MAKING FORAGE FISH COUNT:

RECOMMENDATIONS TO IMPROVE MANAGEMENT IN CANADA

Forage fish species, such as **herring** and **mackerel**, are an important part of the marine ecosystem and support many of Canada's commercial fisheries, both as targeted catch and bait. In addition to being an important part of the human food system for millennia, they are also an **important food source** for many other ecologically and commercially important fish species.

However, many small pelagic have experienced **significant declines** and **large fluctuations** in their populations due to overfishing and climate variability. In order to ensure that these species continue to support healthy fisheries and a healthy marine ecosystem, Canada must take an **ecosystem-based approach** to rebuilding their depleted populations and managing these species in light of climate change and the needs of other species in the ecosystem.

WHAT ARE FORAGE FISH?

A **FORAGE FISH** is an important source of food or prey for fish species higher up in the marine food chain. These species provide an important link by transferring energy from plankton, up the food chain to larger predator species. Forage species often experience high predation mortality and high fishing pressure at the same stage of their lives.

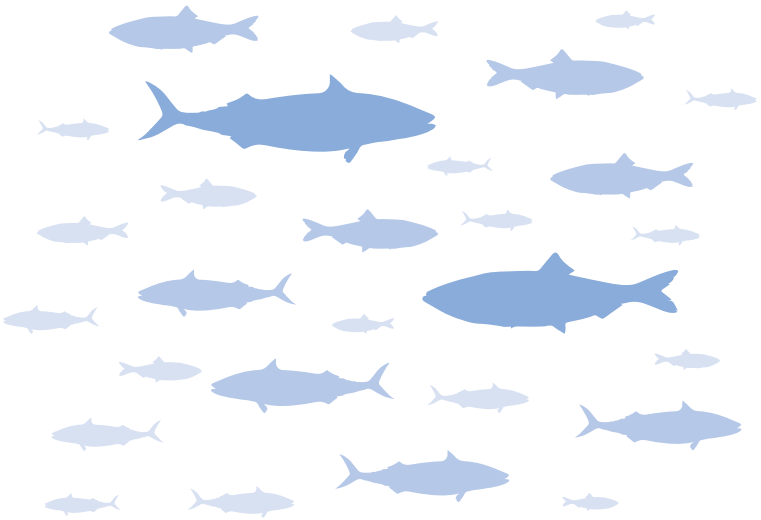
Forage species often have other important biological characteristics that influence their ability to withstand or recover from the impacts of fishing, and our ability to manage them effectively. They undergo large and relatively rapid natural fluctuations in abundance in response to environmental factors. They also form dense schools for at least a part of the annual cycle and are relatively short lived, from several weeks to a few years.[1]

WHY FORAGE FISH REQUIRE UNIQUE ATTENTION

Globally, the economic value of forage fish as prey is twice the value of forage fish as directed catch due to their ability to support the production of other commercial fisheries.[2] Forage fish are estimated to contribute at least 20% to the value of all marine fisheries combined[3]. Furthermore, forage fish exist in an extremely complex system, with many interactions with other species that are difficult to quantify. They are also highly sensitive to changes in their biophysical environment and susceptible to climate change.[4] These species form large dense schools that are easily harvested even when the population size is low, which makes them particularly vulnerable to overfishing. When the effects of fishing, predation and unfavorable environmental conditions act together, population collapse can occur.[5]

Because of their role in the ecosystem, and sensitivity to environmental change as well as fishing, managing forage fisheries is complex. This is exemplified by the interactions between herring, capelin (both forage species) and cod documented in the Barents Sea. Capelin collapses are caused by increased predation on larvae from herring[6], and capelin recovery is delayed by cod predation. The recruitment of both cod and herring are heavily affected by climate, which in turn affects capelin abundance. Capelin collapse results in increased cannibalism and decreased body condition in cod.[7] Overharvesting of capelin by fishermen in this case was found to increase the impact of cod predation on capelin, despite low abundance, because the predators were so dependent on the prey species. This example shows that factors affecting abundance of predator and prey cannot be analyzed individually, and as such must be considered through an ecosystem approach, taking into account environmental changes as well as changes in the predator/prey interactions.

