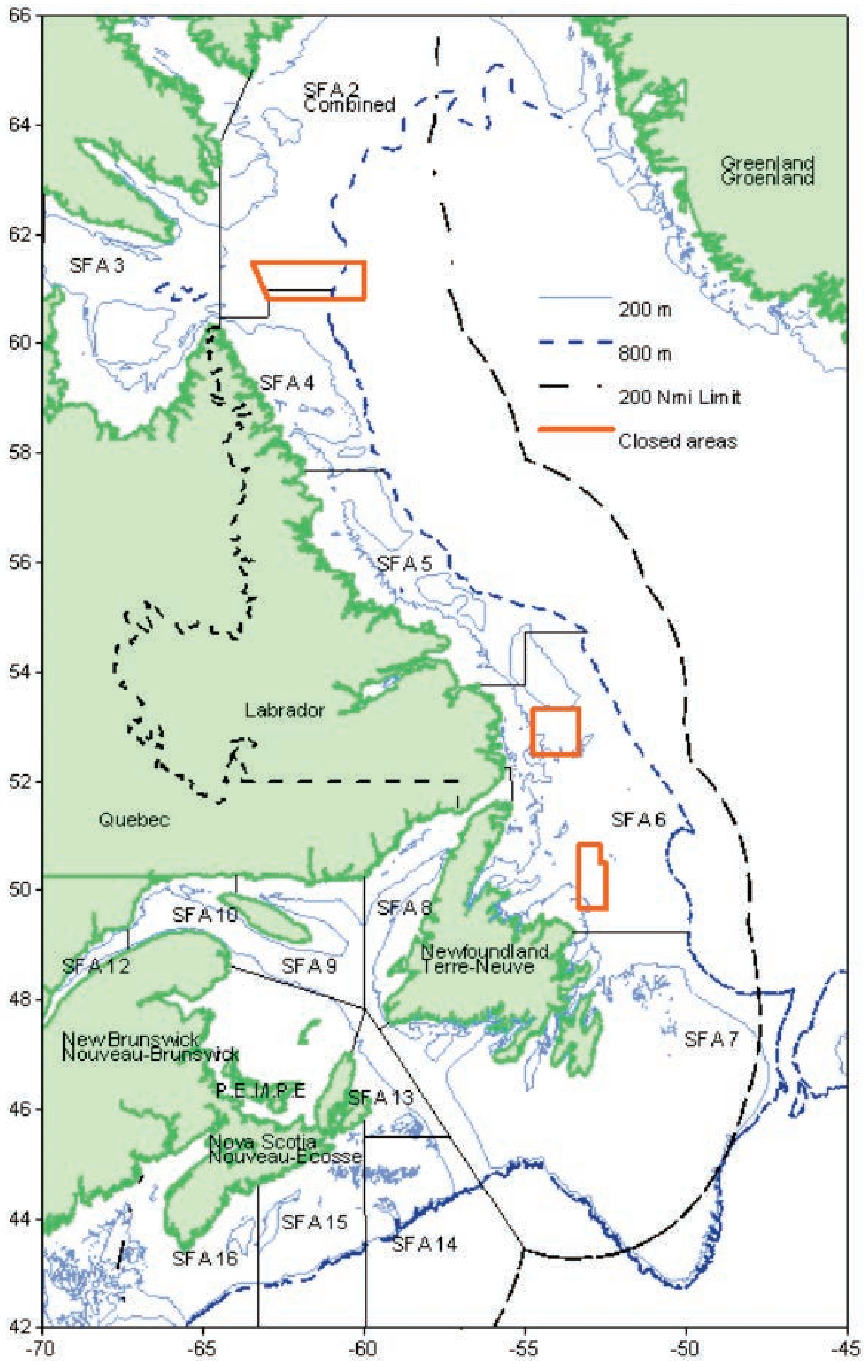


Figure B4: Map of shrimp fishing areas (SFAs) on Canada's Atlantic coast
http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/fisheries-peches/shrimp-crevette-eng.htm



APPENDIX C. METADATA AND PLOTS FOR INDIVIDUAL STOCKS

A separate appendix, available at oceana.ca, contains a two-page summary for each of the 125 marine fish and invertebrate stocks from Canada's East and West Coasts included in this report and the reference list for their corresponding stock assessment documents. The data shown will be incorporated into the next version of the RAM Legacy Database, the world's primary open-source database of marine fish stock assessments (www.ramlegacy.org).

