Study of the small pelagic fisheries for Atlantic herring and Atlantic mackerel on the west coast of Newfoundland (NAFO Division 4R)

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Summary

Small pelagic fish species play a key role in marine ecosystems as important forage species and are also an important contributor to food security and commercial aquaculture production. In eastern Canada, a great deal of attention has been paid to the collapse of multiple groundfish stocks in the early 1990s, and to their largely stalled recovery 20 years later. Less attention has been directed to the catastrophic decline of Atlantic herring (Clupea harengus harengus) populations in the 1960s or to the current weak stock status of many small pelagic stocks in the region.

The need to shift to ecosystem based fisheries management has long been stressed and it is clear that this shift requires active collaboration between harvesters, resource management and scientists. However, most fisheries resources in Canada and elsewhere are managed sector by sector in a single species approach. This research applied a social-ecological mixed methods approach to improve understanding of the multifaceted small pelagic fisheries along western Newfoundland. In particular we asked: i) how the knowledge of fishermen and scientists relates to current management practices in the area; ii) what the factors are that determine fishers' behavior and iii) what the social-ecological consequences of fishing behavior are against the background of current management practices.

In western Newfoundland (NAFO division 4R) fishing for small pelagic species is part of a complex multi-species, multi-gear fishery. Fishers on the west coast of Newfoundland have historically caught small pelagic fish using multiple gear types including traps, gillnets and purse-seines, but more recently traditional gears are used by fewer and fewer harvesters and in 2011, only 20% of fixed gear licenses were active. Of those that were active, roughly 18% were using tuck seines, which are actually a form of purse-seine. Thus there are three fleets using purse-seines: large company owned seiners in the over 65 foot category, smaller privately owned purse-seiners in the under 65 foot category and so called tuck seiners in the under 45 foot category. Purse-seine fishers catch herring in the spring, followed by capelin, and then mackerel and herring in the fall. In addition local fishermen use stationary mackerel and herring traps, gillnets, or jig for mackerel using handlines. Historically herring landings used to be dominant but more recently mackerel have become important. Although largely the same participants are involved in each case, management of the fishery is based on a species specific, sectoral approach that assigns different quota regimes and fishing areas to each fleet sector depending on the targeted species. This stovepipe approach to fisheries management treats these fisheries as temporally and spatially distinct and ignores any interaction between them. A social-ecological lens brings to the surface the social and economic connections that lead effects across fisheries and target species.

The total allowable catch (TAC) for herring in 4R was set at 20,000 metric tons in 2012. Large seiners catching herring are regulated via an individual transferable quota (ITQ) system, the small seiners have individual non-transferable quotas

(IQs) and the fixed gear sector, including tuck seines, operate under a competitive regime. The Atlantic wide TAC for mackerel was set at 200,000 tonnes between 1987 and 2000, equally divided between the USA and Canada. In 2012 the Canadian portion of the TAC was set at 36,000 tonnes, which was 4 times the Canadian scientific recommendation. The Canadian mackerel fishery is competitive and no quotas or caps are set.

How does the knowledge of fishermen and scientists relate to current management practices?

There is strong evidence that both herring and mackerel stocks are declining. While fishing capacity has increased, DFO research capacity is limited. Acoustic surveys along the west coast have been intermittent. During the 1970s, both herring and mackerel were fished heavily by foreign fleets. After implementation of the exclusive economic zone an agreement between the USA and the USSR led to increased foreign landings of mackerel in the 1980s. In 1992 the foreign fleet fishery was closed. Since then mackerel catches in area 4R have increased in proportion to other areas and since 2007 have accounted for the majority of Canadian mackerel landings.

Herring stock structure

In 4R, two herring stocks are defined temporally, based on the time of year that spawning takes place. Nonetheless, a single total allowable catch (TAC) is set annually. The spring spawning stock has declined to the extent that catches are now predominantly composed of fall spawning herring.