Ecosystem-based fisheries management is used to manage krill fisheries in waters surrounding Antarctica. In order to manage the the fishery responsibly, a precautionary, adaptive, long-term strategy was put in place in 1990.[8] This included setting a target biomass for krill at a significantly higher level than is typical (75% of median unfished biomass, as opposed to the 50% normally used), and a limit biomass of 20%.[9] Spatial catch allocations are evaluated by taking into account stock structure, historical catch, and the needs of land-based predators.[10] This population is closely monitored to detect changes in krill population or its dependent predators, and determine whether changes observed are due to fishing or environmental changes. While this system has faced numerous challenges, and is an ongoing work-in-progress, it has demonstrated that ecosystem-based, precautionary management measures for forage species are possible.



[1] DFO 2009. *Policy on New Forage Fisheries.* http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/forage-eng.htm

[2] Pikitch, E., Boersma, P.D., Boyd, I.L., Conover, D.O., Cury, P.,Essington, T., Heppell, S.S., Houde, E.D., Mangel, M., Pauly, D., Plagányi, É., Sainsbury, K., and Steneck, R.S. 2012. Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp. http://www.oceanconservationscience.org/foragefish/files/Little%20Fish,%20Big%20Impact.pdf

[3] Pikitch, E. K., Rountos, K. J., Essington, T. E., Santora, C., Pauly, D., Watson, R., Sumaila, U. R., Boersma, P. D., Boyd, I. L., Conover, D. O., Cury, P., Heppell, S. S., Houde, E. D., Mangel, M., Plagányi, É., Sainsbury, K., Steneck, R. S., Geers, T. M., Gownaris, N. and Munch, S. B. (2014), The global contribution of forage fish to marine fisheries and ecosystems. *Fish and Fisheries*, 15: 43–64. doi: 10.1111/faf.12004

[4] Pikitch, et al 2012.

[5] Pinsky, M. L., O. P. Jensen, D. Ricard, and S. R. Palumbi (2011) Unexpected patterns of fisheries collapse in the world's oceans. *Proceedings of the National Academy of Sciences* 108(20): 8317-8322

[6] Gjøsaeter, H., Tjelmeland, S., and Bogstad, B., 2012. Ecosystem-based management of fish species in the Barents Sea. In: *Global Progress in Ecosystem-Based Fisheries Management*, pp. 333-352

[7] Hjermann, D. Ø., Ottersen, G., and Stenseth, N. C. 2004. Competition among fishermen and fish causes the collapse of Barents Sea capelin. Proceedings of the National Academy of Sciences USA, 101:11679-11684

[8,9,10] Constable, A. J. (2011), Lessons from CCAMLR on the implementation of the ecosystem approach to managing fisheries. *Fish and Fisheries*, 12: 138–151. doi: 10.1111/j.1467-2979.2011.00410.x

CURRENT FORAGE FISH MANAGEMENT IN CANADA

It is clear that conventional fisheries management targets and limits are not conservative enough to protect forage fish populations from collapse or to prevent impacts on other species.[11] Canada has several laws and policies that can and should account for the unique management required for forage fisheries. Under Canada's Ocean Act, the entire ecosystem and the requirements of all stakeholders must be considered in the management of the marine resource and the environment.[12] Canada's Principles of Ecosystem-based Fisheries Management for the Sustainable Fisheries Framework has identified the need for management decisions to take into account all changes in the ecosystem, which can affect the target species, including "the effects of weather and climate, and the interactions of target fish stocks with predators, competitors and prey species".[13] Furthermore, DFO has a "Policy on New Fisheries for Forage Species", launched in 2010 also part of the Sustainable Fisheries Framework. Under this policy, managers are expected to take into account the natural fluctuations of forage species' populations, and consider the impact of the fishery on both the target species and the entire ecosystem while also mitigating bycatch impacts.

Photo: Atle Grimsby (CC BY-SA)

HOWEVER, MANY LIMITATIONS EXIST IN THE CANADA'S MANAGEMENT OF FORAGE FISHERIES, INCLUDING:

- The Policy on New Fisheries for Forage Species does not apply to existing forage fisheries. While existing fisheries were expected to be reviewed against this policy, no such review has occurred, six years after the policy was launched.
- Current policies do not account for predators or large uncertainties in the management of forage fisheries.[14]
- Ecosystem conservation issues that arise from forage fisheries have yet to be incorporated into Integrated Fisheries Management Plans (IFMP). IFMPs are expected to guide the conservation and sustainable use of marine resources in Canada.
- There is no specific national policy that provides guidance on applying an ecosystem approach to fisheries management in Canada.[15]
- Despite being guided by Canada's precautionary framework, many of the key and important forage species do not have defined reference points or reasonable estimates of stock status due to limited data and variable assessment approaches.[16] Many also lack rebuilding plans where populations are depleted.
- While the ecosystem framework provides the foundation for the implementation of the precautionary framework and what to do under a variety of scenarios, current management decisions do not take into consideration the importance or linkages of particular species as forage in the ecosystem.[17]
- Currently, forage fish caught recreationally and for bait are not adequately quantified, monitored or assessed.[18]
- Science advice for some forage fish is based on relative indices or insufficient models and does not provide adequate guidance for management to make responsible, precautionary management decisions.

