FISH STOCK STATUS AND COMMERCIAL FISHERIES

State of the Scotian Shelf Report

AUTHOR:
Robert O'Boyle
Beta Scientific Consulting Inc.
1042 Shore Dr.
Bedford, NS B4A 2E5

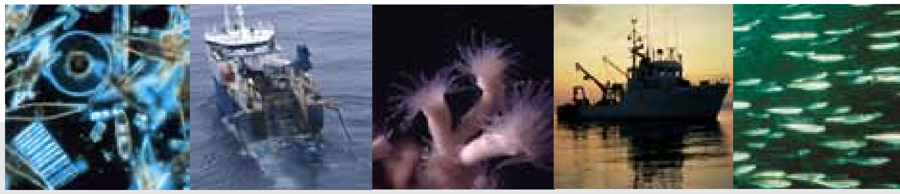
STEERING COMMITTEE:
Heather Breeze, Project Coordinator, Fisheries and Oceans Canada, Ecosystem Management
Glen Herbert, Fisheries and Oceans Canada, Ecosystem Management
Melanie MacLean, Fisheries and Oceans Canada, Ecosystem Management
Tom Sephton, Fisheries and Oceans Canada, Science
Andrew Sherin, Atlantic Coastal Zone Information Steering Committee
Sean Weseloh McKeane, Nova Scotia Department of Fisheries and Aquaculture
Maxine Westhead, Fisheries and Oceans Canada, Ecosystem Management

The material in this document is co-published as:
MacLean M, Breeze H, Walmsley J and Corkum J (eds). 2013.
State of the Scotian Shelf Report. Can. Tech. Rep. Fish. Aquat. Sci. 3074.

First published July 2012

ISBN: 978-0-9869437-9-9

ATLANTIC COASTAL ZONE INFORMATION STEERING COMMITTEE



CONTENTS

1 ISSUE IN BRIEF 4

2 DRIVING FORCES AND PRESSURES 6
2.1 Climate Change and Ecosystem Influences 7
2.2 Seafood Demand and Market Forces 10
2.3 Socio-Economic Conditions 11
2.4 Fishing Effort 12

3 STATUS AND TRENDS 14
3.1 Status of Stocks 14
3.2 Status of Fishery Sector 20

4 IMPACTS 22
4.1 Health of Ecosystems 23
4.2 Social and Cultural Well-Being 25
4.3 Economic Well-Being 26

5 ACTIONS AND RESPONSES 27
5.1 Legislation and Policy 27
5.2 Management Activities 28
5.3 Industry-based Initiatives 29
5.4 Research and Monitoring 31

6 REFERENCES 33

1 ISSUE IN BRIEF

LINKAGES

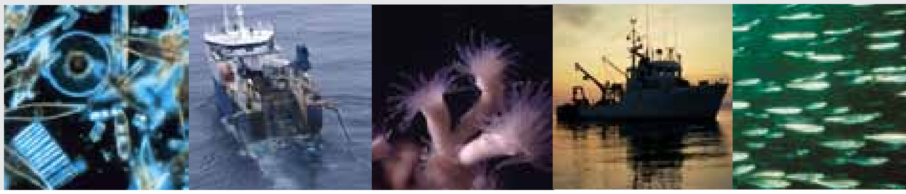
This theme paper also links to the following theme papers:

- Climate Change and its Effects on Ecosystems, Habitats and Biota
- Primary and Secondary Productivity
- Marine Habitats and Communities
- Trophic Structure
- Species at Risk
- Incidental Mortality

The status of the commercial fisheries of the Scotian Shelf is impacted by driving forces and pressures, which influence the long-term productivity of the ecosystem as well as the demand for ocean uses (**Figure 1**). Changes in the region's oceanography (as measured by sea surface temperature) due to the effects of climate change will likely lead to changes in ecosystem productivity and thus aggregate fisheries yield. Global and regional demands for seafood due to growing population size will continue to apply pressure on the stocks while competition for ocean space from other ocean industries such as aquaculture and energy extraction will have both direct effects on fishing and indirect effects on the stocks. Fishing effort, as measured by exploitation rate, which applies pressure to the stocks, is currently under control. The impacts on stock status of these driving forces and pressures are likely to be different for each of the major species groups (**see box**) occupying the Scotian Shelf. These pressures have implications for the profitability of the fishing and processing sectors. Stock productivity will be influenced by changes in species diversity, which will have long-term implications for the well-being of the local fishing communities.

The response of the management system to these changes is and has been multi-faceted and will need to be adaptive. A new Sustainable Fisheries Framework has been established which out-

There are three major species groups commercially fished on the Scotian Shelf. Groundfish, also known as demersal fish, live near the bottom for much of their adult life. They include important commercial species such as cod, haddock, pollock, redfish and flatfishes. Pelagic fish live in the water column and near the surface of the ocean, and include small schooling fish such as herring and capelin as well as large-bodied species such as swordfish, sharks and tunas. Shellfish are invertebrates with an external skeleton (shell), such as snow crab, lobster, scallop and shrimp.



lines harvest control rules and offers promise that the management of the commercial fisheries of the Scotian Shelf will adapt to future driving forces and pressures. Both internationally and within Canada, there is a move towards an ecosystem approach to management which takes into consideration the broader effects of fishing on ecosystems. If consistently applied, this should lead to the recovery of many depleted species. Industry has responded with a suite of activities that are both complementary to these changes (i.e., providing fishery and stock monitoring) as well as being pro-active to meet the demands of the global market place (i.e., eco-certification).

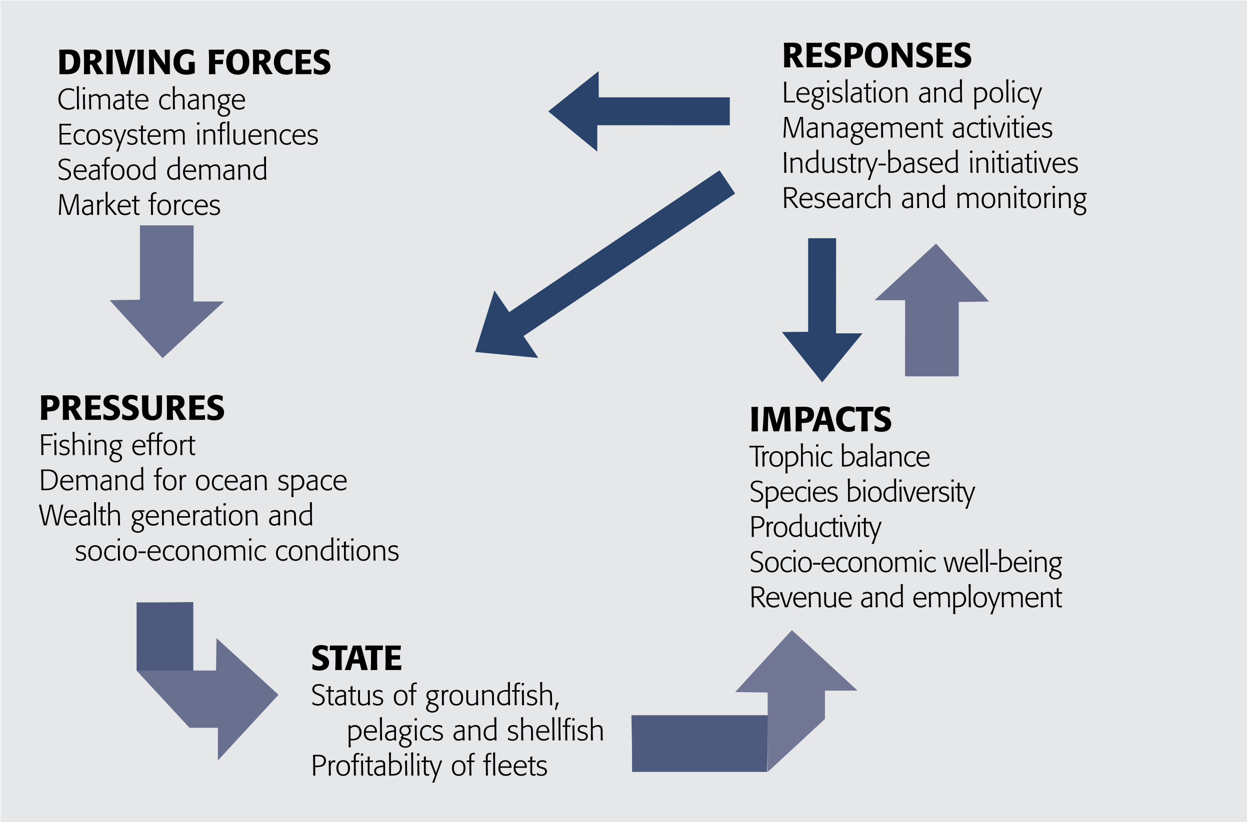
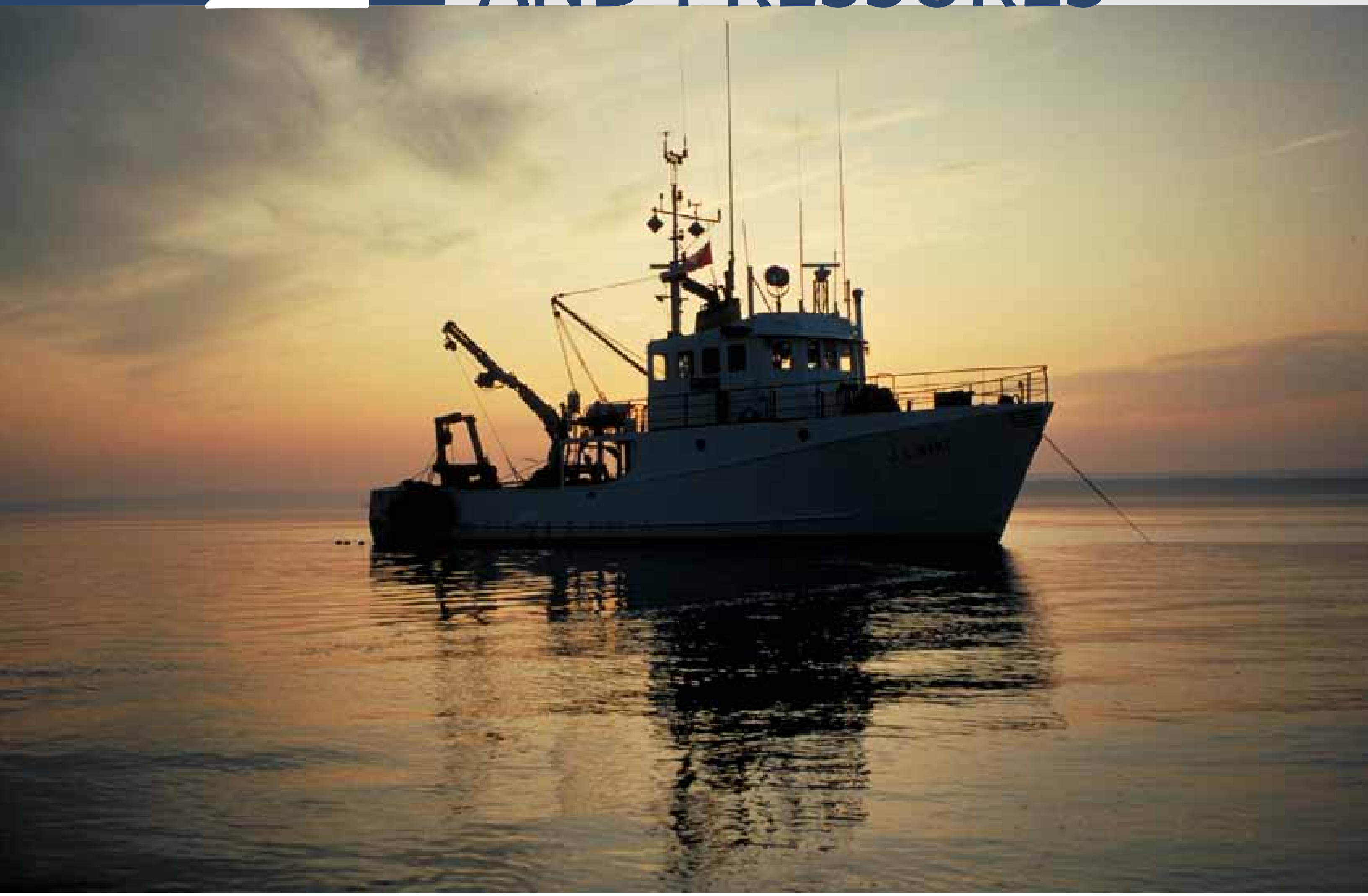
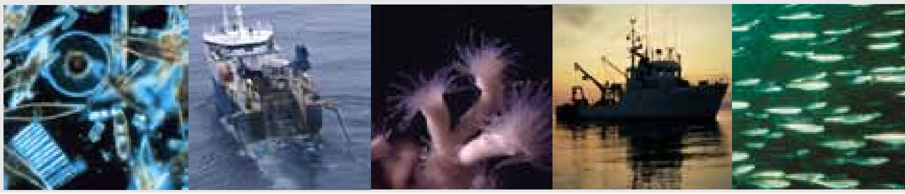


Figure 1. Driving forces, pressures, state, impacts and responses (DPSIR) implicated in the commercial fisheries of the Scotian Shelf. The DPSIR framework consists of the relation between the environment and humans. According to this framework, social and economic developments and natural conditions (driving forces) exert pressures on the environment and, as a consequence, the state of the fisheries. This leads to impacts on ecosystems and human well-being, which elicit a societal or government response that feeds back on the other elements of the framework.

2 DRIVING FORCES AND PRESSURES



The fisheries of the Scotian Shelf are affected by forces and pressures that both change the productivity of the ecosystem, and thus the long-term expected yield of fisheries, and the demand for fish. Natural drivers include the oceanographic conditions of the Scotian Shelf which are in turn affected by climate change. Anthropogenic drivers include the demand for seafood, which is influenced by food markets both in the United States northeast as well as those in other parts of the world. Increasingly, other activities such as aquaculture and ocean energy development are competing with fishing for the use of the ocean.