DFO commercial landings data for western Newfoundland and harvester opinion expressed during interviews agree that the main spring spawning ground has been subject to severe fishing pressures in the past, which resulted in the overfishing of the spring spawning stock in Bay St George. Because this stock has never recovered in spite of management measures, it has been suggested that environmental factors such as water temperature may have caused 4R herring to shift from spring spawning to fall spawning. However, this explanation implies that 4R herring are one single stock and exhibit population dynamics that are different from herring elsewhere in Atlantic Canada. A more reasonable explanation is that as spring and fall spawning have been observed on the west coast, these stocks are separate and the spring spawning stock has been overfished.

While management measures have focused on Bay St. George and Port au Port Bay as the primary spawning grounds, less attention has been given to other spawning grounds. However, during interviews harvesters, local residents and other key informants report that spring spawning has been observed in other areas. In addition fall spawning of herring has been observed in the same areas that are associated with spring spawning events. In the absence of dedicated tagging projects there is no knowledge about the movement of spring spawners throughout the year. The lack of attention given to protecting other spawning aggregations of spring spawning herring may have contributed to the erosion of

these subpopulations and consequent loss of genetic biodiversity, which may be further hindering the recovery of the spring spawning stock.

The scientifically recommended spatial management measures were eroded based on short term views regarding spring spawning stock recovery that were not supported by data time series on herring caught in the spring bait fishery. This fishery in Bay St George and Port au Port Bay takes place during the lobster fishery and involves between 200-300 fixed gear harvesters and an annual allocation of 2,000 tonnes of herring. Logbook data are the only potential source of data from this fishery. But, although logbooks are mandatory, few logbooks are returned. Thus no catch rates are calculated for the fixed gear sector in either spring or fall and scientific data for use in abundance estimates of the spring spawning stock is limited making it difficult to establish trends.

Despite this source of uncertainty, current catch levels in 4R (20,000 tonnes) are approaching those of peak exploitation levels in the past (27,000 tonnes) and, as catches are now dominated by fall spawners, are concentrated on only one of the two spawning stocks.

Mackerel stock structure

Two spawning stocks of mackerel are recognized in the North Atlantic, one associated with the Gulf of St Lawrence, the other with the waters off the US coast. The northward spring migration of the northern stock usually ends in late July. The southward fall migration usually starts in September and is targeted by harvesters along western Newfoundland.

During interviews harvesters expressed concern about the mackerel stock, referring to a recent downward trend in catches and a delayed fall migration. Environmental variability and changes in the temperature regime may be playing a role in influencing mackerel migration and abundance, but the single most important factor seems to be catch levels and a TAC that is set far above scientific recommendations.

There seem to be contestations among harvesters as well as between scientists and harvesters regarding whether there is one body of mackerel in the Gulf or several. A younger harvester also expressed concern that if there is indeed one distinct body of mackerel that is targeted by the local fishery then the fishing pressure might be too hard.

Industry participation

Annual advisory meetings with the industry, including representatives of the fishing fleets and the processing sector, provide the only common forum for stakeholders to raise issues and discuss problems. Dominant participants can misuse this common approach to stakeholder involvement as a platform to assert their influence. Although stakeholder representation in the 4R herring co-management committee is aimed at equal participation it allows representatives of the processing and large seiner fleet sector to align their interest against those of the other fleet sectors.

Past collaboration between scientists and fixed gear harvesters was discontinued due to lack of DFO capacity and lack of participation by the harvesters. Recent scientific collaboration with industry has taken the form of larval surveys funded by Barry Group Inc., one of the main processing companies, which also operates large purse-seiners in the area.

Focusing on information from seiners alone, ignores the fact that fixed gear harvesters can potentially provide highly pertinent information regarding the spawning grounds of herring. Fixed gear harvesters are more likely to observe this than seiners because their gear stays in the water at a fixed location for several weeks and is often set at those same locations in several seasons. The greater mobility of the purse-seiners enables them to follow the fish, which can easily mask spatial changes in the distribution of spawning herring that could be an indication of the erosion of local spawning aggregations.

In contrast to the management approach in 4R, in the Bay of Fundy (NAFO division 4X), the individual spawning stocks are defined spatially linking each spawning stock component to a particular location and catch limits are set for each stock. Each individual spawning area is surveyed with active participation by the local fishing fleet and catch limits are set at the level of each area. This resource intensive research has been made possible through collaborations between fisheries scientists and industry, including mobile and fixed gear sectors.