In Atlantic Canada, herring and mackerel are two key forage species. We provide two case studies – science and management of Scotia-Fundy Atlantic herring and Atlantic Canadian mackerel – to detail fishing history, current catch levels as well as science advice followed by recommendations to better manage and asses these species for the needs of the entire ecosystem.

[11] Pikitch et al 2012.

[12] S. Guénette, G. Melvin, A. Bundy 2014. A review of the ecological role of forage fish and management strategies. Canadian Technical Report of Fisheries and Aquatic Sciences 3065. http://www.dfo-mpo.gc.ca/Library/352141.pdf

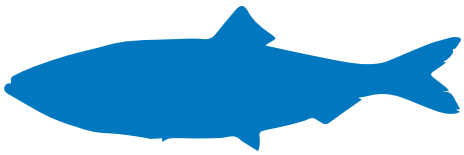
[13] Fisheries and Oceans Canada, *Sustainable Fisheries Framework: Principles of ecosystem-based fisheries management*, http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/ecosys-back-fiche-eng.htm

[14] Guénette et al. 2014.

[15] Fisheries and Oceans Canada, Integrated Fisheries Management Plans, http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/index-eng.htm

[16,17,18] Guénette et al. 2014.

ATLANTIC HERRING *(CLUPEA HARENGUS)*



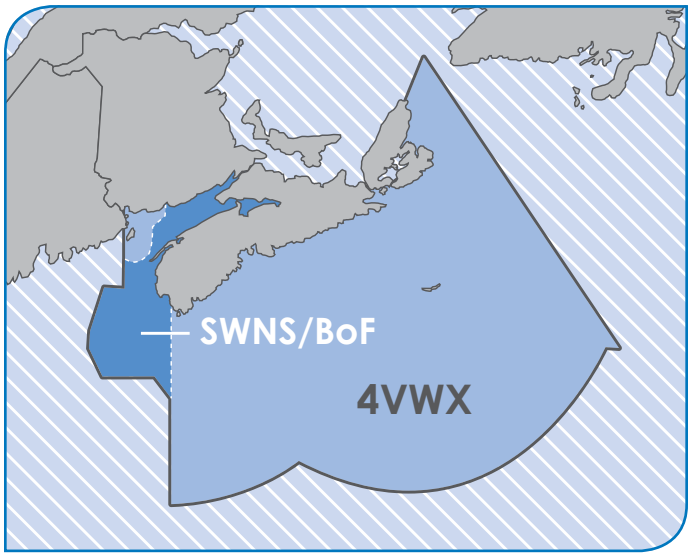
Atlantic herring are small silver fish that grow up to 44 cm in length and inhabit waters on both sides of the North Atlantic. In the Northwest Atlantic, herring are distributed from northern Labrador, south to Cape Hattaras.[19] They are a pelagic species, which means that they spend much of their time in the water column, rather than near or on the seafloor. Herring feed on plankton, smaller fish and larvae, and are able do so by swimming with their mouths open and filtering small food particles from the water.[20] Atlantic herring mature around 3 or 4 years of age, and then begin a pattern of migration for feeding, spawning and overwintering.[21] Herring provide an important food source for larger fish such as cod, tuna and sharks, dolphins and porpoises, whales, seals and seabirds. Herring tend to travel in large, dense schools and spawn in distinct locations – certain stocks of herring are strongly tied to the locations in which they spawn.[22]

Herring populations are known to experience large and sudden changes in abundance from one year to the next and, globally, there have been several instances of herring fisheries collapsing.[23] These include the collapses of the Gulf of Maine-Georges Bank fishery in the 1960s and 70s[24], the North Sea fishery in the mid-late 1900s[25] and the Icelandic summer-spawning herring fishery in the late 1960s.[26] Typically, the stock collapse happens very quickly, usually within a few years, while subsequent recovery has happened much more slowly, often upwards of 10 years.