2.1 CLIMATE CHANGE AND ECOSYSTEM INFLUENCES

The ocean conditions of the Scotian Shelf are determined largely by ocean currents.[1] The cold, low-salinity Labrador Current flows past the Grand Banks of Newfoundland and influences the whole Scotian Shelf. Fresher water also flows from the Gulf of St. Lawrence which primarily influences the eastern Scotian Shelf (ESS) while the Gulf Stream, which flows north along the edge of the Continental Shelf, primarily influences the western Scotian Shelf (WSS). Thus, while the Scotian Shelf is one ecosystem, within it are found distinct eastern and western components (**Figure 2**).

Anthropogenic climate change, principally global warming, due to greenhouse gas (GHG) emissions, is evident at the global scale from ocean circulation models (IPCC 2007a,b,c; see also *Climate Change and its Effects on Ecosystems, Habitats and Biota* theme paper). These

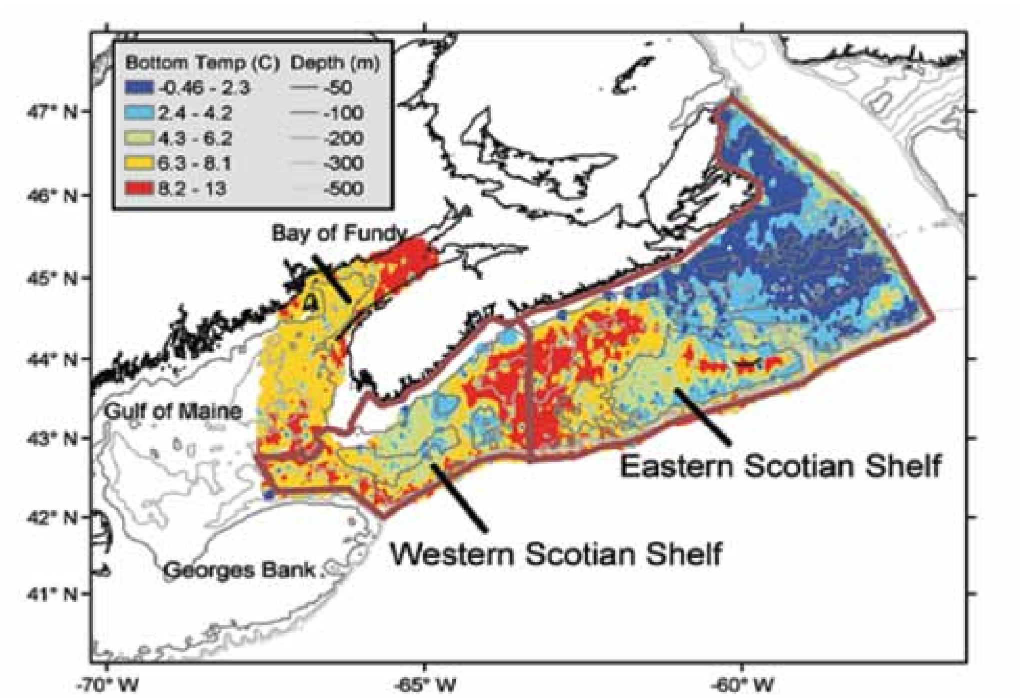


Figure 2. Bottom summer temperature of the Eastern and Western Scotian Shelf highlight its subdivision into eastern and western components (from Shackell 2011).

[1] For more information on the geology, climate, oceanographic conditions and habitat of the Scotian Shelf, see *The Scotian Shelf in Context* (DFO 2012b).

global-scale patterns are modified at the local scale by natural variability, which on the Scotian Shelf is very pronounced due to the strong seasonal cycle, large scale circulation and atmospheric forcings (e.g., the North Atlantic Oscillation). Over the next 5–10 years, natural variability is expected to dominate but in the longer-term, the combined effect of natural variability and anthropogenic climate change is likely to lead to pronounced ecosystem change (Shackell 2011).

Temperature heavily influences the species inhabiting ecosystems through its effects on growth, feeding, migration and reproduction, any of which can lead to changes in a stock's productivity. Since the early part of the twentieth century, sea surface temperature (SST) measured near Halifax, an indicator of the local effects of climate change, has shown no long-term increase (Shackell 2011). On the other hand, since the 1960s, there has been a 1°C increase of SST in the waters off St. Andrews,

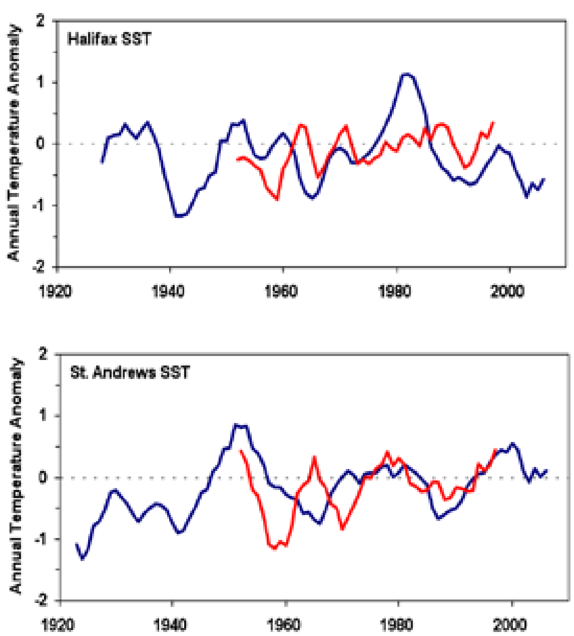


Figure 3: Sea surface temperature (SST) measured off Halifax (top panel), and St. Andrews, New Brunswick (bottom panel); units are expressed as differences above and below the long-term average. The blue line indicates the 5-year running mean based on observations while the red line indicates the 5-year running mean based on a predictive model (from B. Petrie, DFO, pers. comm. in Shackell 2011).

New Brunswick in the Bay of Fundy (**Figure 3**). In other words, natural variability still dominates the trend in SST off Halifax while the effects of climate change are becoming evident off St. Andrews (Shackell 2011). In general, the ESS and WSS are expected to respond differently to the effects of climate change. There has also been a decrease in salinity of the Scotian Shelf and Gulf of Maine (Greene et al. 2008) due primarily to the melting of Arctic sea ice. As sea ice melts, freshwater is added to the system. This large pulse of freshwater increases the strength of the southward flowing Labrador Current and reduces sea surface salinity.

Early speculation (Frank et al. 1988) on how commercial fisheries might be affected by climate change included a northward displacement of coldwater species, expansion of southerly warm water species from the Gulf of Maine, earlier arrival and later departure of pelagic migrants, a change in the overall fish community from groundfish to pelagics and an overall reduction in total fish production. Some of these predictions appear to have come true; however, whether or not climate change is involved is being debated (e.g. see Frank et al. 2011).

Since the 1960s, there have been changes along the full extent of the food chain on both the ESS and WSS, particularly in the former (**Figure 4**). In both areas, phytoplankton abundance increased from the 1960s to the mid-2000s (Shackell 2011). On the ESS, zooplankton decreased during this period while the biomass of pelagic and groundfish species increased and decreased respectively. There are differing hypotheses on the reasons for these changes. Frank et al. (2005; 2007) have argued that environmental influences are not primarily responsible and that overfishing of groundfish in the 1980s led to an imbalance in the ecosystem. With fewer groundfish predators, their prey (forage species) increased. The more numerous

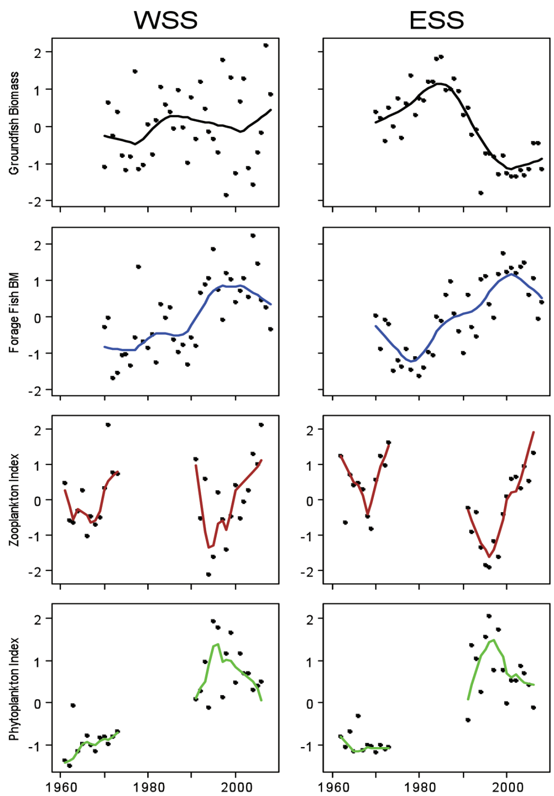


Figure 4. Abundance trends for different parts of the food chain on the Western Scotian Shelf (WSS) and Eastern Scotian Shelf (ESS); from bottom to top panel: phytoplankton (green line); large copepods (brown line); forage fish such as herring, sandlance, argentine and mackerel (blue line); predatory groundfish including cod, haddock, pollock, dogfish, white hake, silver hake, redfish, etc. (purple line); all units are as differences from long-term mean (from Shackell 2011).

forage fish then depleted their main source of food (zooplankton), resulting in fewer zooplankton to eat phytoplankton, which in turn increased. This is referred to as a trophic cascade because removal of top predators can affect the dynamics of all lower trophic levels (Shackell 2011). Consistent with this theory is the hypothesis that an apex predator (grey seals) has inhibited the recovery of the ESS cod stock (O'Boyle and Sinclair 2012). More recently, there is some evidence to suggest that the Scotian Shelf ecosystem is reverting from one dominated by forage species to one dominated by groundfish (Frank et al. 2011).

A competing hypothesis is that environmental forcings are indeed mainly responsible for changes in the Scotian Shelf ecosystem. Natural mortality for a large number of groundfish stocks has been high since the 1990s (Halliday and Pinhorn 2009), as evidenced in the WSS Atlantic cod stocks (**Figure 5**). Associated with this have been long-term reductions in the growth and condition of many of these stocks (**Figure 6**). These changes are coincident with increased strength of the North Atlantic Oscillation (NAO) leading to speculation that climate is playing an important role in the dynamics of the Scotian Shelf's fish stocks.

Whatever processes or combination of processes are responsible for changes in the Scotian Shelf ecosystem, they are having significant consequences for the productivity of the commercial fisheries. For instance, they have led to long-term declines in the productivity of some resources (e.g., ESS haddock, Mohn and Chouinard 2007; see section 4).

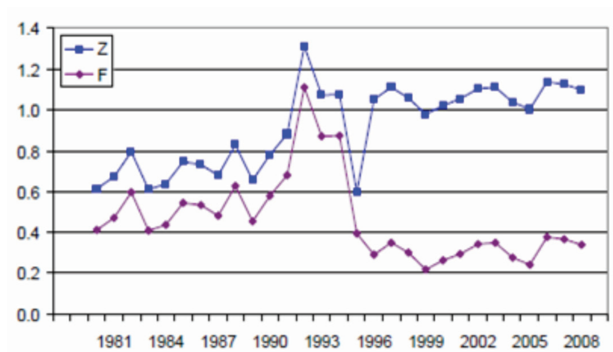


Figure 5. Total mortality (Z) and fishing mortality (F) of cod on the western Scotian Shelf and Bay of Fundy (NAFO Division 4X). The difference between Z and F is due to natural mortality (from DFO 2011f).

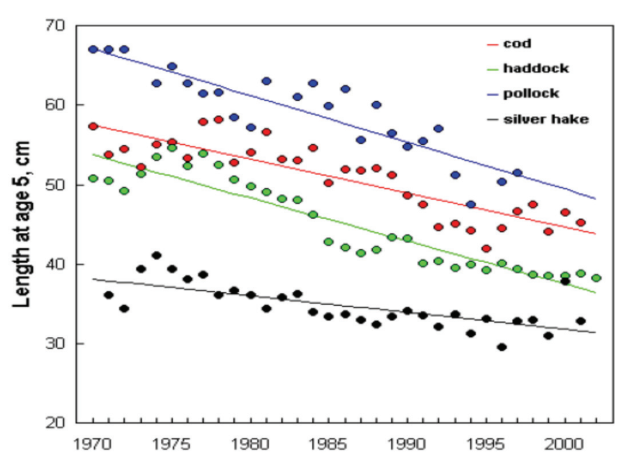


Figure 6. Length at five years of age for Scotian Shelf cod, haddock, pollock, and silver hake (from DFO 2010c).

2.2 SEAFOOD DEMAND AND MARKET FORCES

A major driving force of the Maritimes fisheries is the global and local demand for food. The current global population size is about seven billion, growing at a rate of about 1.1% per year (USCB 2012). This contrasts with the Nova Scotia population size of 945 000 in 2011 which has been growing at an average annual rate of 0.26% during 2002–2006 (Statistics Canada 2012). During this period, Nova Scotia seafood production averaged about $1.04 billion per year with 57% of this being from exports. Of these exports, 44% went to US markets, 29% to Europe, 14% to Asia and the remainder to other countries (**Figure 7**). There has been a 7% per year decline in revenue in recent years due to a strong Canadian dollar although the number of licensed fish plants and active plants has also declined due to difficulty in securing raw product and increasing consolidation in the processing industry (GPCE 2009).

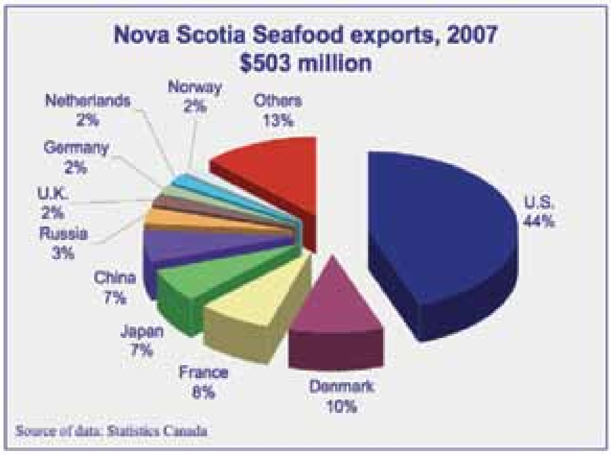


Figure 7. Percent global distribution of Nova Scotia seafood exports in 2007 (from GPCE 2009).