It seems that an innovative approach of this kind would be useful for the 4R herring fishery. However, development and implementation seem impossible because the team responsible for the assessment of 4R herring is understaffed and has to address four fisheries.

What are the factors that determine fishers' behavior?

The 4R mackerel fishery has benefitted from high abundance of mackerel in recent years. This abundance coupled with an increase in mackerel value and the absence of local catch limits have made this fishery the most profitable of the small pelagic fisheries in this area.

As a consequence there has been a dramatic increase in small pelagic fishing capacity in 4R. The majority of mackerel landings are caught by purse-seines. Local harvesters started to use high frequency sonars in the late 1980s and early 1990s. With a growing interest in mackerel more and more harvesters invested in this technology.

Since the early 2000s a new type of gear has appeared in the fixed gear fleet, the so-called "tuck seiner". For fixed gear harvesters who use tuck seines, the mackerel fishery is the longest fishery in their annual cycle. In addition harvesters in the under 65 foot seiner fleet have invested in larger boats that can catch more fish per trip and in new fish finding equipment. Thus although the number of mackerel licenses hasn't changed, harvesting capacity has increased substantially.

Harvesters concentrate on catching as much mackerel as they can while the fish are available, and postpone the herring fishery. Thus purse-seine effort is concentrated on the southern bays. Acoustic survey results suggest that herring in the northern part are unavailable to the purse-seine fleet. However, harvesters from the northern area make an economic argument for catching the higher valued mackerel first and concentrating effort on the southern bays. Because mackerel is a competitive fishery and the mackerel are only available for a limited time, the highly mobile purse-seiners follow the mackerel shoals south along the coast as far as they are permitted. They then catch their herring quotas in the southern bays before they return home.

Thus, contrary to the scientific recommendation to disperse fishing effort on herring to prevent uneven pressure on the spring spawning component, fishing effort is concentrated on the southern bays, further eroding any protection of the spring spawning stock.

What are the social-ecological consequences of fishing behavior against the background of current management practices?

Since the mackerel fishery is a competitive fishery, harvesters will catch as much fish as quickly as they can. Since mackerel tend to turn into a "dead weight" soon after they are caught, the likelihood of bursting nets seems to be higher in this fishery. The practice of transporting surplus fish in the seines is highly questionable: not only is dragging a heavy weight alongside the vessel dangerous for vessel and crew, there is also the risk of breaking the seine which means that the catch is lost to the harvesters. Moreover, the lost fish will not be reported, thus contributing to uncertainty around fishing mortality.

Interview results suggest a high likelihood of pulse fishing, i.e. large numbers of vessels fishing simultaneously in the same bay both while targeting mackerel and also during the herring fishery. Several harvesters suggested that this practice of pulse fishing has negatively affected the availability of mackerel in Bonne Bay. Another issue arising from competitive fisheries that target aggregations of fish is that of safety when boats fish in close proximity to each other.

For fishers operating in the mobile gear sector, vessels have become larger while individual quotas have remained the same. As a consequence some successful harvesters who have the financial means to do so, have increased their individual quota by obtaining additional licenses. The number of licenses in the fixed gear fleet has not changed but as many have changed to tuck seining there is now a highly efficient and mobile gear being used within that fleet that is contributing to increased landings. Many of the smaller seiners, both under 65 foot purse-seiners as well as some tuck seiners, expressed concern about the increasing number of participants in the purse-seine fishery, which is created by fixed gear harvesters changing to tuck seining, and the absence of catch limits.

Introduction

Small pelagic fish species play a key role in marine ecosystems as important forage species for marine mammals, birds and other fish; they are also an important contributor to food security and to commercial aquaculture production. Stocks are under pressure in many parts of the world from the effects of past and present overfishing as well as the impacts of climate change (Nayler et al 2000, Melvin et al 2009, Barange et al 2009). The rapid expansion of intensive aquaculture of carnivorous species in recent decades has contributed to strong global demand for small pelagics, which contribute up to 50% of global annual landings (Fréon et al 2005). In eastern Canada, a great deal of attention has been paid to the collapse of multiple groundfish stocks in the early 1990s, and to their largely stalled recovery 20 years later. Less attention has been directed to the catastrophic collapse of Atlantic herring (Clupea harengus harengus) populations in the 1960s or to the current weak stock status of many small pelagic stocks in the region (DFO 2012, DFO 2011) that are the prey species for cod and other groundfish (FRCC 2009).