Due to the complicated nature of herring stocks, which undergo considerable migration and mixing with other spawning populations, as well as the existence of numerous spawning areas, Atlantic Canada's herring fisheries are assessed and managed by dividing the fisheries into four main areas which are the Gulf of St. Lawrence, the west and east coast of Newfoundland, respectively, and the Scotia-Fundy region. These management areas do not represent biological units, but rather spatial management units that relate more closely to the distribution of fisheries. Within the Scotian Fundy Region, also known as area 4VWX, it is further divided into four spawning components: Offshore Scotian Shelf, Coastal Nova Scotia, Southwest New Brunswick, and Southwest Nova Scotia/Bay of Fundy.

SOUTHWEST NOVA SCOTIA BAY OF FUNDY HERRING

The South West Nova Scotia/Bay of Fundy (SWNS/BoF) spawning component of Atlantic herring is of particular interest due to its proximity to the Gulf of Maine, the diversity of the fishery it supports, and the fact that landings in this area are significantly larger than the anywhere else within the 4VWX area.



The status of the herring stock in this area has been of concern for a decade or more – as stock status reports have indicated the need for rebuilding since at least 2001and recovery has not yet occurred.[27] There has also been a trend of declining weight at age – with fish being smaller than historical averages and as a result the population is becoming less productive.[28]

[19] Fisheries Resource Conservation Council (FRCC)2009. *Fishing into the Future – The Herring Fishery in Eastern Canada: A report to the Minister of Fisheries and Oceans*, http://publications.gc.ca/site/eng/354169/publication.html

[20] DFO 2015a *Atlantic Herring Profile* http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/fisheries-peches/herring-hareng-eng.htm (Accessed April 2016).

[21,22] DFO 2015b *Assessment of 4VXW Herring*. Canadian Science Advisory Secretariat. Science Advisory Report 2015/040 http://www.dfo-mpo.gc.ca/csas-sccs/publications/sar-as/2015/2015_040-eng.pdf

[23] FRCC 2009.

[24] Overholtz, W. J. 2002. The Gulf of Maine-Georges Bank Atlantic herring (Clupea harengus): spatial pattern analysis of the collapse and recovery of a large marine fish complex. Fish. Res., **57**:237-254

[25] Dickey-Collas, M., Nash, R.D., Brunel, T., Van Damme, C.J., Marshall, C.T., Payne, M.R., Corten, A., Geffen, A.J., Peck, M.A., Hatfield, E.M. and Hintzen, N.T., 2010. Lessons learned from stock collapse and recovery of North Sea herring: a review. ICES Journal of Marine Science: Journal du Conseil, p.fsq033

[26] Dragesund, O., Johannessen, A. and Ulltang, Ø., 1997. Variation in migration and abundance of norwegian spring spawning herring (Clupea harengus L.). Sarsia, 82(2), pp.97-105.

[27,28] DFO 2015b.

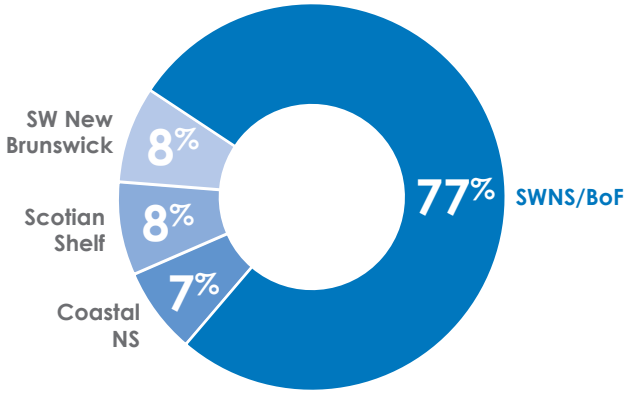
THE FISHERY

As of 2016, the herring fishery continues to use a variety of fishing gear, including several types of fixed gear - weirs, traps, gillnets as well as mobile gear - midwater trawls and purse seines. In recent years, the purse seine has made up the vast majority of the fishery, typically 80-90%.