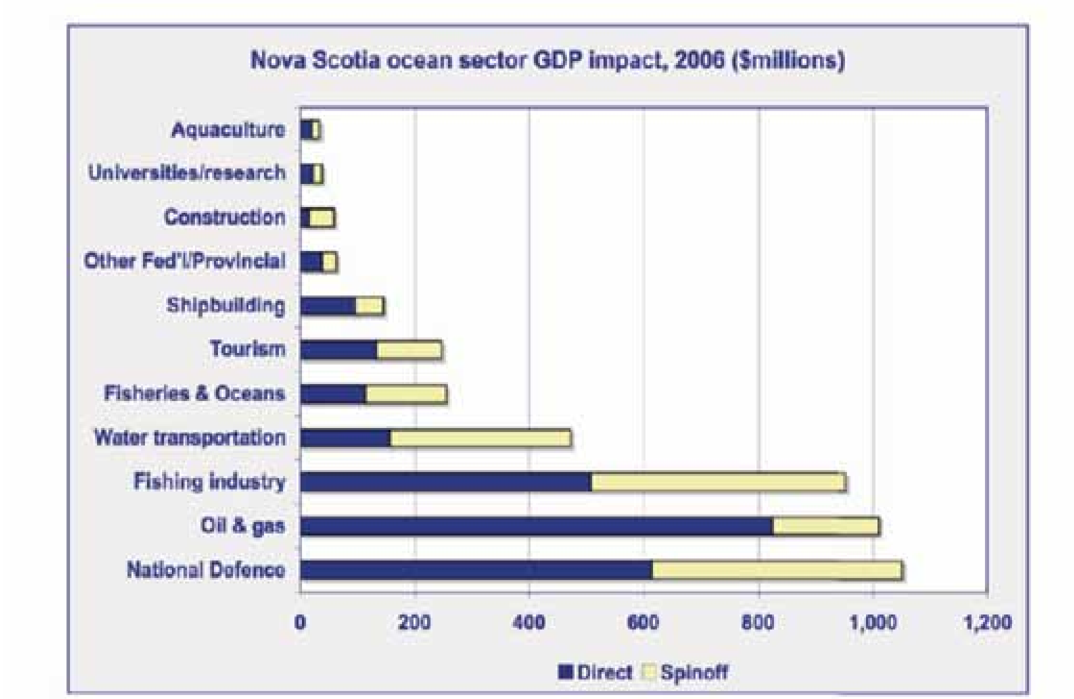


Figure 8. Distribution of Gross Domestic Product (GDP) 2006 impact ($ millions), both direct and spinoff by Nova Scotia ocean sector (from GPCE 2009).

2.3 SOCIO-ECONOMIC CONDITIONS

The social and cultural well-being of the Nova Scotia fishing communities that harvest the Scotian Shelf is tightly linked to ocean access. Of the 2006 Nova Scotia Gross Domestic Product (GDP) of $32 billion, 15.5% was of ocean industry origin, due to a number of industries including fisheries, aquaculture, fish processing, oil and gas, transport, tourism, shipbuilding and government related activities (e.g., national defence). In 2001, commercial fisheries were ranked number two in terms of GDP (GPCE 2005), but dropped to number three in 2006, or 17.6% of the ocean sector, behind oil and gas (Figure 8). Full-time employment in Nova Scotia's commercial fishery sector was 7121 in 2006, compared to 2778 and 517 in the oil and gas and aquaculture sectors respectively, both of which compete for ocean space with the fisheries. The oil and gas sector has leases to develop petroleum reserves primarily along the shelf edge off Nova Scotia (**Figure 9**) while aquaculture sites (321 in 2012) are located along the coast of Nova Scotia, where they would interact with coastal fisheries such as lobster.

Photo: Wikipedia commons

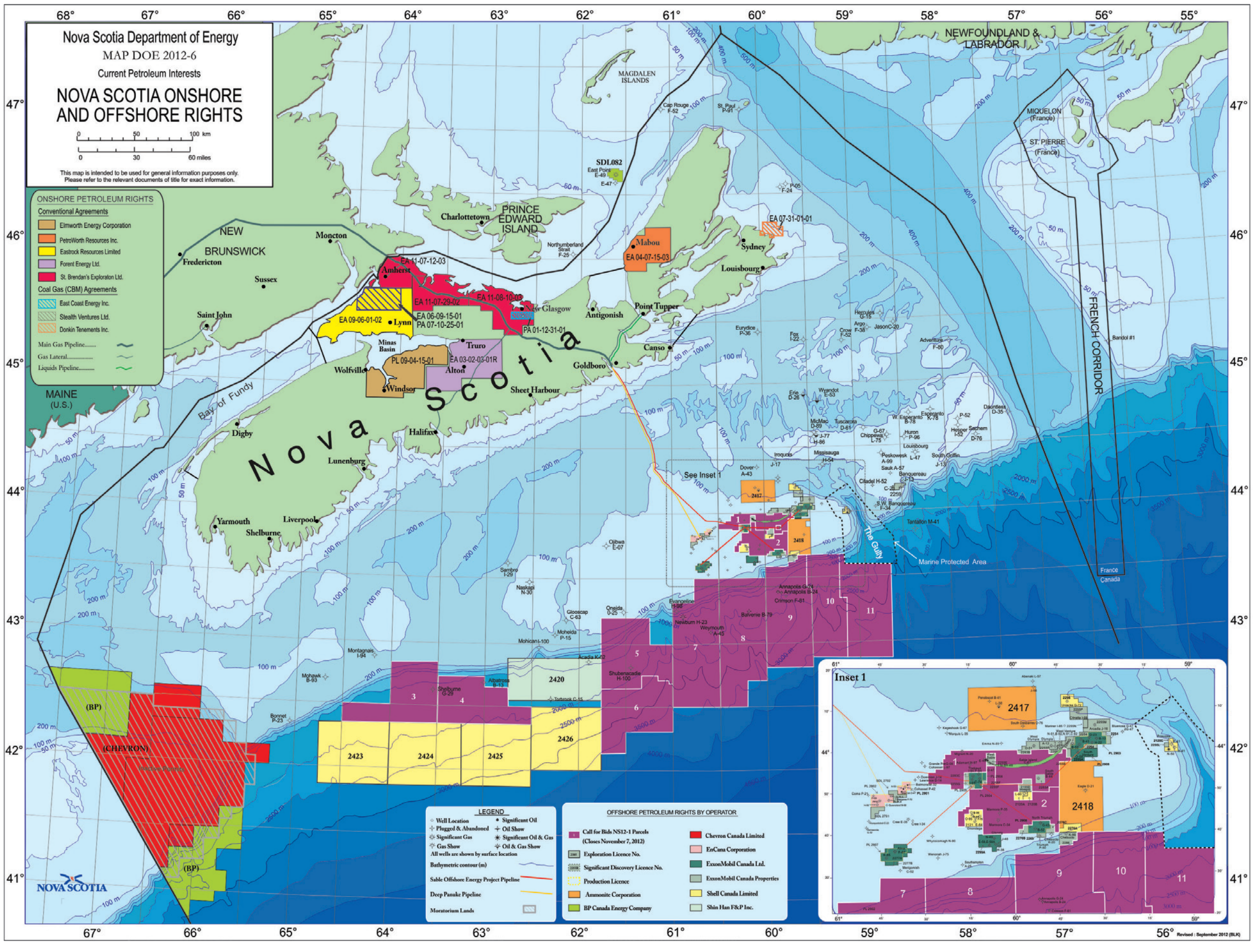


Figure 9. Nova Scotia onshore and offshore rights for petroleum exploration and development as of September 2012 (from http://www.gov.ns.ca/energy/resources/RA/maps/Onshore-Offshore-Rights.pdf).

2.4 FISHING ACTIVITY

The most immediate pressure applied to the stocks on which the Scotian Shelf fisheries depend is from fishing activity, as measured by the exploitation rate (% of biomass taken each year by fishing) experienced by each stock. The trend in exploitation rate varies markedly by groundfish (such as cod, haddock and pollock), pelagic (such as herring, mackerel and swordfish) and shellfish stocks (such as lobster, shrimp, and snow crab). Only a subset of the main species exploited is discussed here; these are intended to illustrate general trends.

Since 1993, most of the groundfish fishery on the ESS (including cod and haddock) has been closed and thus all stocks there have experienced low exploitation rates. On the WSS, the groundfish fishery has remained open. While the exploitation rate on WSS haddock has steadily declined since 1982, that on cod remained high until the early 1990s and then dropped in the mid-1990s to a relatively stable level (**Figure 10**). The exploitation rate on pollock was very high up until the mid-2000s after which it declined. Current exploitation rates are generally at or below their target (e.g., haddock and pollock harvest rates are 75% of their targets). However, for cod on the WSS, while exploitation is lower than what it was in the 1990s, overall mortality is still high due to unaccounted for high natural mortality (**Figure 5**).

For the main shellfish stocks, the fishery has been prosecuted throughout the Scotian Shelf, with shrimp and snow crab primarily caught on the ESS and lobster and scallop on the WSS. Exploitation rates for shrimp and snow crab have been close to target levels of 10–20% (**Figure 11**). Exploitation rates of the lobster stocks are currently very high (in the order of 70–80%) but do not appear to be threatening the sustainability of any of the LFAs under current environmental conditions (DFO 2011d). The scallop fishery on the WSS is primarily exploited in SFA 29 just off the coast of Southwest Nova Scotia and on Browns Bank. Exploitation rates on these stocks have ranged from 1 to 40% (DFO 2010a; DFO 2011c).

The situation is more complicated with the pelagic species. While swordfish, bigeye tuna and blue shark are being exploited below their target exploitation rates, Atlantic mackerel and porbeagle shark are above theirs. Exploitation of herring off Southwest Nova Scotia has been relatively constant since the late 1990s but it is not clear whether or not it is high relative to the target level (DFO 2011a).

In response to the collapse of the traditional groundfish stocks, a number of new fisheries developed in the early 1990s. These include fisheries for monkfish, skates, dogfish, sea urchins, bloodworms and so on. Some of these fisheries prospered while others have not.

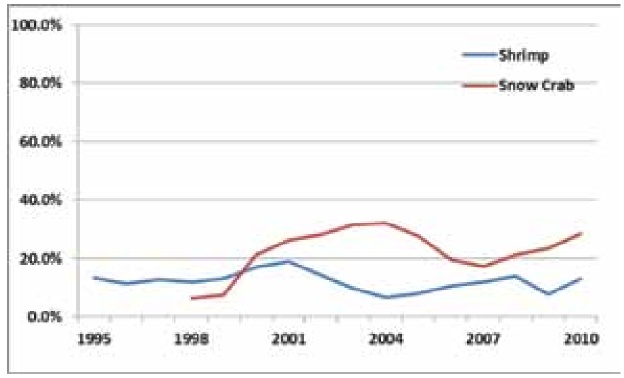


Figure 11. Trends in exploitation rates (percent biomass taken by fishing) of shrimp and snow crab on the ESS (data from Choi and Zisserson 2011 and Hardie et al. 2012).

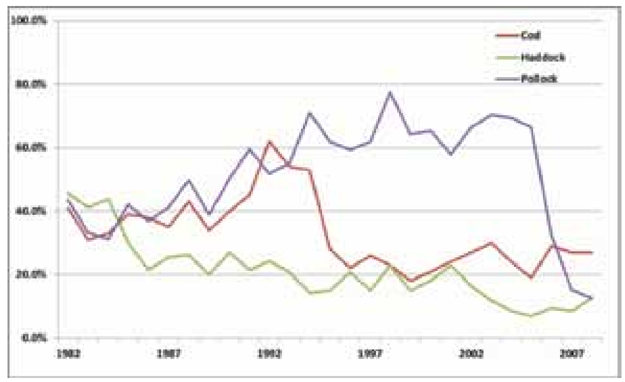


Figure 10. Trends in exploitation rates of cod, haddock and pollock on the WSS, as percent of the biomass taken by fishing each year (data from Clark and Emberley 2009, Stone et al. 2009 and Mohn et al. 2010).

3 STATUS AND TRENDS

In the wake of the collapse of traditional groundfish stocks on the ESS (e.g. cod, flatfishes and pollock), shellfish stocks have grown significantly in their contribution to the revenue and profitability of the Scotian Shelf fishery. As well, other groundfish, such as Atlantic halibut and redfish, have grown in prominence. This situation is expected to continue until the groundfish stocks recover. The status of some of the more important stocks is described below followed by observations on their economic consequences.

3.1 STATUS OF STOCKS

As part of its Sustainable Fisheries Framework, DFO introduced biomass reference points (**see box**) to describe whether or not a stock was in a critical (below a Limit Reference Point or LRP), healthy (above an Upper Stock Reference point or USR), or cautious (between the LRP and USR) state (DFO 2012d). The section

Reference Points

Biomass reference points are particular values of indicators used to judge the status of a stock. For instance, spawning stock biomass is the total weight in tonnes of the mature female fish in a stock and is an indicator. When a stock is at the biomass which provides the Maximum Sustainable Yield (MSY), it is at the BMSY reference point. When stock biomass is at or above 80% of BMSY, it is at the Upper Stock Reference (USR) point. BMSY is typically used as a biomass target in many fisheries. If stock biomass is below 40% of BMSY, it is below the Limit Reference Point (LRP). This is typically a level below which biomass should not drop. As part of a Harvest Control Rule (HCR), managers take different regulatory actions (e.g. close or open fisheries) based on where biomass is in relation to these reference points (see section 5.1 for further discussion on reference points and HCRs).