In western Newfoundland (NAFO division 4R) fishing for small pelagic species is part of a complex multi-species, multi-gear fishery. Large company-owned purse-seiners fish in the Northern part of the west coast of Newfoundland including Bonne Bay, while smaller, privately owned purse-seine vessels come to Bonne Bay from further up the coast. In addition local fishermen use stationary mackerel and herring traps, gillnets, or jig for mackerel using handlines.

Although there are two herring stocks in 4R, a single total allowable catch (TAC) is set annually. In contrast, in the Bay of Fundy (NAFO division 4X), each individual spawning area is surveyed with active participation by the local fishing fleet and catch limits are set at the level of each area (Stephenson et al 1999). This contrast in the management approaches raises the question why there are different management approaches being used for herring fisheries in Atlantic Canada.

The need to shift to ecosystem based fisheries management has long been stressed (Ommer et al 2012) and it is now clear that this shift requires active collaboration between harvesters, resource management and scientists (e.g. Armitage et al 2009). Nonetheless most fisheries resources in Canada and elsewhere are managed sector by sector in a single species “stovepipe” approach (Pinkerton 2007).

This research applied a social-ecological lens to improve understanding of the multifaceted small pelagic fisheries along western Newfoundland. In particular we asked i) how the knowledge of fishermen and scientists relates to current management practices in the area; ii) what the factors are that determine fishers’ behavior and iii) what the social-ecological consequences of fishing behavior are against the background of current management practices.

Social-ecological analysis recognizes that human activities and marine ecologies are iteratively inter-dependent, meaning that people not only influence

environmental conditions but are also vulnerable to such change (Ommer 2007). There is a growing body of literature supporting the notion of local fisheries as integrated social-ecological systems (Ommer 2007, Perry et al. 2010, Murray et al. 2008). The economic aspects of fisheries are linked to the ecological and social conditions in which these fisheries operate. Because most social-environmental issues are complex and often hard to define or fix it has been argued that fisheries and coastal governance together constitute "wicked" problems (Jentoft and Chuenpagdee 2009), and as such require clumsy solutions that include working closely with stakeholders, integrating their knowledge and diverse perspectives and addressing power relations (Khan and Neis 2010). To understand the complexities that are involved it is important to look at how different factors interact on different levels. With funding from a Robin Rigby Trust grant from Saint Mary's University and additional support from University of Cape Town an exploratory mixed-methods social-ecological research project was conducted in Newfoundland in the fall of 2011. The funding paid for travel, three months of fieldwork, and research dissemination but much of the data analysis work and the development of this report were done on a volunteer basis. For that reason, although the study collected data on three fisheries, i.e. herring, mackerel and capelin, only herring and mackerel data have to date been analyzed and are included in this report. The results are presented and discussed in three sections: i) herring ii) mackerel and iii) interactions between the herring and mackerel fisheries.

Method

This research is a case study. Fieldwork was conducted during the period from 16 July to 14 October 2011, in St John's (NL), St Andrews (NB) and in several communities along the west coast of Newfoundland (Figure 1). Katherine Rundquist, a conservation corps intern provided research assistance.