Catches have fluctuated over time, and have in some cases been well above and in other cases well below the agreed total allowable catch (TAC). In the 1970s and 80s, the average reported landings of Atlantic herring in SWNS/BoF averaged 131,000t, approximately 24% above the agreed TAC of 106,000t. Quotas increased to 112,000t in the 1990s but landings fell to just 96,000t. Since the mid-2000s the TAC has fluctuated between 50,000t and 55,000t, representing a halving of quota since the start of industrial fishing.[29] Landings since that time have been in line with the TAC, with most of the quota, (and occasionally more) being taken each year. Landings in 2013 and 2014 were 46,55t and 50,250t respectively, against a 50,000t TAC.

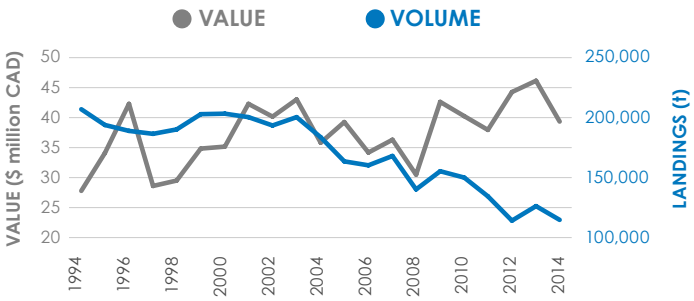
SWNS/BoF landings have comprised between 81 and 92% of total 4VXW landings since 2012 (Figure 1), which makes this an area of particular concern. Prior to this, New Brunswick weirs and shutoff fisheries as well as the Scotian Shelf fisheries were contributing more to total landings, with SWNS/BoF landings contributing to 62-73% of total.[30]

FIGURE 1. Average percentage of total 4VWX landings by spawning component from 2010-2014



In addition to being used directly for human consumption, herring is also used as a reduction fishery – for fish meal and fish oil – and in Nova Scotia has also been used directly for feed in Southwest Nova Scotia mink farms.[31] Herring caught as food is often exported in many different forms – one of the most valuable markets for herring comes from their roe, which is sent to the Japanese market.[32] The landed value of herring has remained relatively steady relatively steady in recent years, with an average value of $41 million dollars (CAD) from 2010-2014 for all of Atlantic Canada (Figure 2), despite declines in catch.

FIGURE 2. Landings by volume and value of Atlantic herring for all Atlantic Canada from 1994-2014



While the direct value of herring only made up about 1.7% of the value of all Atlantic Canada's $2.4 billion fishing industries in 2014[33], herring is also an important source of bait for other fisheries, including lobster, snow crab, bottom longline for groundfish and pelagic longline for tuna and swordfish. The lobster fishery alone makes up 40% of the total value, at $942 million in 2014, with snow crab contributing another 23% or $534 million. As such, the true value of herring extends well beyond its landed value.

The herring bait fishery poses a significant concern, largely because there are nearly 1200 herring bait licence holders in the Scotia-Fundy region alone[34] (this area, broader than the focus of this case study, extends from the northern most tip of Cape Breton south and west to the Maine-New Brunswick border) and there is no TAC to limit the amount of herring caught as bait. These licence holders are not required to report their landings[35], that could account for a large amount of removals beyond what is being measured in the commercial fishery or what is accounted for in the herring stock assessments.

CURRENT CHALLENGES

One of the most pressing issues facing the management of Atlantic Herring is the lack of regulation and monitoring of herring bait fisheries, the magnitude of which are largely unknown. Furthermore, scientists have been unable to estimate the level of fishing mortality on this stock, which means that there is no accurate estimate of fishing impacts on the population. Without proper catch and abundance estimates, it is difficult to accurately determine stock status. Furthermore, scientific assessments do not account for additional mortality caused by predation on herring. Finally, quotas have not been set with consideration to the needs of primary predator species, nor the ecosystem as a whole.

[29,30] DFO 2015b.

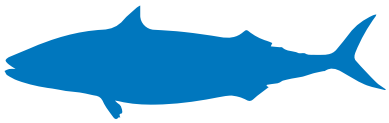
[31] FRCC 2009.

[32] DFO 2015a.

[33] DFO 2015c, Commercial Fisheries Statistics. http://www.dfo-mpo.gc.ca/stats/commercial-eng.htm

[34,35] DFO 2013a. Fisheries and Oceans Canada, Canadian Atlantic Herring (Clupea harengus) SWNS Rebuilding Plan 2013. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/herring-hareng/herring-hareng-2013-eng.htm

ATLANTIC MACKEREL *(SCOMBER SCOMBRUS)*



Atlantic mackerel, like Atlantic herring, are a small, pelagic, schooling fish related to tuna. The underside of the fish is silver, while the upper side shimmers green and blue with irregular dark stripes down the back. Mackerel are distributed across the North Atlantic, also ranging in the Northwest Atlantic from Labrador to Cape Hattaras.[36] Mackerel can grow to be about 40cm in length and weigh up to 800 grams. They can live up to 15 years and typically mature between age 2 or 3. Like herring, mackerel feed on small organisms in the water column and are an important prey species for many larger fish, marine mammals and seabirds.