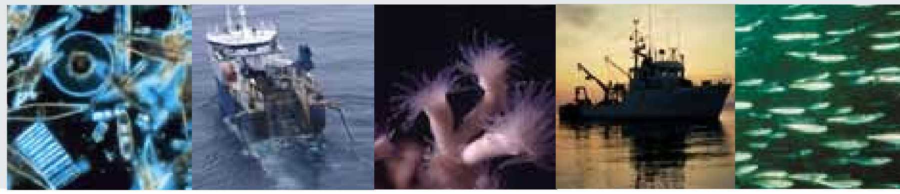


Table 1. Status of Scotian Shelf commercially fished stocks; ESS – Eastern Scotian Shelf, WSS – Western Scotian Shelf, SS – Scotian Shelf.

STOCK GROUP	STATE			TOTAL
	CRITICAL	CAUTIOUS	HEALTHY	
Invertebrate		1 (14%) SFA 29W scallop	6 (86%) snow crab, shrimp, inshore lobster, offshore lobster, surf clam, Browns Bank scallop	7
Pelagic	7 (47%) bluefin tuna, albacore tuna, shortfin mako, porbeagle shark, blue marlin, white marlin	3 (23%) mackerel, dogfish, basking shark	4 (27%) swordfish, bigeye tuna, yellowfin tuna, blue shark	15
Groundfish	14 (54%) ESS cod, ESS haddock, ESS pollock, ESS plaice, ESS sculpin, WSS cod, WSS witch flounder, SS silver hake, SS white hake, SS spotted wolfish, SS northern wolfish, SS cusk	5 (19%) ESS monkfish WSS pollock, WSS monkfish, WSS skate, SS Atlantic wollfish	7 (27%) ESS witch flounder, ESS yellowtail flounder, WSS haddock, WSS winter flounder, WSS sculpin, SS halibut*, SS redfish*	26
Total	21	10	17	48

*The halibut stock extends to the south coast of Newfoundland, the southern part of the Grand Banks and west of the Scotian Shelf to the U.S. boundary. The redfish stock (Unit 3) includes part of the eastern Scotian Shelf west into the Bay of Fundy.

below on Responses describes this framework in more detail. Here, the biomass reference points are used to indicate stock status for those stocks for which biomass estimates from assessments are available and alternate reference points have not been formally established. In many cases, reference points have not been formally established. For stocks without estimates of assessed biomass, DFO summer survey trends are used to infer stock status.

Based on a sample of 48 of the management units on the Scotian Shelf, the majority of the shellfish stocks are in a healthy state (**Table 1**). The status of the pelagic stocks is split between the three states, with 47% in the critical state, 27% in the cautious state and 27% in a healthy state. Most of these stocks are part of the large pelagic fish community, such as swordfish, bluefin tuna and porbeagle shark. Of the groundfish stocks, over 50% are in a critical state, many of which reside on the ESS. Overall, the status of shellfish stocks is better than that of the groundfish.

3.1.1 Shellfish

Snow Crab

The snow crab fishery, which occurs primarily on the ESS, has been in existence since the 1970s. Annual landings rose significantly to above 10 000 t in the early 2000s, the majority of this from the southern area of the ESS. Since 2000, biomass first declined and then increased (**Figure 12**) and is now above 50 000 t, higher than the Sustainable Fisheries Framework reference points.

The recent increase in biomass is due to a pulse of immature crab (recruitment) which was detected in the mid-2000s and will reach fishable sizes during 2011/2012. Positive signs of adolescent crab suggest continued good recruitment to the fishery for the next two–three years. The only recent negative sign was that egg production, which while above the historical average, is expected to decline due to a lack of immature female crabs. Overall, though, the stock is in a healthy state.

Shrimp

The shrimp fishery started on the ESS in the early 1980s and, after a decline in the late 1980s, dramatically rose in intensity in the early 1990s. Since then, annual landings reached a peak of 5500 t in 2000, declined to 3000 t in 2003, and subsequently increased again to range between 3500–4600 t annually. Stock biomass was below the LRP of 5000 t in the early 1980s but rose to above the USR of 14 558 t by 1998 and has been either at or above this level since then (**Figure 13**).

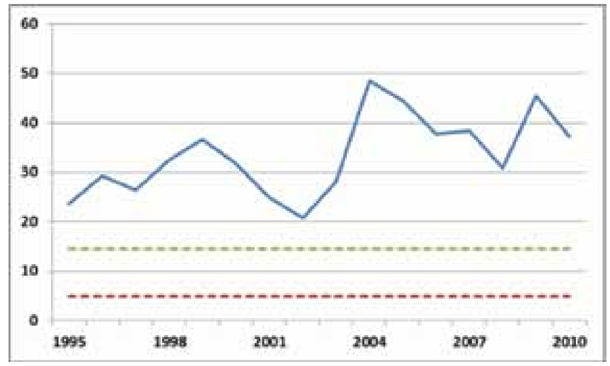


Figure 13. Trend in shrimp stock biomass (kt) on the ESS, 1982–2010; the lower and upper dashed lines indicate the LRP and USR respectively (from DFO 2012a).

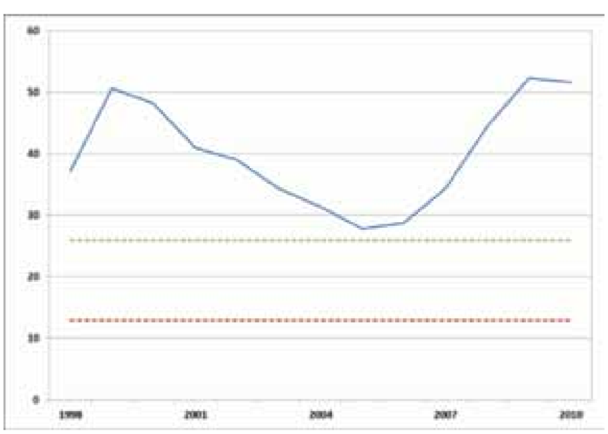


Figure 12. Trend in snow crab stock biomass in kilotonnes (kt) on the Scotian Shelf, 1998–2010; lower and upper dashed lines are the LRP and USR respectively (from Choi and Zisserson 2011).

The increase in biomass during the 1990s was due to the maturation of strong year-classes during 1993–1995 and 2001. More recently, the 2007 and 2008 year-classes also appear to be abundant and will enter the fishery during 2011–2013. There are, however, signs that recruitment of the 2010 and 2011 year-classes may be weak and the stock will start to decline (DFO 2012a).

Lobster

The lobster fishery on the Scotian Shelf is managed according to six Lobster Fishing Areas (LFAs 27 - 33) along the coast of Nova Scotia and one for the offshore fishery that takes place on the WSS and Gulf of Maine (LFA 41). Landings from the coastal LFAs rose from below 2000 t in 1980 to about 7000 t in 1990, and dipped to below 4000 t in the late 1990s before increasing to above 10 000 t in 2009 (**Figure 14**). Landings are

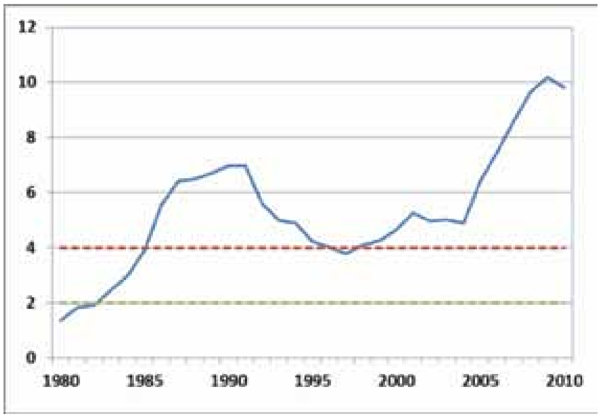


Figure 14. Trend in LFA 27–33 lobster landings (kt), 1980–2010; upper and lower dashed lines are the USR and LRP respectively (from DFO 2011d).

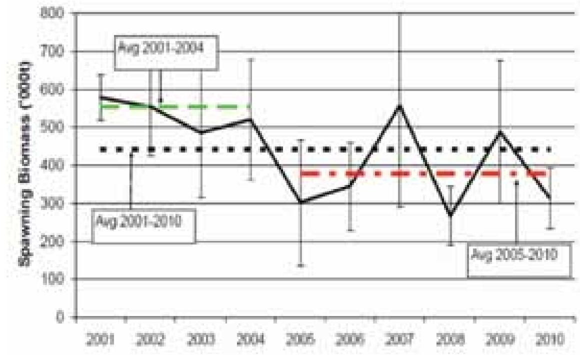


Figure 15. Trend in herring spawning biomass from acoustic surveys; recent average levels are indicated by the green (2001–2004), black (2001–2010) and red (2005–2010) dotted lines (from DFO 2011a).

the only available proxy for lobster abundance over the long-term, with the 1985–2004 period being used to develop a lower (LRP) and upper (USR) biomass-related reference to determine stock status. Based upon these, the coastal stocks are healthy. As exploitation rates in this fishery have remained stable (DFO 2011d), increased landings are due to increased abundance which is in turn due to increased stock productivity.

Landings of the offshore LFA 41 have been fairly stable since the early 2000s, being about the Total Allowable Catch (TAC) of 720 t. Abundance indicators from the different subareas of LFA 41 suggest that biomass is either stable or has increased since 1999 (DFO 2009a). The stock is considered to be healthy.

3.1.2 Pelagics

Herring

The main herring stock (Southwest Nova Scotia/Bay of Fundy spawning component) annually migrates from the Scotian Shelf to its fall spawning grounds in the Bay of Fundy (DFO 2011a). Historically, annual landings were in the order of 100 000 t but since 2000, they have ranged from 50 000 to 70 000 t annually. Recently, there has been difficulty assessing the stock, although there is general consensus that the stock has declined over the past decade (**Figure 15**). There are a number of indications of declining stock status. There has been a recent declining trend in individual fish weight, consistent with unusual environmental conditions in 2010. Also, fish condition (plumpness of a herring) is at its lowest level since 1974. Fat content is also low. While the stock is not in a critical state, it is clearly in the cautious zone.

The status of the two other Scotian Shelf herring stocks (offshore Scotian Shelf Banks and Coastal Nova Scotia components) is uncertain (DFO 2011a).

Atlantic Mackerel

The Atlantic mackerel stock stretches along the whole Atlantic coast, from off New England to the north coast of Labrador. Long-term landings have averaged 53 744 t annually, about 50% of this being taken in American waters (Deroba et al. 2010). During 1999–2008, total annual landings were about 68 000 t, with just over half by Canada. Biomass was high in the 1970s, being over 1.3 million tonnes and declined to the 200 000–400 000 t range during the 1980s (**Figure 16)**. Recent assessments have estimated stock sizes ranging 71 710 t to 141 196 t.

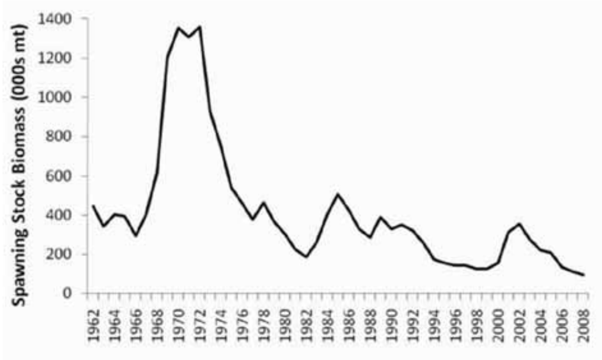


Figure 16. Trend in mature mackerel or spawning stock biomass (kt), 1962–2008 (from Deroba et al. 2010).

Recruitment to the stock is characterized by occasional large year-classes, especially those of 1967, 1982 and 1999. Recruitment during 1985–2009 has generally been low, which partly explains the relatively low level of current biomass. The stock is considered to be in the cautious state.

Swordfish

Swordfish is one of the main large pelagic fish species found in the waters of the Scotian Shelf. Similar to other large pelagic species, swordfish migrate extensively throughout various regions of the Atlantic Ocean but frequent the waters off Atlantic Canada during the spring to fall. North Atlantic swordfish landings averaged almost 14 000 t during 1980–2008, of which the Canadian fleet, which operates almost exclusively off Nova Scotia, landed an average of almost 1200 t annually. Canadian landings were at a low of 500 t in the 1980s but have gradually increased since then, being in the order of 1300–1500 t annually since 2005.

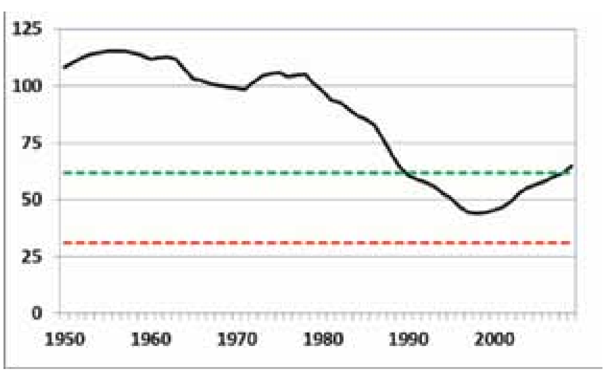


Figure 17. Trend in North Atlantic swordfish biomass (kt), 1950–2009; the International Commission for the Conservation of Atlantic Tunas (ICCAT) assesses and manages most of the large pelagic stocks fished in Canadian waters. The upper and lower dashed lines are BMSY and 50% BMSY respectively and are analogous to the USR and LRP used in Canadian fisheries (from ICCAT 2009).

Swordfish stock biomass was well above the B_{MSY} target of 61 860 t until the 1980s, at which time it decreased to its lowest point (43 870 t) in 1998 (**Figure 17**). Since then, it has increased and is currently just above B_{MSY}. Recruitment follows a similar trend to that of biomass, with strong recruiting year-classes in the 1980s, followed by a decline to a low in the late 1990s and an increase until the present. Overall, the stock is judged to be in a healthy state.

Other Pelagic Species

The other primary large pelagic species caught by the Canadian fleet include bluefin tuna, bigeye tuna, yellowfin tuna, albacore, sharks such as porbeagle, shortfin mako and blue shark, and blue and white marlin. All of these species are highly migratory and three stocks (bigeye tuna, yellowfin tuna and blue shark) are in a healthy state, none are in the cautious state, and six stocks (bluefin tuna, albacore, shortfin mako, porbeagle, blue and white marlin) are in the critical state. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed bluefin tuna as endangered (COSEWIC 2011), shortfin mako as threatened (COSEWIC 2006) and porbeagle as endangered (COSEWIC 2004).