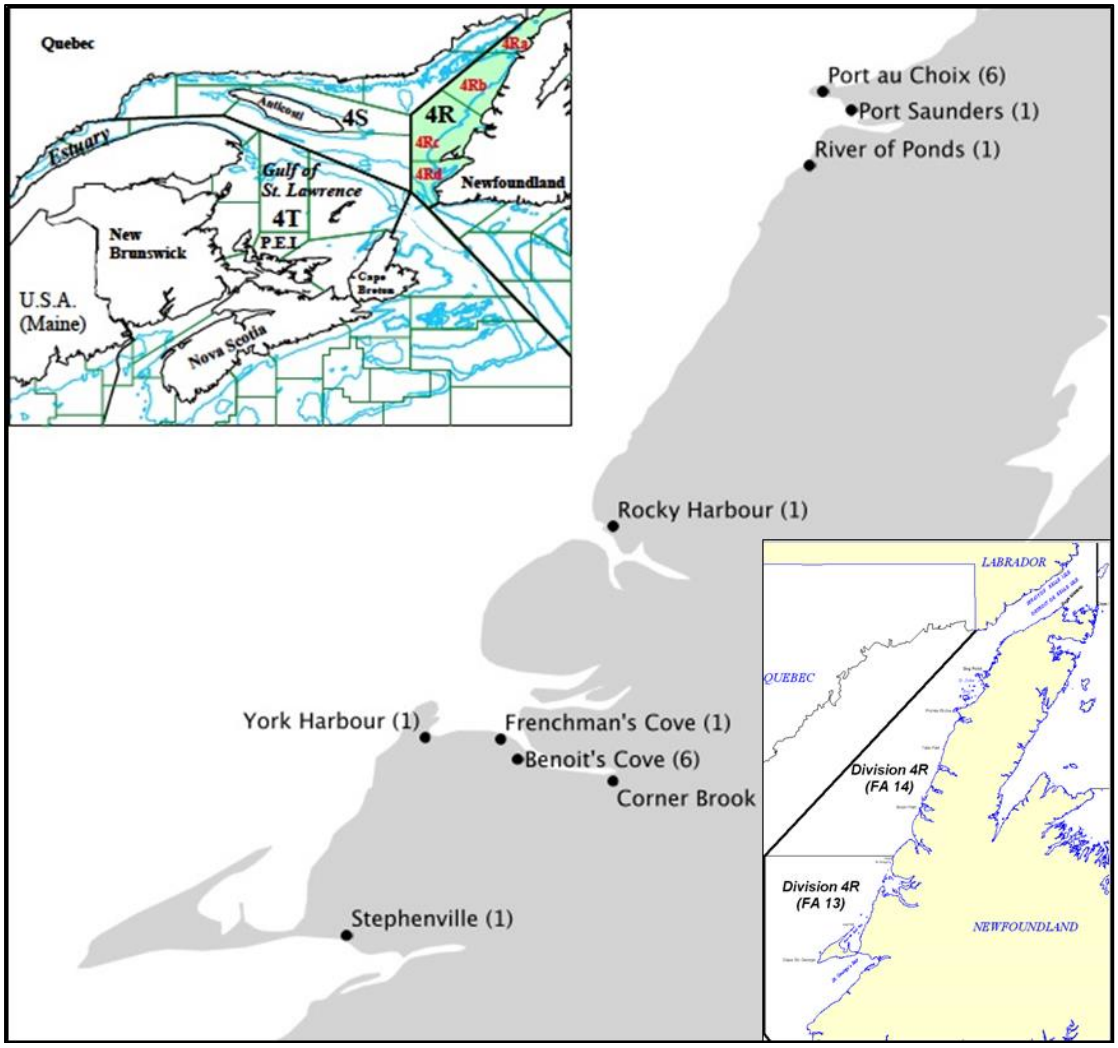


Figure 1 Study area and number of interviews with fish harvesters per community. The insert shows the management units in the Gulf of Saint Lawrence, source: DFO Stock Status report 2003b

Landings Data

The herring stocks of the west coast of Newfoundland are managed in terms of NAFO division 4R, which is further divided into four unit areas (Figure 1 insert top left) and two fishing areas (FA) FA 13 and FA 14 (Figure 1 insert bottom right). Landings data for 4R were retrieved from the NAFO Annual Fisheries Statistics Database (STATLANT 21), fisheries statistics Canada, and DFO regional fisheries statistics (http://www.dfo-mpo.gc.ca/stats/stats-eng.htm). Data on the value of landings were retrieved from DFO regional fisheries statistics. These data were processed in Excel. Landings and fishers' data were imported into, and graphed in, Microsoft Excel 2010. In order to put these data into context, I consulted DFO stock status reports. I also examined the peer-reviewed literature on Atlantic Herring and relevant DFO reports on small pelagic fisheries.

Interviews

In order to supplement the available data I conducted semi-structured career history interviews with 18 local fish harvesters, 15 active and three retired. In addition key informant interviews were conducted with DFO representatives, a fish processor, union representatives and university researchers (Table 1).