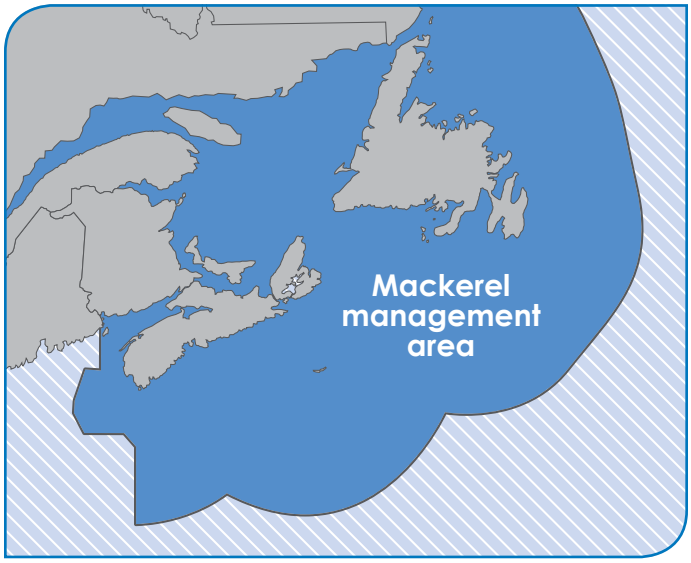
In Atlantic Canada, mackerel are found in inshore waters in the spring and summer, and move to deeper, warmer waters at the edge of the continental shelf in late fall and water.[37] Spawning in this area occurs mostly in the southern Gulf of St. Lawrence in June and July. Mackerel are not always considered a "forage fish" as they feed on plankton as juveniles and feed on smaller fish as adults, but for the purposes of this report they have been included because they fill a similar niche in the ecosystem, are an important species for marine predators and for commercial fisheries.

THE ATLANTIC CANADIAN MACKEREL STOCK

Unlike herring, the management area for Atlantic Canadian mackerel is quite large, and includes the entire Atlantic region; the waters off Quebec, New Brunswick, Prince Edward Island, Newfoundland and Nova Scotia. As such we have used this as our area of overview.

Between 1969 and 1992, fishing mortality on Northwest Atlantic mackerel remained relatively stable, and in 1993 has been increasing quite steadily. A decrease in mortality was observed in 2012 and 2013, following its historical peak in 2011. Increases in fishing mortality were accompanied by declines in spawning stock biomass (SSB) and total biomass, with the lowest biomass of the historical series estimated in 2012 and 2013. This relationship indicates that the stock in critical condition.[38] According to projections based on this data, the SSB for 2015 and 2016 would be 7,532 and 9,045t, for catches of 662t and 821t in 2014 and 2015. These projections also predict that the stock is both overfished and experiencing overfishing.[39]

Egg surveys and analytical assessments, used to determine the population size of the fishery, suggest that the abundance index for this stock in 2012/2013, around the time of the most recent stock assessment, was at its lowest level in the recorded history of the fishery, which began in the late1970s.[40] According to this same assessment, spawning biomass has been declining since the mid 2000s as a result of fishing mortality being several times higher than historic sustainable levels.



THE FISHERY

In Atlantic Canada, mackerel are harvested using a variety of methods including purse seine, trap, weir, handline, gillnet and jig.