3.1.3 Groundfish

Cod

There are two main cod stocks on the Scotian Shelf, one (4VsW) on the ESS and the other (4X) on the WSS and in the Bay of Fundy. There is a smaller stock resident off Cape Breton (4Vn) while the Gulf stock (4TVn) annually overwinters on the ESS. The annual landings of ESS cod ranged from 10 000–80 000 t during 1958–1993 (Worcester et al. 2009). The directed fishery was closed in September 1993 with small amounts of bycatch (catch of species caught incidental to directed fishing) being the only source of landings since then (Gavaris et al. 2010; see also *Incidental Mortality* theme paper). Stock biomass declined during the 1980s and has remained at critically low levels (**Figure 18**). Recruitment declined during this period and has also remained low. Recent surveys show signs of recovery although further observations are needed to confirm this (O'Boyle and Sinclair 2012).

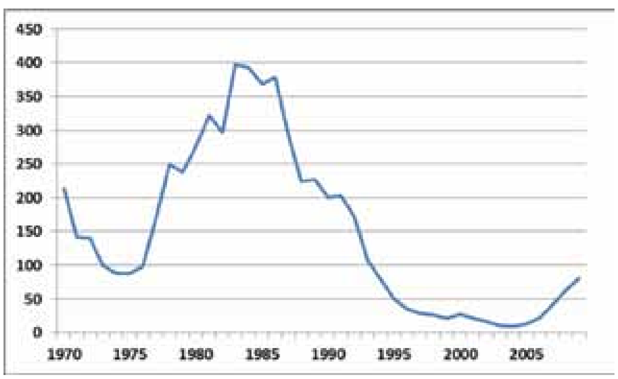


Figure 18. Trends in ESS cod mature biomass (kt), 1970–2009; note that Sustainable Fisheries Framework reference points have not been determined (data from O'Boyle and Sinclair 2012).

Landings of WSS/Bay of Fundy cod averaged 20 000 t annually over several decades but declined after 1990 to a range of 3000–5000 t since 2000 (Worcester et al. 2009). Biomass has steadily declined since 1980 such that it has been below the LRP of 24 000 t since 2002 (**Figure 19**) and, like ESS cod, this stock is in a critical state.

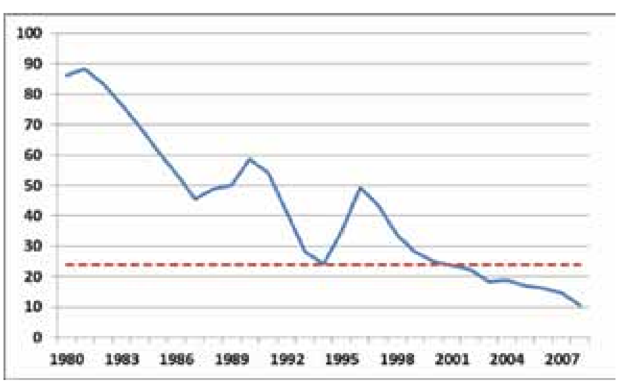


Figure 19. Trend in WSS/Bay of Fundy cod biomass (kt), 1980–2008; dashed line is LRP (from Clark et al. 2009; 2011).

Haddock

Two haddock stocks reside on the Scotian Shelf, one on the ESS and the other on the WSS and Bay of Fundy. The ESS stock has been closed since 1993 and is still depleted. On the WSS/Bay of Fundy, the fishery historically landed 10 000–20 000 t annually prior to the late 1980s but since then, landings have ranged from 5000–7000 t (DFO 2010b). Biomass over the long term has fluctuated around the USR of 35 000 t and has never fallen below the LRP of 17 000 t (**Figure 20**). Thus, this stock, contrary to that on the ESS, is considered healthy.

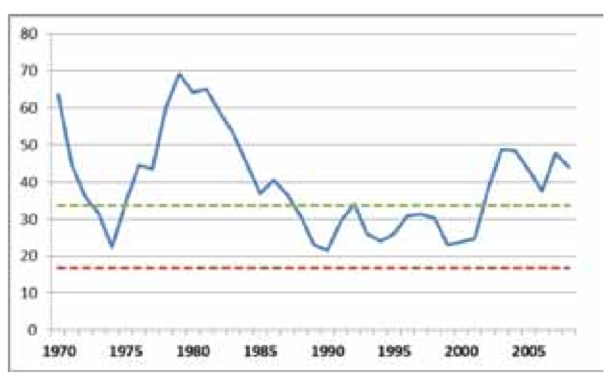


Figure 20. Trend in WSS/Bay of Fundy haddock biomass (kt), 1970–2009; the upper and lower dashed lines indicate the USR and LRP respectively (from DFO 2010b).

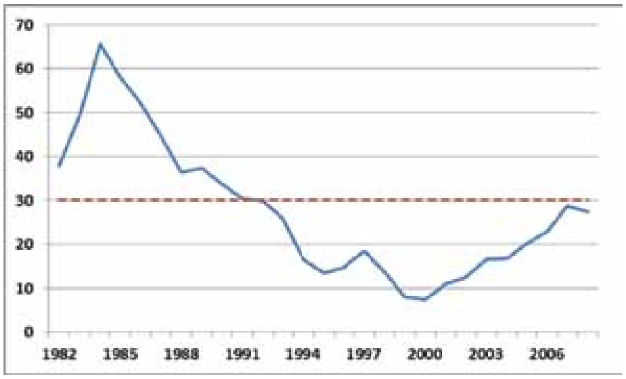


Figure 21. Trend in WSS pollock biomass (kt), 1980–2008; dashed line is the biomass reference point used in the fishery (from DFO 2009b).

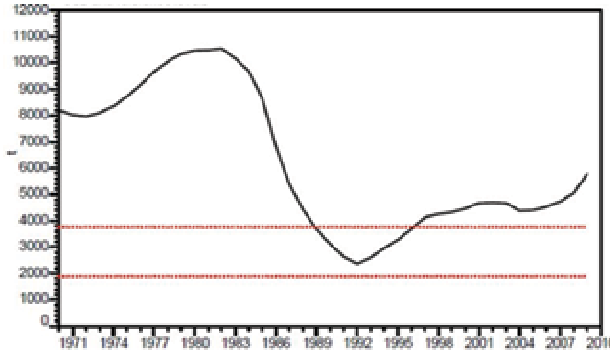


Figure 22. Trend in 3NOPs4VWX5Zc Atlantic Halibut biomass (t), 1970–2009; the upper and lower dashed lines indicate the USR and LRP respectively (from Trzcinski et al. 2011).

Pollock

Annual landings of the eastern and western components of pollock ranged from 30 000–40 000 t prior to 1990 but have only been 4000–5000 t, almost all from the western component, since 2005 (DFO 2009b). The eastern component of the resource is severely depleted. Biomass of the western component was relatively high in the 1980s, declined to its lowest level in 2000, and has subsequently increased due to improved recruitment (**Figure 21**). It has not returned to historical levels and is thus considered in the cautious state.

Photo: Wikipedia commons

Atlantic Halibut

The Atlantic halibut stock extends from the south coast of Newfoundland to the Canada–U.S. boundary. In the 1960s, annual landings averaged 2460 t but have dropped to an average of 1484 t in the 2000s (DFO 2011b). Spawning stock biomass was high in the 1970s, well above the USR of 3920 t, dropped below the LRP of 1960 t in the early 1990s and has steadily increased since to once again being above the USR (**Figure 22**; Trzcinski et al. 2011). The stock is currently in a healthy state.

3.2 STATUS OF FISHERY SECTOR

Landed value ($000), which represents gross revenue (before costs) from the fishery off Nova Scotia peaked in 2003 but has been declining since due to a strong Canadian dollar and the US recession (GPCE 2009; **Figure 23**). Groundfish landings dominated the Nova Scotia fishery up to the early 1990s, providing the main driver for the size of the processing sector and the economic strength of many dependent communities. Groundfish landings dropped by 80% between 1991 and 1995, undermining many of the plants dependent on this resource. The pelagic fisheries also declined over the years, with the tonnage landed gradually dropping to 50% of the level in the early

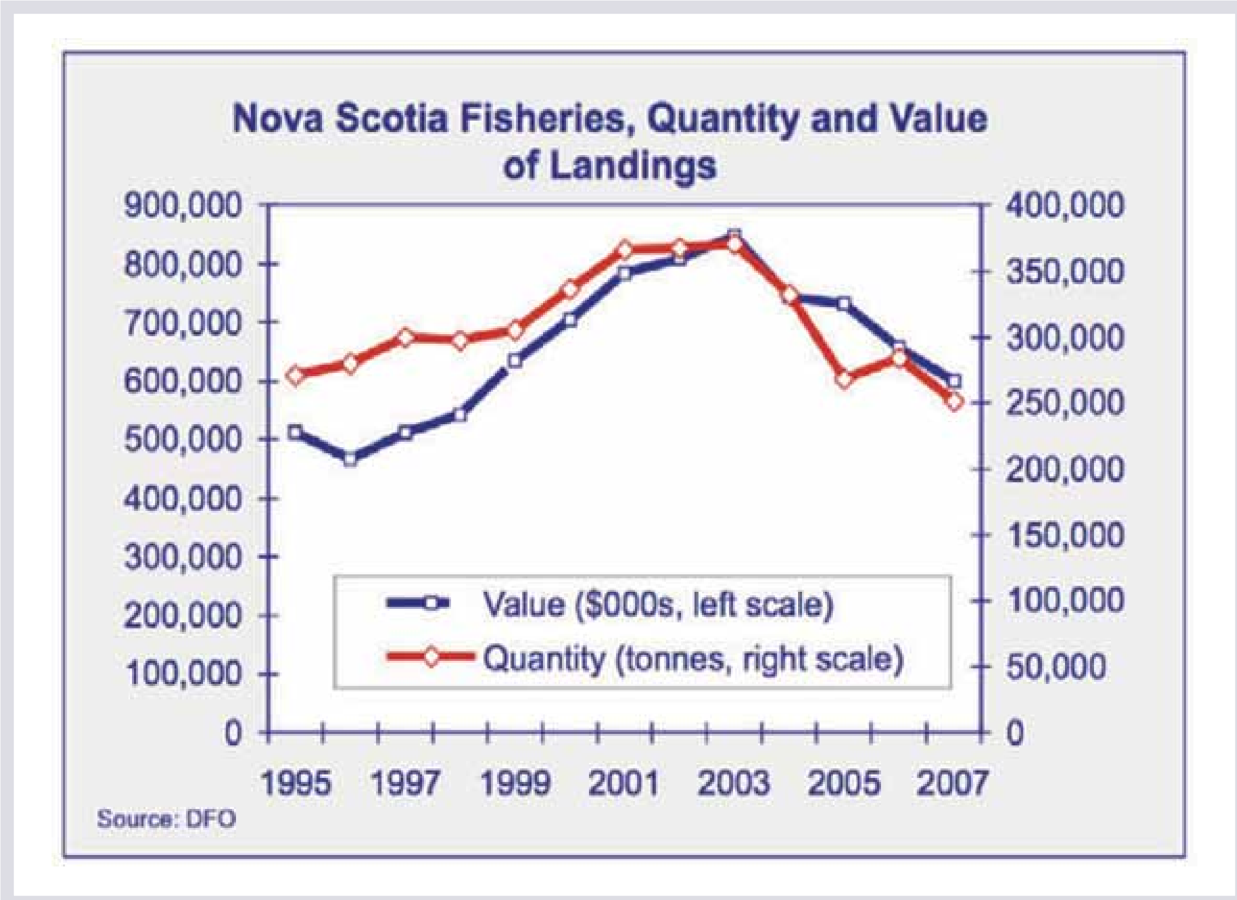


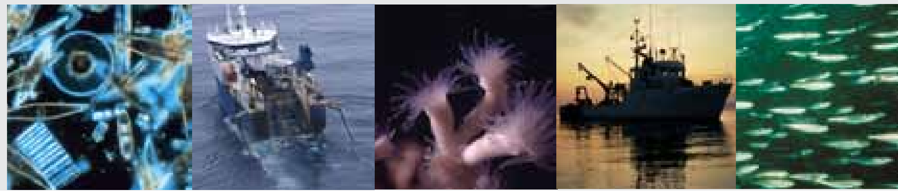
Figure 23. Trends in landings (t) and value ($000s) from 1995 to 2007 of the Nova Scotia commercial fisheries (from GPCE 2009).

1990s. The rise in shellfish landings offset the impact of these declines to some extent, but with the exception of crab, shellfish does not generate significant onshore processing opportunities (GPCE 2007). Consequently, the number of fish plants has been reduced from over 400 in the early 1990s to 223 in 2006, most of these in Southwest Nova Scotia. With the exception of lobster holding and crab processing, there has been limited investment in new plants and equipment during the past 5–10 years. Overall, the financial position of many plants has deteriorated (GPCE 2007).

Regarding the profitability of the harvesting sector, DFO has conducted cost and earnings surveys since the mid-1980s, with the most recent one being in 2004 (DFO 2004a). Unfortunately, this survey provides only useful information on the profitability of the Scotian Shelf lobster fishery with limited sampling conducted on the other fisheries. The highest gross earnings were reported by the LFA 34 fleet. Notwithstanding this, the lobster fleets were left with less than half their earnings from fishing after taking into account costs. The latter have risen for all fisheries due to rising fuel and other costs after 2006. Though fuel costs dropped in mid-2008, gains were more than offset by a sharp drop in shore prices due to weak markets. The weak markets continue but are expected to improve as and if the US and other markets recover from the current recession (GPCE 2009). The economic crisis in Europe could however adversely affect market recovery.

4 IMPACTS

The changes in the stocks and their environment have impacted not only the structure and function of the Scotian Shelf ecosystem but also the social and economic well-being of the communities supported by the commercial fisheries.