This first page of the summary for each stock includes the following three tables:

- **Metadata:** This table includes the scientific name, common name, the stock ID (the code used in the RAM Legacy database), the assessment ID from the RAM Legacy Database (region – stockID – years – person who entered the assessment), the region, specific stock area, management authority, scientific body conducting the stock assessment, and the years covered in the assessment.

- **References Points:** This table includes available reference point data for the stock, as follows:

Btarget =	target biomass
SSBtarget =	target spawner stock biomass
Ntarget =	target abundance
B0 =	initial biomass
SSB0 =	initial spawner stock biomass
MSY =	maximum sustainable yield
Ftarget =	target fishing mortality
Utarget =	target primary fishing mortality rate
M =	natural mortality

- **Time Series:** This table summarizes the available time series data for the stock, including the unit and the current value for the following parameters:

TB =	total biomass
SSB =	spawner stock biomass
TN =	total numbers (i.e., abundance)
R =	recruits
TC =	total catch
TL =	total landings
F =	fishing mortality
U =	the primary fishing mortality rate
ER =	the proportion of the numbers or biomass removed by fishing

The second page of the summary for each stock shows up to eight standard plots (depending on data availability), with the same template followed on each page, as follows:

1. Biomass vs. Fishing Mortality

2. Spawner - Recruits

3. Production

4. Total and Spawning Biomass

5. Catch and Fishing Mortality

6. Catch and Total Biomass

7. Biomass Relative to BMSY over time

8. Harvest Relative to UMSY over time

Top Row

1. **Left Plot: Biomass vs. Fishing Mortality.** Plots SSB scaled relative to SSB_{MSY} vs. U/U_{MSY} if available, otherwise plots SSB vs. U. If SSB unavailable, uses TB instead. Note: U may be either F or ER. Dot colouring corresponds to time, with blue being the earliest years in the time series, progressing through purple to pink, and ending with the most recent years in the time series in red.

2. **Right Plot: Spawner – Recruits.** Plots spawner stock biomass (SSB) vs. recruits (R). Dot colouring corresponds to time, with blue being the earliest years in the time series, progressing through purple to pink, and ending with the most recent years in the time series in red.

Second Row:

3. **Left Plot: Production.** Plots TB (or abundance) vs. production. Dot colouring corresponds to time, with blue being the earliest years in the time series, progressing through purple to pink, and ending with the most recent years in the time series in red. Dashed line is zero production.

4. **Right Plot: Total and Spawning Biomass.** Plots TB (or TN) in blue and SSB in red. If available, TB_{MSY} and SSB_{MSY} are plotted as a dashed line of the appropriate colour.

Third Row:

5. **Left Plot: Catch and Fishing Mortality.** Plots TC (or TL) in green and F (or U) in purple. If available, F_{MSY} (or ER_{MSY}) is plotted as a dashed line of the appropriate colour. If TAC is available, it is plotted as a lighter green and Cpair is plotted for catch (Cpair is the catch time series corresponding to TAC).

6. **Right Plot: Catch and Total Biomass.** Plots TB (or TN) in blue and TC (or TL) in green on the same scale if both are available and have the same units.

Bottom Row:

7. **Left Plot: Biomass Relative to B_{MSY} over time.** Plots SSB scaled relative to SSB_{MSY} over time. Plots TB and TB_{MSY} if SSB not available. The dashed line at 1 indicates when the SSB (or TB) of the stock was at SSB_{MSY} (or TB_{MSY}).

Right Plot: Harvest Relative to U_{MSY} over time. Plots fishing mortality (F) of the stock scaled relative to F_{MSY} of the stock over time. Plots ER and if F not available. The dashed line at 1 indicates when the F of the stock was at F_{MSY}.

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