Table 1 Research participants and their affiliations

Number	Affiliation	Locality where based
18	Fish harvesters	Rocky Harbour, Port Saunders, Port au Choix, York Harbour, Benoit's Cove, Stephenville, Frenchman's Cove;
5	DFO scientists	St John's (NL); St Andrews (NB); Mont-Joli (Qc);
3	DFO manager	Corner Brook (NL); St John's (NL);
1	DFO Compliance	Corner Brook (NL)
1	DFO Economist	St John's
1	Processor	West Coast
1	Dock Side FRC monitoring	Port au Choix
1	Professional Fish Harvesters Licensing Board	St John's
2	FFAW	Corner Brook (NL); St John's (NL)
3	MUN Dept. of Biology; MUN Ocean Sciences Center; MUN, Dept. of History	St John's (NL)

Fieldwork took place from mid-July to mid-October, 2011. A snowball sampling method was used and potential participants were identified based on recommendations from other informants. Initial recommendations were sought from researchers who had previously worked in the area and from representatives of the Fish Food and Allied Workers Union (FAAW). During the interviews participants were asked to recommend further participants. Potential participants were approached either directly or through initial telephone calls. During the first meeting, an information sheet was given to participants providing information about the research and indicating what questions would be asked and why. Every participant was asked to sign a consent form, which was signed by both the participant and the researcher. The research was given full ethics clearance in accordance with the Tri-Council Policy Statement on Ethical Conduct for Research involving Humans (TCPS2) by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) of Memorial University of Newfoundland.

We mostly interviewed currently active harvesters during the harvesting season for mackerel at the time when they were busy preparing their vessels. Most of the interviews took place on board the vessels with fishers who were hoping to go to sea the same day. We started the interview with demographic questions, followed by questions regarding the vessel history and finally asked about fishing areas and observations regarding the spawning and migration of the three fish species, herring, capelin and mackerel that were the focus of the study using electronic as well as paper charts (depending on the participant's preference and the availability of the charts) to record spatial information (See appendices 1-3 for the interview protocols). Doing the chart work last allowed us to use vessel history information to elicit changes over time in fishing locations.

In addition, I visited St Andrews Biological Station to gain a better understanding of the different management approach used for the Bay of Fundy Herring fishery.

Gears and fleet sectors

The different gears employed by harvesters require different vessels ranging from simple skiffs to sophisticated 100ft long purse-seine vessels. For management purposes DFO distinguishes three fleets. Two fleets fall within the mobile sector: large seiners in the over 65 foot category and small seiners in the under 65 foot category. The third fleet is part of the fixed gear sector. In practice the fixed gear sector is further divided into tuck seiners (a modified bar seine) and small boat fishers, using handlines, gillnets or traps. Gillnets and traps are anchored at a fixed location, but can be moved from one location to another. Over the last six years the use of tuck seines has become increasingly popular among fixed gear license holders.

Most gillnet and trap fishers use small 25'-27' long wooden or fiberglass boats with 130 hp engines. These open boats may or may not have a wheelhouse and can load about 8,000 pounds of fish. The harvesters use echo-sounders, GPS and laptop computers for navigation and fish finding. Tuck seine gear is operated from a larger vessel between 45 and 65 feet in length which is equipped with a power block and pumps to load and offload the fish and a 200-380 hp engine depending on the size of the vessel. These vessels can carry from 40,000 to 110,000 pound loads. A tuck seine is a slightly smaller purse-seine which is considered to be a fixed gear within the current management regime.

The small purse-seiners that are operated under the mobile gear license are between 45 and 65 feet long and can carry between 120,000 and 250,000 pound loads. Their engine power ranges from 430 to 620 hp. The large purse-seiners are over 100' long with much stronger engines and greater loading capacity (Table 2).

Table 2 Vessel sizes, loading capacity, engine power and gears in the 4R small pelagic fishery

Type	**Fixed gear**		**Mobile gear**	
Length (ft)	25-27'	45-65'	45-65'	113'
Capacity (p)	8,000	40,000-110,000	120,000-250,000	815,000
Engine (hp)	130	200-380	430-620	1,000
Gear	Gillnet, trap, handline, mechanical reel;	Tuck seine fitted with rings, equivalent to purse-seine; power block, winch.	Purse-seine; power block, winch.	Purse-seine; power block, winch.