4.1 *Health of Ecosystems*

The commercial fisheries have impacted the structure and functioning of the ESS and WSS ecosystems in a number of ways. The over-exploitation of the groundfish stocks during the 1980s led to a severe decline in groundfish in both areas but most dramatically on the ESS (Zwanenburg et al. 2002). In this area, the entire groundfish community declined, only recently showing signs of recovery (Frank et al. 2011). While groundfish biomass did not decline to the same extent on the WSS, there was a change in the community structure with some species increasing (e.g., dogfish) and others decreasing (e.g., cod, white hake, pollock). This difference in impact has been attributed to colder environmental conditions (the ESS is, on average, 2°C colder than the WSS) and higher rates of natural mortality (Sinclair et al. 1997; Shackell 2011), suggesting that the ESS is less resilient to human impacts than the WSS. There is recent evidence to suggest that the shift to a pelagic species dominated system that occurred in the 1990s may be returning to a groundfish-dominated system (Frank et al. 2011).

These changes in biodiversity were also accompanied by severe declines in some species (termed "depleted species"), leading to their consideration for listing under Canada's *Species at Risk Act* (SARA). (see *Species at Risk* theme paper for a comprehensive summary of these species and their status). Some of these species may have been reduced to such low levels that predation from any source may be preventing recovery, termed a "predator pit." Another process, termed the "cultivation effect," suggests that a species, when abundant, keeps in check predators and/or food competitors of its early life stages (i.e., eggs and larvae). When depleted, these predators are released, decreasing survivorship of the early life stages of the depleted species, further causing a lack of recovery (see *Trophic Structure* theme paper for further discussion). For instance, Frank et al. (2011) suggest that following the collapse of ESS cod, due to overfishing, forage species such as herring increased in abundance. The latter have inhibited the recovery of ESS cod through both competition with and predation on the early life history stages of cod. Declining forage species, who have now outstripped their own zooplankton food supply, have more recently allowed the cod stock to once again increase in biomass. This theory has been challenged (Swain and Mohn 2012) who suggest that the recent recovery of ESS is not due to declining forage species and is due to as yet unidentified other processes. Reductions in community biodiversity due to the irreversible loss of species components can have a ripple effect throughout the ecosystem and are a cause for concern.

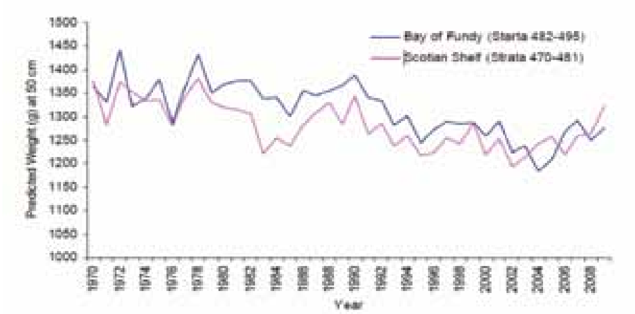


Figure 24. Trend in weight (g) of 50 cm WSS haddock from summer research trawl survey; blue and red lines refer to Bay of Fundy and Scotian Shelf areas respectively (from DFO 2010b).

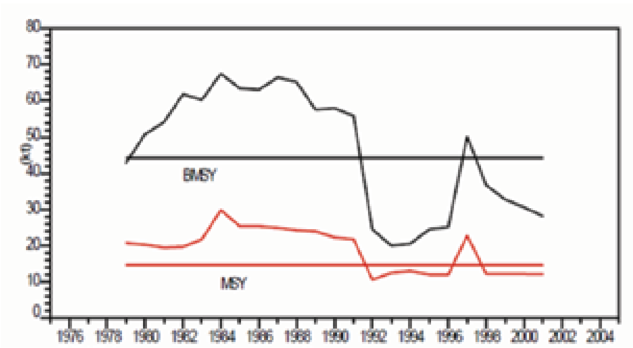


Figure 25. Trend in MSY and BMSY of WSS haddock, 1976–2004 (from DFO 2010b).

Productivity changes are also a consequence of the impacts of fisheries. It has been shown that the multi-species aggregate surplus production of the Gulf of Maine ecosystem is lower (about 28%) than the summed production of the individual species (NEFSC 2008). This difference has been attributed to biological interactions such as predation and competition. In a highly stressed ecosystem, this difference may not be as great as in less stressed systems. This effect is modified by a change in the composition of the fish communities. As noted above, the Scotian Shelf ecosystem shifted from a groundfish-dominated system to one dominated by pelagic species. The latter species are typically shorter lived and faster growing than the former and consume prey at lower levels of the food chain. Their production dynamics are quite different, thus resulting in an overall change to the productivity of the ecosystem.

Despite the reduction in exploitation rates from the high levels observed in the 1980s, there have been fish size and age at maturity reductions over the long-term that have significantly reduced the productivity of primarily the groundfish stocks (Shackell 2011). This is evident in WSS haddock which has experienced a long-term decrease in the weight of a 50 cm fish since 1970 (DFO 2010b; **Figure 24**). One of the implications of this is that stock productivity, measured as Maximum Sustainable Yield (MSY) and the biomass at MSY, has declined over the long-term (**Figure 25**). For WSS haddock at least, it appears that fish size is currently on the increase and this stock productivity should once again increase.

Fisheries also impact benthic habitat. For instance, it is known that trawlers and dredges can seriously impact sensitive habitats such as coral beds (DFO 2010e). However, the impact of bottom impacting gears is dependent on the sensitivity of the habitat being impacted (see *Marine Habitats and Communities* theme paper). Highly naturally disturbed habitats are less sensitive to impacts than less disturbed ones. Also, the link between benthic habitat and fish productivity is not well understood.

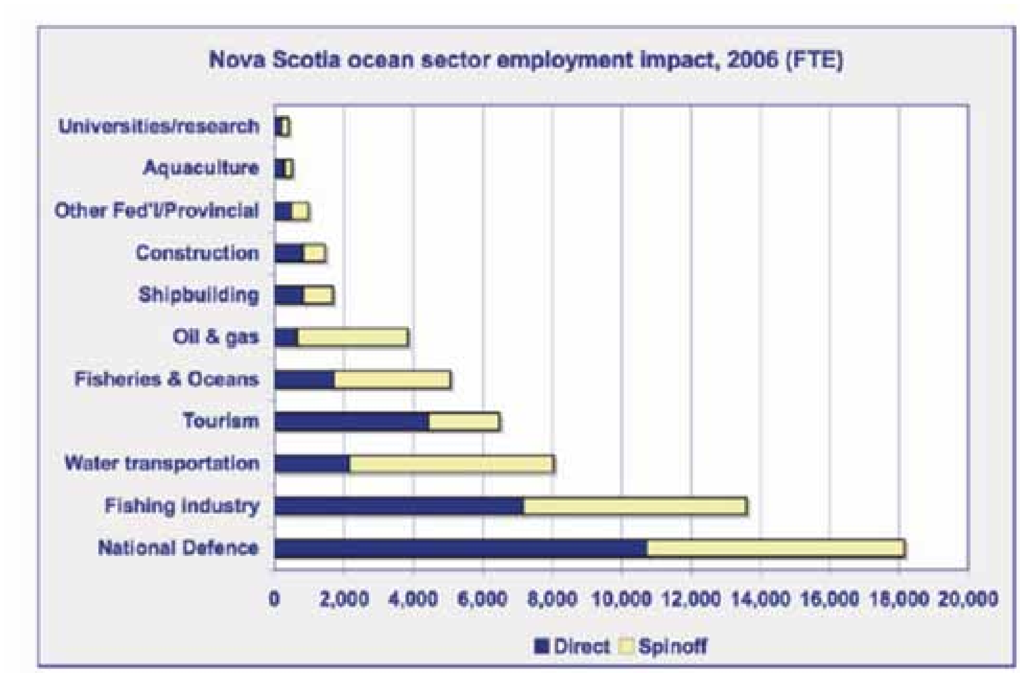


Figure 26. Nova Scotia ocean sector full-time employment impact in 2006 (from GPCE 2009).

4.2 SOCIAL AND CULTURAL WELL-BEING

Some of the biggest impacts of the fishery have been on employment in coastal communities. While full-time employment in the commercial fisheries of the Scotian Shelf was 7121 in 2006, there were an additional 6000 that were involved in spinoff industries. The fishing sector is ranked second in employment to national defence in Nova Scotia's ocean sector (GPCE 2009; **Figure 26**). Compared to Canada, Nova Scotia has a low immigration rate. In 2006, immigrants made up 5% of the provincial population compared to 19.8% for Canada (Pilkey 2009). However, the overall provincial population has remained relatively stable, despite emigration from coastal communities. From 1991 to 2006, the population in the non-coastal regions of Halifax increased almost 19% while rural coastal areas experienced a 7% decline (Pilkey 2009; **Figure 27**). Much of this emigration was young people moving to western Canada, which has created challenges for the fishery to find and retain crews (GPCE 2009). This has in turn resulted in a shift, to older ages, of participants in the fishery.

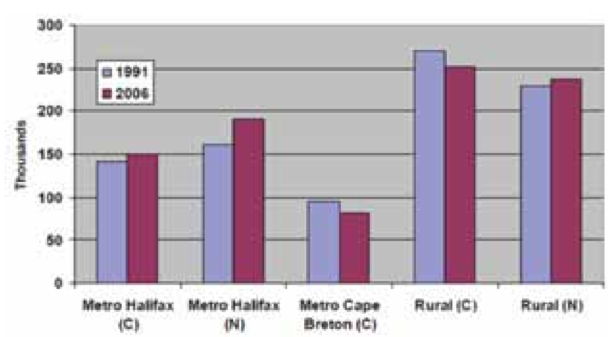


Figure 27. Change in Nova Scotia population size (000s), 1991–2006 by community; C and N indicate coastal and non-coastal communities respectively (from Pilkey 2009).

4.3 ECONOMIC WELL-BEING

The trends in the fishery have also impacted the Nova Scotia fish processing sector which consists of just over 220 licensed enterprises with 182 in operation in 2006. Processors buy fish from some 5000 vessels, utilizing all 30 species landed in the province and producing a wide range of fresh, frozen and value-added products. Full Time Employment (FTE) varies seasonally with fishing activity and landings, ranging from a low of 2900 FTEs in winter to a peak of 4850 FTEs in summer. The value of production is estimated at $1.1 billion in 2006, with total exports of about $975 million. Processors have seen their competitive position eroded over the past 10-15 years due to declining resources (primarily groundfish which requires more on-shore processing than shellfish), competition from low-cost producers, rising raw material costs, increasing concentration of buying power in major markets, adverse exchange rate movements and the regulatory environment as it affects the terms and conditions of access to raw material (GPCE 2007).

Notwithstanding these trends, market conditions should improve as and if the United States and other markets recover from the current recession (GPCE 2007), although the economic crisis in Europe could adversely affect recovery. Whether the resource recovers to levels experienced in the 1980s is more difficult to say. What seems more certain is that there will continue to be structural change in the industry, with cost and earnings pressures likely to force further consolidations through concentration of quota and combining licenses. This will result in less capital in the industry and a decrease in the numbers employed. In the long-term, fisheries will continue to be one of Nova Scotia's leading ocean industries.

5 RESPONSES

5.1 LEGISLATION AND POLICY

In response to the *Oceans Act* (1997), DFO initiated the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative, which developed a strategic plan (DFO 2007a) to achieve a suite of conservation and socio-economic objectives that apply to all human activities, including commercial fisheries, on the Eastern Scotian Shelf. The conservation objectives were developed nationally and included sub-objectives for the conservation of biodiversity, productivity and habitat (DFO 2004b). This plan has required development of operational objectives to achieve the conservation objectives. The fishing and other

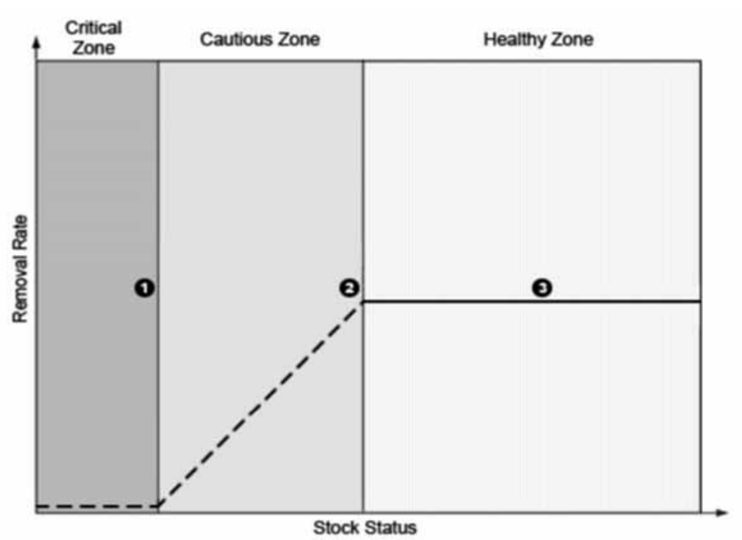


Figure 28. Harvest Control Rule (HCR) of DFO Sustainable Fisheries Framework; below the LRP (1), the removal rate is set as low as possible. Above the USR (2), removal rate is set at the target removal rate (3) and between the LRP and USR, removal rate is set proportional to stock size.

industries developed action plans to help implement the objectives. The initiative is currently (2012) in the evaluation stage and in the future will transition to a bioregional integrated ocean management process.

In 2009, DFO introduced the Sustainable Fisheries Framework which included a decision-making framework incorporating the Precautionary Approach (DFO 2012b). Once implementation is complete, it will provide the operational objectives for the Scotian Shelf fisheries. The key element of this framework is a Harvest Control Rule (HCR) by which biomass Limit Reference (LRP) and Upper Stock Reference (USR) points are used to set fishery removal or harvest rates (**Figure 28**).

For the Scotian Shelf, the new HCR has been discussed with industry and implemented in 15 of the 40 main stocks commercially fished. As experience is gained with the HCR on these stocks, implementation will be undertaken in the remaining ones.