Changes in Canada's historical landings of mackerel have been heavily affected by variations in market demand, the invention of new fishing methods such as the purse seine, the expansion of the fishery to new areas, natural fluctuations in year-classes and changes in migration patterns.[41] Atlantic Canadian landings declined between 1880 and 1900, and levelled off at around 10,000t until around 1940. There was a marked increase during World War II, and another decline in the 50s. Strong year classes in the 60s, 70s, and 80s resulted in an increase in landings, followed by another decline in the 90s, but increased quickly between 2000-2006, reaching historic highs, due to a strong year class in 1999 and a significant increase in fishing effort. Since 2006, landings of mackerel have decreased drastically, with 2012 being the lowest landings in recent history at 6,468t. Atlantic Canadian landings in 2014 were 6,540t.[42]

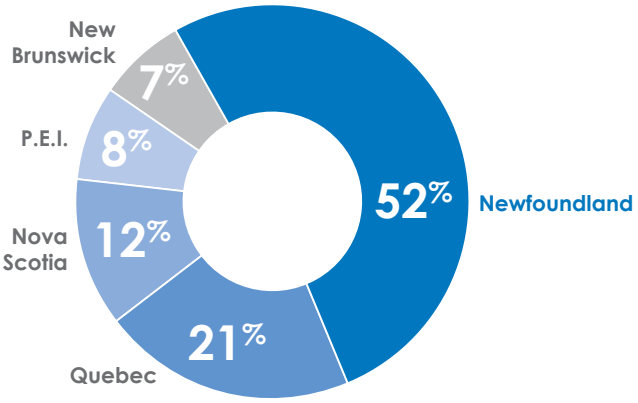
In the waters off Atlantic Canada and Quebec, the Atlantic mackerel fishery currently involves the participation of over 15,000 commercial fishermen. In 2014, the majority of mackerel were landed in NL with 52% of the total 6,450t of Canadian landings. Next highest was Quebec with 21%, NS with 12%, PEI with 8% and NB with 7% (Figure 3).

[36,37,38,39,40] DFO 2014. Assessment of the Atlantic Mackerel Stock for the Northwest Atlantic (Subareas 3 and 4) in 2013. Canadian Science Advisory Secretariat, Science Advisory Report 2014/30 http://www.dfo-mpo.gc.ca/csas-sccs/publications/sar-as/2014/2014_030-eng.pdf

[41] DFO 2007. Integrated Fisheries Management Plan, Atlantic Mackerel effective from 200Z. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/mackerel-atl-maquereau/mac-atl-maq-2007-eng.pdf

[42] DFO 2014.

FIGURE 3. **Atlantic mackerel landings by province.**



The main fishing gear used in this fishery in recent years has been purse seine, with larger seines making up 46.7% of landings, smaller seines with 20.4%, and handlining with 17.4% (Figure 4).

Atlantic Canada's total allowable catch in 2015 for Atlantic Mackerel was set 8,000t. Quotas have decreased dramatically in the last several years due to concerns around population health – the TAC in 2010 was lowered from 75,000t to 40,000t, further reduced to 36,000t in 2012, 10,000 in 2014, and 8,000 in 2015.[43] According to the latest IFMP from 2007 for Atlantic Mackerel, this quota is allocated 40% to purse seiners larger than 65', and 60% to smaller purse seiners, tuck seine and fixed gear such as traps gillnets, lines and weirs.[44] At this time the full quota is not being caught.

While the direct value of mackerel only made up less than 0.2% of the value of all Atlantic Canada's $2.4 billion fishing industries in 2014[45], like herring, mackerel is also an important source of bait for other fisheries, like lobster and snow crab, and so its true value to Atlantic Canada's fisheries overall should not be underestimated. Unlike herring, over the years, the value and volume of mackerel have followed the same trends, with an average value of $9.1 million from 2010-2014 (Figure 5).

FIGURE 4. **Average Atlantic Canadian mackerel landings by gear type between 2011-2014**

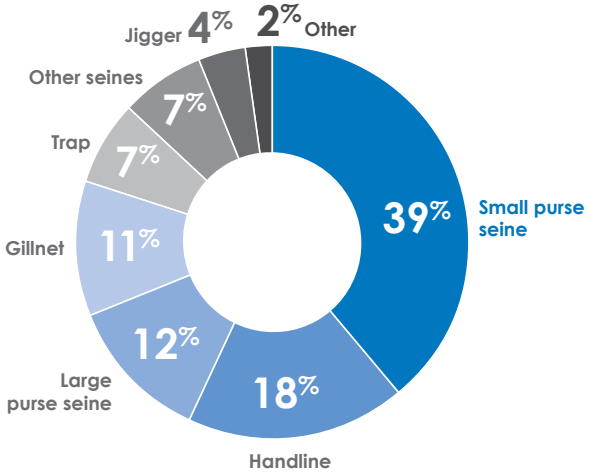
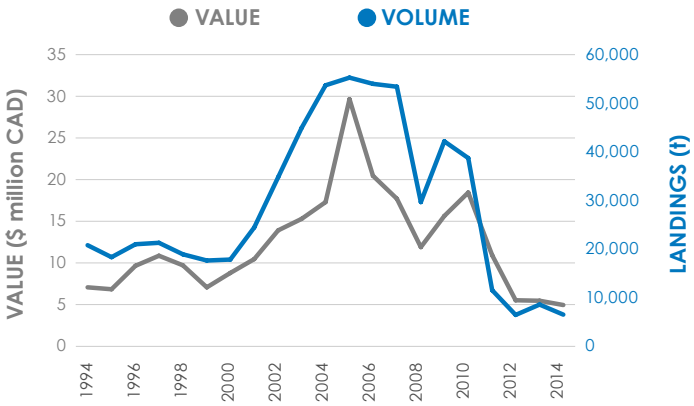