The three different fleets operate under different management regimes, which affect the size of the fishing area, and, in the case of herring, the quota share (DFO 2007a; DFO 2010a).

Participants

Most of the harvesters who participated in our study come from families that have been involved in fishing or the processing of fish on the west coast of Newfoundland for more than three generations. Some of these fishers employ methods for catching herring, capelin and mackerel that are associated with traditional inshore and small boats fisheries, such as traps, hand-lines and gillnets. But most of the harvesters we interviewed catch small pelagic fish using purse-seines and larger boats in the 40-65 foot category, with two of the interviewed harvesters fishing on vessels that are more than 100 foot long.

Participating harvesters are engaged in different fleet sectors and use different fishing gear (Table 3). They are also based in different fishing communities. We tried to arrive at a sample that included both fixed and mobile license holders, and was distributed throughout the entire study area. However, the snowball sampling method resulted in a sample with relatively large proportions from the area around Port au Choix and the Bay of Islands. This is linked to the fact that the major part of the purse-seine fishing fleet is based in these two areas. Only one large seiner is based in Bonne Bay, at Woody Point. We identified two crews of trap fishermen in Bonne Bay. However, only one crew was active during the research period and only one trap fisher was willing to be interviewed.

Besides five large, corporate-owned seiners, the purse-seine fleet mostly consists of owner-operator fishing enterprises using boats that are under 65 feet long. These boats have a crew of five or six people, who are mostly family members and almost always members from the local community (one boat is crewed by a father and his five sons and one grandson). Kinship relations also exist between boats and across fleet sectors. A harvester working on a privately owned purse-seiner in the under 65 foot category may have a cousin who works on a large company-owned seiner. Similarly, the skipper of a 64 foot mobile seiner may have a brother in law who handlines for mackerel or a cousin who owns a fixed gear enterprise and operates a 45 foot tuck seiner.

During our field research it was not uncommon for us to speak to several members of one family or to be referred to the same person several times. As was pointed out to us by harvesters, very close kinship relations exist within the communities on the west coast of Newfoundland and these kinship relations are reflected in the fishing fleet. In most cases the wives of the harvesters we interviewed are also involved in the fisheries in that many take care of the "book work" for the enterprise, some go fishing with their husbands (one as 2nd skipper), and some work or have worked in the local fish plants.

There is a possibility that we fell into a "sector trap" by dividing potential participants into DFO defined fisheries sectors according to vessel category and licensing (mobile vs. fixed). The kinship ties that exist across these sector categories imply that these divisions are artificial and do not match the realities of the local fishing communities. On the other hand the purse-seiners are clearly prospering while fewer and fewer fixed gear harvesters are participating in the fishery.

Table 3 Number of harvesters by license type, gear type and vessel category

number of harvesters	type of license	gear type	vessel category	Communities
1	fixed	Trap	<45'	Rocky Harbour
5	fixed	tuck seine	<45'	Port Saunders, Port au Choix, York Harbour
1	fixed	gillnet & handline	<45'	Port au Choix
8	mobile	purse-seine	<65'	Benoit's Cove, Port au Choix, Stephenville
3	mobile	purse-seine	>85'	Frenchman's Cove, Benoit's Cove
18				

We were able to contact 5 of the 6 active large purse-seine skippers and one retired skipper, but only 3 agreed to be interviewed. In the fixed gear sector we contacted 14 people, and interviewed 7. Many of the fixed gear harvesters could either not be reached, were unable to meet with us, or simply refused to be interviewed.

Most of the harvesters (11) operate in the mobile gear sector and use purse seining to catch small pelagic fish; two of them are currently employed as skippers of large (over 85 foot), company-owned seining vessels and one is a retired skipper who used to work in the large seiner sector. The remaining mobile gear harvesters either own or work on owner operated, under 65 foot vessels, rigged for seining. We also interviewed six harvesters who operate under fixed gear licenses, one uses inshore traps and another uses gillnets and handlines to catch small pelagic fish. The remaining five use a tuck seine. All harvesters we interviewed target capelin, mackerel and herring, with the exception of the gillnetter/handliner who does not fish for capelin. All fixed gear harvesters and some of the under 65 foot seiners target other species besides capelin, herring and mackerel.