5.2 MANAGEMENT ACTIVITIES

The management activities used to control the commercial fisheries of the Scotian Shelf are outlined in Integrated Fisheries Management (IFMP) and Conservation Harvesting (CHP) plans. These consist of catch controls such as annual quotas and effort regulations which stipulate seasonal and spatial restrictions as well as gear type, configuration and amount. The effectiveness of the regulatory package can be judged by comparing the realised fishing mortality (F) in the fishery to that established as a target. The target is based upon both biological and socio-economic considerations. Fishing mortality targets are typically a fraction (e.g. 75%) of F_{MSY} (**see box**). For shellfish stocks, except for lobster in LFAs 27–33, current fishing mortality is either at or below the target. In the case of lobster, while exploitation rates are high, they do not appear to be endangering the sustainability of the stocks. In the case of the pelagic fisheries, for some stocks (e.g., mackerel), exploitation has been in excess of the target but for most pelagic stocks, exploitation is either at or below the target or not known (herring). Regarding the groundfish stocks, those on the ESS such as cod and haddock are not prosecuted by directed fisheries and are only caught as bycatch while those on the WSS, such as pollock and Atlantic halibut are prosecuted by targeted fisheries. Where it has been assessed, exploitation rate is either at or below the target.

Maximum Sustainable Yield (MSY) is commonly used to describe the maximum tonnage of fish that can be harvested on an ongoing basis from a stock. A stock, whose biomass is at BMSY and is harvested at an exploitation rate of FMSY produces a yield of MSY. MSY is a consequence of balancing processes such as recruitment and body growth with mortality, both fishing and natural.

To achieve conservation objectives associated with biodiversity and habitat, DFO has either implemented or is in the process of implementing a number of spatial closures, most prominent of these being the Gully Marine Protected Area, St. Ann's Bank Area of Interest (a site that may become a marine protected area) and the Coral Conservation Areas (**Figure 29**). Monitoring programs have been established to measure the effectiveness of these closures (e.g., DFO 2010d for the Gully) but implementation is too recent to allow determination of outcomes.

Seventeen groundfish and pelagic stocks and species have been assessed by COSEWIC as

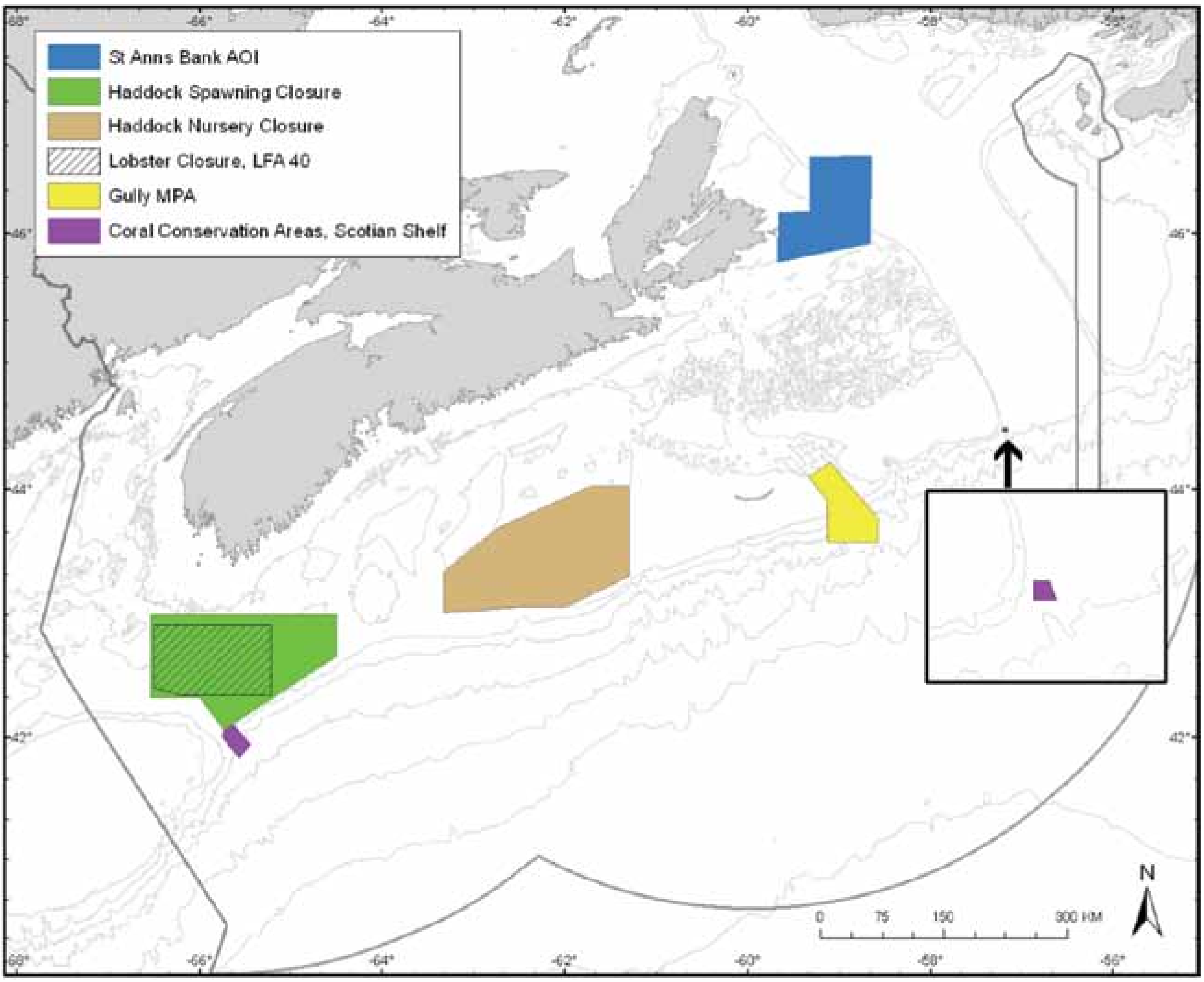


Figure 29. Spatial closures to achieve biodiversity and habitat conservation objectives. Grey line indicates Canada's Exclusive Economic Zone.

special concern, threatened or endangered. Of these, three (Atlantic, northern and spotted wolfish) have been added to Schedule 1 of SARA. The two threatened species (northern and spotted wolffish) require recovery strategies, while the species of special concern (Atlantic wolffish) requires a management plan (Walmsley 2011). These have been drafted and implemented for all three species. The remaining species are managed under the *Fisheries Act* which stipulates special conditions within IFMPs for fisheries which encounter them. Any stock which is being considered for listing under SARA must undergo a Recovery Potential Assessment (DFO 2007b; 2011e) which assesses recent status, estimates the scope for management to facilitate recovery and considers scenarios for mitigation and alternative activities. So far, of the 17 stocks assessed by COSEWIC, 15 have undergone Recovery Potential Assessments, the results of which will inform recovery efforts (see for instance DFO 2011f).

5.3 INDUSTRY-BASED INITIATIVES

The Canadian Code of Conduct for Responsible Fishing Operations (http://www.dfo-mpo.gc.ca/fm-gp/policies-politiques/

cccrfo-cccppr-eng.htm) was developed by the fishing industry in 1998 to ensure sustainable harvesting. It outlines 36 guidelines to achieve the nine principles of the Code and aims to avoid the problems that caused the groundfish collapse of the early 1990s. As well, the Nova Scotia Swordfishermen's Association has developed a Code of Conduct for Responsible Sea Turtle Handling and Mitigation Measures. Initially, compliance with the Code of Conduct was optional but it is now a condition of licence.

Of 50 Scotian Shelf commercial fish stocks and fisheries, nine have either been or are in the process of being certified by the Marine Stewardship Council (**see box**), including ESS shrimp, snow crab, offshore scallop, offshore lobster, surf clam, swordfish, spiny dogfish, Atlantic halibut and WSS haddock. Increasingly, markets are requiring that eco-certification of the fisheries supplying the resources be undertaken. It is expected that the number of certified fisheries will increase in the future.

To control over-capacity in the inshore groundfish mobile gear fishery, Individual Transferable Quotas (ITQs) were implemented in 1991. The industry has adapted to this system, actively buying and selling quota shares. A similar system was introduced in the fixed gear fishery soon after this, with the unit of quota allocation being one of seven communities rather than the fishing licence (Fanning 2007). By 2002, ITQs were implemented in all groundfisheries on the Scotian Shelf. Currently, except for lobster, all major commercial fisheries are managed using either ITQs or community-based quotas. Overall, the program has provided more certainty in allocation for harvesters and has reduced harvest capacity (DFO 2004c; Gough 2007).

Addressing Consumers' Concerns: Eco-certification, Community Suported Fisheries and Seafood Traceability

The Marine Stewardship Council (MSC) is the best-known fisheries eco-certification organization in this region. It has articulated and manages a set of standards against which fisheries are assessed. Increasingly, markets are requiring that fishery products are eco-certified to address consumer concerns about the sustainability of fisheries.

To help ensure stability of price, some fish harvesters have established consumer supported fishery groups, similar to the concept of community supported agriculture. Consumers pay a set price at the beginning of the fishing season for a share of the season's catch. By direct marketing to consumers, harvesters receive a greater share of the profits, while consumers receive fresher fish. Off the Hook was the first community supported fishery group formed in Atlantic Canada and was named runner-up in National Geographic's global contest, Turning the Tide for Coastal Fisheries Solutions (Off the Hook 2012).

An innovative seafood traceability program called "This Fish" allows consumers to find out who caught the fish they are eating. Participating fish harvesters tag their fish and enter information on how, when and where they caught it into an online database. After purchasing the fish, consumers can look up the tag number to find out more about the fish and the harvester that caught it. More than two hundred fish harvesters take part, mostly from Atlantic Canada, as do several Nova Scotia-based seafood companies (ThisFish 2012).

5.4 RESEARCH AND MONITORING

Since the 1990s, the fishing industry has invested heavily in research and monitoring. While DFO manages the ITQ program, the monitoring costs, both at-sea observer and dockside, are borne by the industry. Industry-run surveys are now a critical element for assessing the WSS groundfish, Atlantic halibut, WSS herring, surf clam, ESS shrimp and snow crab stocks and represent almost 25% of the total DFO Science monitoring budget (R. Claytor, Fisheries and Oceans Canada, pers. comm. 2012). Indeed, the fishing industry has been proactive in a number of cases in not only undertaking monitoring but also in assisting DFO Science in identifying and funding research to fill essential knowledge gaps (e.g., O'Boyle 2004). Another example of this is the Fishermen and Scientists Research Society (http://www.fsrs.ns.ca/) which has played an invaluable role in facilitating the participation of inshore fishing groups in the monitoring, assessment and research of inshore lobster stocks.

There is increasing awareness of the need to undertake research and monitoring of depleted stocks. The annual surveys of DFO Science (Shackell 2011), which contribute to the Atlantic Zonal Monitoring Program (http://www.bio.gc.ca/monitoring-monitorage/azmp-pmza/index-eng.htm) are an essential element of efforts to monitor and assess long-term trends in biodiversity. Data collected by this program, along with that of the industry, are used in the Recovery Potential Assessments of depleted species (see section 4.1). These assessments also benefit from a number of specially designed bycatch studies which describe the "ecological footprint" of a fishery. Gavaris and others (2010) provide a description of the bycatch in the Scotian Shelf groundfish fisheries. Similar studies are being conducted on the scallop, snow crab, lobster and other fisheries. These are allowing managers and industry to mitigate the unintended bycatch of depleted species.

Research and monitoring is also being conducted on the impacts of commercial fisheries on benthic habitat (see *Marine Habitats and Communities* theme paper for more details). One example of this is research to identify habitat where scallop and clams reside thus allowing fishing while avoiding the adverse effects of dredging. Multibeam imagery of large areas of the Scotian Shelf has been undertaken to characterize the benthic habitat. Using this imagery, Robert (2001) found that scallop prefer gravel bottoms and when fishing is targeted on this habitat, the amount of bottom impacted by the dredges was reduced by 74%. This reduced footprint likely resulted in reduced impacts on the benthic communities. As well, fuel costs were reduced, which was a plus for the fishermen (**Table 2**). This study illustrated well the advantages of science-industry collaboration to both fishermen and the ecosystems of the Scotian Shelf.

Table 2. Advantages of identifying scallop-preferred benthic habitat through multi-beam imagery for a scallop quota of 13 640 kg (from Robert 2001).

	WITHOUT IMAGERY	WITH IMAGERY	REDUCTION
Time gear on bottom	162 hours	43 hours	73%
Area of bottom towed	1176 km^2	311 km^2	74%
Fuel usage	27 697 litres	17 545 litres	36%

INDICATOR SUMMARY

INDICATOR	POLICY ISSUE	DPSIR	ASSESSMENT[1]	TREND[2]
Sea surface temperature (°C)	Global warming is occurring with some evidence on ESS	Driving Force	Unknown	/
Aggregate MSY	Many groundfish stocks have experienced low productivity since the early 1990s	Driving Force	Poor	/
Global population size (number)	Markets for N.S. exports remain strong due to global demand	Driving Force	Good	+
Export revenue ($M)	Export revenue has declined in recent years due to strong Canadian dollar and weak U.S. market	Driving Force	Fair	-
% Fisheries of GDP	Fisheries are increasingly competing for ocean space with other ocean industries	Pressure	Fair	-
Exploitation rate	Excessive exploitation due to high effort can cause overfishing	Pressure	Good	+
Shellfish stock group status ($B_{current}/B_{RP}$)	86% of the major shellfish stocks are healthy	State	Good	+
Pelagic stock group status ($B_{current}/B_{RP}$)	74% of the major pelagic stocks are in critical or cautious state	State	Poor	-
Groundfish stock group status ($B_{current}/B_{RP}$)	73% of the major groundfish stocks are in critical or cautious state	State	Poor	-
Landings value / revenue ($M)	Landed value has declined since 2003 due to weak U.S. markets and lack of groundfish recovery	State	Poor	-
Species diversity (number of depleted species)	Loss of species can lead to reduced ecosystem resilience	Impact	Poor	-
Productivity ($Yield_{current}$ / MSY)	Overfishing can lead to reduced stock productivity and lost yield	Impact	Fair	/
Coastal community population size	Fishing communities are having difficulty retaining youth	Impact	Poor	-
Processing sector employment	Lack of groundfish recovery is challenging processing sector	Impact	Poor	-
% Stocks with HCR	HCRs are an integral component of the DFO Sustainable Fisheries Framework	Response	Fair	+
% Fishing mortality of target	To ensure sustainability, F needs to be maintained at that determined by the HCR	Response	Good	+
% Depleted species that have undergone Recovery Potential Assessments	All stocks assessed as threatened, endangered or special concern by COSEWIC must undergo an RPA	Response	Good	+
% Fisheries eco-certified	Eco-certification provides industry standard of sustainability	Response	Good	+
% Stocks with dedicated monitoring	Monitoring is critical element of stock assessment	Response	Good	+

[1]Assessment: assessment of the current situation in terms of implications for the state of the environment. Categories are poor, fair, good, unknown.
[2]Trend: is the trend positive or negative in terms of implications for the state of the environment. It is not the direction of the indicator, although it could coincide with the direction of the indicator.