FIGURE 5. **Landings of mackerel by value and tonnes from 1994-2014 in the Atlantic region**



CURRENT CHALLENGES

According to the most recent science advice, released in 2013, catches of Atlantic mackerel should not exceed 800t – landings in 2014 totaled 6394t, 8 times the limit suggested appropriate by science, and the TAC is set at 8000t, which is 10 times this limit.[46] The position of scientists and managers on the discrepancy between the quota recommendation and the TAC is that the 800 tonne recommendation was more of a guideline and a relative figure and there was not confidence that the number was accurate.[47] This is due to the fact that the statistical model used in the assessment did not fit the data well. Currently, no reference points exist for this fishery.

Mackerel catches that are sold directly between fishermen in the commercial fishery are not recorded by the Department of Fisheries and Oceans, and neither are catches from the mackerel bait fishery. In Nova Scotia and New Brunswick, there is also a significant recreational fishery for mackerel, in which there is no limit to catch and catches are not recorded. As a result, the estimates of mackerel catch are considered significantly underestimated. As with herring, without accurate estimates of fishing mortality, accurate estimates of abundance cannot be made and the status or health of the stock cannot be determined with certainty.

[43] DFO 2014.
[44] DFO 2007.
[45] DFO 2015c.
[46] DFO 2014.
[47] Maritimes Mackerel Advisory Committee, 26 Feb 2016.


Photo: Vincent van Zeijst (CC-BY-SA)

CONCLUSIONS

Given the important role forage fish play in the marine ecosystem, and their contribution to Atlantic Canadian fisheries as both target and prey species, as well as bait, action must be taken to ensure the long-term health of forage fish populations in the region. In particular, both herring and mackerel have experienced significant population declines. Both have experienced gaps in the ability of science to accurately or confidently estimate abundance, give strong advice on sustainable catch levels and properly account for environmental conditions and requirements/ effects of predator species. Their populations are also subject to large quantities of removals, for bait or recreation purposes, that are largely unmonitored and unregulated.

Due to the vulnerability of such species to fishing, predation and environmental change, Canada must take concrete steps towards a precautionary and ecosystem-based approach to managing their populations.

Recommendations to Achieve Recovery and Sustainability of Atlantic Canada's Herring and Mackerel Populations

Based on the current shortcomings in Canada's approach to managing forage fish overall as well as the specific needs of Atlantic herring from southwest Nova Scotia/Bay of Fundy and Atlantic mackerel, we recommend that the Department of Fisheries and Oceans (DFO) take the following actions:

- Assess existing forage fisheries against the Policy on New Fisheries for Forage Species to ensure that the policies are met with existing and as well as new fisheries,
- Acquire ecological knowledge of the predator-prey interactions, predator needs, environmental factors that allows a broader perspective and can better explain or predict sudden changes,
- Implement an ecosystem based approach, that accounts for predation, predator needs and other dependant fisheries in setting quotas for forage fish,
- Develop data sources outside of the fishery to use in assessing the stock,
- Develop reference points that include forage species' role in the ecosystem, including the needs of predators and take into consideration effects changing environmental conditions on stock estimates,
- Increase capacity to monitor fisheries/abundance by:
  - Quantifying natural mortality,
  - Quantifying mortality from recreational and bait fisheries,
  - Increasing knowledge of trophic interactions (predator/prey), and
  - Exploring issues with using Cath Per Unit Effort (CPUE) to quantify abundance for fish that aggregate in large schools regardless of abundance.
- Implement a catch monitoring system for recreational and bait fisheries, and implement catch control measures in these fisheries.

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