Data Confidence:

- Good data are available for most of the main commercial stocks and the environment in which they reside.
- A large source of uncertainty is the high and unexplained natural mortality observed in many of the groundfish stocks.

Data Gaps:

- There are gaps in the bycatch data although some work is being undertaken to resolve these.
- While knowledge and understanding of ecosystem dynamics is advancing, it is not clear whether or not recovery of many depleted species will occur and that the Scotian Shelf ecosystems will attain a state comparable to that before the groundfish collapse of the 1990s.
- Changes related to fishing effort–for example, changes in vessels, gear, technology used, and fishermen's knowledge–and their overall impacts on fish stocks are difficult to track.

Key:

Negative trend: -
Unclear or neutral trend: /
Positive trend: +
No assessment due to lack of data: ?

See more about the DPSIR framework at http://coinatlantic.ca/index.php/state-of-the-scotian-shelf/217

6 REFERENCES

Choi JS and Zisserson BM. 2011. Assessment of Scotian Shelf snow crab in 2010. Canadian Science Advisory Secretariat Research Document 2011/110. viii + 95 pp.

Clark DS, Clark KJ, and Andrushchenko IV. 2011. Precautionary approach limit reference points for Atlantic cod (*Gadus morhua*) in NAFO Divisions 4X5Yb and 5Zjm. Canadian Science Advisory Secretariat Research Document 2011/085. vi + 6p.

Clark DS and Emberley J. 2009. Assessment of cod in Division 4X in 2008. Canadian Science Advisory Secretariat Research Document 2009/018. vi + 101 pp.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2004. COSEWIC assessment and status report on the porbeagle shark *Lamna nasus* in Canada. Ottawa: COSEWIC. viii + 43 pp.

COSEWIC. 2006. COSEWIC assessment and status report on the shortfin mako *Isurus oxyrinchus* (Atlantic population) in Canada. Ottawa: COSEWIC. vi + 24 pp.

COSEWIC. 2011. COSEWIC assessment and status report on the Atlantic bluefin tuna *Thunnus thynnus* in Canada. Ottawa: COSEWIC. ix + 30 pp.

Deroba JJ, Shepherd G, Gregoire F, Nieland F and Link J. 2010. Stock assessment of Atlantic mackerel in the Northwest Atlantic – 2009. TRAC Research Document 2010/01. iv + 59 pp.

DFO (Fisheries and Oceans Canada). 2004a. Cost and earnings survey for 2004. Atlantic Region Report. Ottawa: DFO Economic Analysis and Statistics, Policy Sector. 72 pp.

DFO. 2004b. Habitat status report on ecosystem objectives. Canadian Science Advisory Secretariat Habitat Status Report 2004/001.

DFO. 2004c. A policy framework for the management of fisheries on Canada's Atlantic coast. http://www.dfo-mpo.gc.ca/fm-gp/policies-politiques/afpr-rppa/framework-cadre-eng.pdf

DFO. 2007a. Eastern Scotian Shelf integrated ocean management plan. Oceans and Habitat Branch, Maritimes Region, Fisheries and Oceans Canada. 68 pp.

DFO. 2007b. Revised protocol for conducting recovery potential assessments. Canadian Science Advisory Secretariat Advisory Report 2007/039.

DFO. 2009a. Assessment of lobster in Lobster Fishing Area 41 (4X + 5Zc). Canadian Science Advisory Secretariat Advisory Report 2009/033.

DFO. 2009b. Pollock in Div. 4VWX+5. Canadian Science Advisory Secretariat Advisory Report 2009/025.

DFO. 2010a. Assessment of scallops (*Placopecten magellanicus*) in Scallop Fishing Area (SFA) 29 west of longitude 65°30'W. DFO Canadian Science Advisory Secretariat Advisory Report 2010/039.

DFO. 2010b. Assessment of the status of Division 4X5Y haddock in 2009. Canadian Science Advisory Secretariat Advisory Report 2010/005.

DFO. 2010c. Canadian marine ecosystem status and trends report. Canadian Science Advisory Secretariat Advisory Report 2010/030 (Revised).

DFO. 2010d. Gully Marine Protected Area monitoring indicators, protocols and strategies. Canadian Science Advisory Secretariat Advisory Report 2010/066.

DFO. 2010e. Potential impacts of fishing gears (excluding mobile bottom-contacting gears) on marine habitats and communities. Canadian Science Advisory Secretariat Advisory Report 2010/003.

DFO. 2011a. 2011 assessment of 4VWX herring. Canadian Science Advisory Secretariat Advisory Report 2011/046.

DFO. 2011b. Assessment of Atlantic halibut on the Scotian Shelf and Southern Grand Banks (NAFO Divisions 3NOPs-4VWX5Zc). Canadian Science Advisory Secretariat Advisory Report 2011/001.

DFO. 2011c. Assessment of Browns Bank North scallops (*Placopecten magellanicus*). Canadian Science Advisory Secretariat Advisory Report 2011/027.

DFO. 2011d. Assessment of lobster off the Atlantic coast of Nova Scotia (LFAs 27-33). Canadian Science Advisory Secretariat Advisory Report 2011/064.

DFO. 2011e. A complement to the 2005 framework for developing science advice on recovery targets in the context of the *Species At Risk Act*. Canadian Science Advisory Secretariat Advisory Report 2010/061.

DFO. 2011f. Recovery Potential Assessment (RPA) for the southern designatable unit (NAFO Divs. 4X5Yb and 5Zjm) of Atlantic cod (*Gadus morhua*). Canadian Science Advisory Secretariat Advisory Report 2011/034.

DFO. 2012a. Assessment of northern shrimp on the Eastern Scotian Shelf (SFAs 13-15). DFO Canadian Science Advisory Secretariat Advisory Report 2012/001.

DFO. 2012b. A fishery decision-making framework incorporating the precautionary approach. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm

DFO. 2012c. The Scotian Shelf in Context. State of the Scotian Shelf Report. Oceans and Coastal Management Division, Bedford Institute of Oceanography, Dartmouth, NS and ACZISC. 67 pp. http://coinatlantic.ca/index.php/state-of-the-scotian-shelf

DFO. 2012d. Sustainable Fisheries Framework. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/overview-cadre-eng.htm

Fanning L. 2007. Evaluating community fish quota management in Atlantic Canada: Lessons from the start-up years. MAST 5: 27–54.

Frank KT, Perry RI, Drinkwater KF and Lear WH. 1988. Changes in the fisheries of Atlantic Canada associated with global increases in atmospheric carbon dioxide: A preliminary report. Canadian Technical Report of Fisheries and Aquatic Sciences 1652. 52 pp.

Frank KT, Petrie B, Choi JS and Leggett WC. 2005. Trophic cascades in a formerly cod dominated ecosystem. Science 308: 1621–1623.

Frank KT, Petrie B and Shackell NL. 2007. The ups and downs of trophic control in continental shelf ecosystems. TREE 22: 236–242

Frank KT, Petrie B, Fisher JAD and Leggett WC. 2011. Transient dynamics of an altered large marine ecosystem. Nature 477: 86–91.

GPCE (Gardner Pinfold Consulting Economists Ltd). 2005. Economic impact of the Nova Scotia ocean sector 1996–2001. Prepared for Government of Canada and Nova Scotia Government, January 2005. 81 pp.

GPCE. 2007. Nova Scotia Seafood Processing Sector. Prepared for Nova Scotia Department of Fisheries and Aquaculture. 57 pp.

GPCE. 2009. Economic impact of the Nova Scotia Ocean Sector 2002–2006. Prepared for Government of Canada and Nova Scotia Government, March 2009. 38 pp.

Gavaris S, Clark KJ, Hanke AR, Purchase CF and Gale J. 2010. Overview of discards from Canadian commercial fisheries in NAFO Divisions 4V, 4W, 4X, 5Y and 5Z for 2002–2006. Canadian Technical Report of Fisheries and Aquatic Sciences 2873. 112 pp.

Gough J. 2007. Fisheries Management in the Maritimes Region 1990-2005. Prepared for Fisheries and Oceans Canada, Communications Branch, Maritimes Region. http://www2.mar.dfo-mpo.gc.ca/fishmgmt/fm/fm-eng.pdf

Greene CH, Pershing AJ, Cronin TM and Ceci N. 2008. Arctic climate change and its impacts on the ecology of the North Atlantic. Ecology 89: S24–S38.

Halliday RG and Pinhorn AT. 2009. The roles of fishing and environmental change in the decline of northwest Atlantic groundfish populations in the early 1990s. Fisheries Research 97: 163–182.

Hardie D, Covey M, King M and Zisserson B. 2012. Scotian Shelf Shrimp 2010-2011. Canadian Science Advisory Secretariat Research Document 2011/102. vi + 76 p.

ICCAT (International Commission for the Conservation of Atlantic Tunas). 2009. Report of the 2009 Atlantic swordfish stock assessment session. SCRS/2009/016. 78 pp.

IPCC (Intergovernmental Panel on Climate Change). 2007a. Climate Change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Geneva: IPCC.

IPCC. 2007b. Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Geneva: IPCC.

IPCC. 2007c. Climate Change 2007: Synthesis report. An assessment of the Intergovernmental Panel on Climate Change. Geneva: IPCC.

Mohn RK and Chouinard GA. 2007. Harvest control rules for stocks displaying dynamic production regimes. ICES Journal of Marine Science 64: 693–97.

Mohn RK, Trzcinski MK, Black GAP, Armsworthy S, Young GA, Comeau PA and den Heyer CE. 2010. Assessment of the status of division 4X5Y haddock in 2009. Canadian Science Advisory Secretariat Research Document 2010/085. vi + 61 pp.

NEFSC. 2008. Assessment of 19 northeast groundfish stocks through 2007: Report of the 3rd groundfish assessment review meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Department of Commerce, Northeast Fisheries Science Center Reference Document 08-15. xvii + 884 pp.

O'Boyle R. 2004. Atlantic halibut research: report of planning meeting: 24–25 August 2004. Canadian Science Advisory Secretariat Proceedings Series 2004/027.

O'Boyle R and Sinclair M. 2012. Seal–cod interactions on the Eastern Scotian Shelf: Reconsideration of modeling assumptions. Fisheries Research 115–116: 1–13.

Off the Hook. 2012. Atlantic Canada's First Community Supported Fishery. http://www.offthehookcsf.ca/description

Pilkey DW. 2009. Rural development assessment. Final Assessment. Prepared for the Coastal Community Network. http://www.coastalcommunities.ns.ca/documents/RuralDevAssessmentFinalReport.pdf

Robert G. 2001. Impact of multibeam surveys on scallop fishing efficiency and stock assessment. In: D Geddes (ed), Bedford Institute of Oceanography 2001 in Review. Dartmouth, NS: Fisheries and Oceans Canada and Natural Resources Canada. pp. 40-41.

Shackell N. 2011. Trophic Structure. State of the Scotian Shelf Report. Fisheries and Oceans Canada and ACZISC. 29 pp. http://coinatlantic.ca/index.php/state-of-the-scotian-shelf

Sinclair M, O'Boyle R, Burke DL and Peacock G. 1997. Why do some fisheries survive and others collapse? In: DA Hancock, DC Smith, A Grant and JP Beumer (eds), Developing and sustaining world fisheries resources. The State of Science and Management, 2nd World Fisheries Congress. Collingwood, Australia: CSIRO. pp. 23-35.

Statistics Canada. 2012. Population by year, by province and territory. http://www.statcan.gc.ca/tabl—tableaux/sum-som/l01/cst01/demo02a-eng.htm

Stone H, Nelson C, Clark D and Cook A. 2009. 2008 Assessment of Pollock in 4VWX+5. Canadian Science Advisory Secretariat Research Document 2009/001. viii + 79 pp.

Swain DP and Mohn RK. 2012. Forage species and the factors governing recovery of Atlantic cod (*Gadus morhua*) on the eastern Scotian Shelf. Canadian Journal of Fisheries and Aquatic Sciences 69: 997–1001.

ThisFish. 2012. Discover the story of your seafood. http://thisfish.info/

Trzcinski MK, Armsworthy SL, Wilson S, Mohn RK and Campana SE. 2011. A framework for the assessment of the Scotian Shelf and Southern Grand Banks Atlantic halibut stock. Erratum: December 2011. Canadian Science Advisory Secretariat Research Document 2011/002. vi + 113 pp.

USCB. 2012. World POPClock Projector. http://www.census.gov/population/popclockworld.html

Worcester T, Brattey J, Chouinard GA, Clark D, Clark KJ, Deault J, Fowler M, Fréchet A, Gauthier J, Healey B et al. 2009. Status of Atlantic cod (*Gadus morhua*) in 2008. Canadian Science Advisory Secretariat Research Document 2009/027. vi + 167 p.

Walmsley D. 2011. At Risk Species. State of the Scotian Shelf Report. Fisheries and Oceans Canada and ACZISC. 24 pp. http://coinatlantic.ca/index.php/state-of-the-scotian-shelf

Zwanenburg KCT, Bowen D, Bundy A, Drinkwater K, Frank K, O'Boyle R, Sameoto D and Sinclair M. 2002. Decadal changes in the Scotian Shelf large marine ecosystem. In: K Sherman and HR Skoldal (eds), Large marine ecosystems of the North Atlantic: Changing states and sustainability. Amsterdam: Elsevier. pp. 105-150.