Of the 18 fish harvesters who participated in this study, four were under 40 years of age, 11 were between 41 and 65 years of age, and three were older than 65. The youngest participant was 29; the oldest was 82. Fishing experience ranged between 10 and 71 years and most of them had between 10 and 40 years of experience fishing small pelagic fish (Table 4).

Table 4 Fishing experience of harvesters who participated in the study

	< 10 years	10-20 years	21-40 years	> 40 years
Fishing experience general	1	2	7	8
Fishing experience small pelagic	3	6	7	2

The various interview schedules are included in Appendix 1.
Everybody we spoke with in the course of this study was helpful and supportive. The harvesters in particular were very generous with both their time and in sharing their knowledge and experience. Of the 3 processors who buy and process capelin, herring and mackerel in the study area, only two agreed to meet us and in the end only one was able to meet with us.

Data collection and management

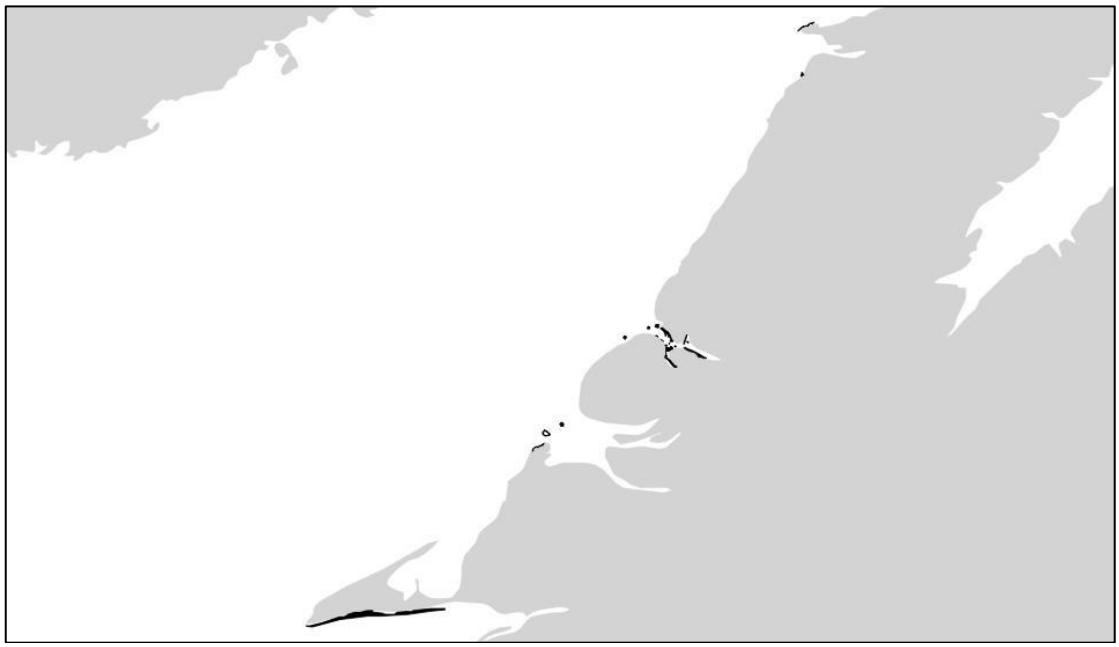
All interviews were audio recorded and transcribed where consent was given for digital audio recording, or hand recorded where it was not. Copies of the audio recordings were returned to those participants who had requested a copy of their interview. The contents of the interviews were organized and prepared for analysis in various ways. Notes and transcriptions were coded and analysed qualitatively using TAMS Analyzer 4.13b. Quantitative data such as demographic data, vessel characteristics, gear type and effort data was organized into Excel spread sheets. Spatial information was recorded on charts (Table 5) and has

been organized using GIS (Figure 2) for further analysis. Both electronic and paper charts were used during the interviews.

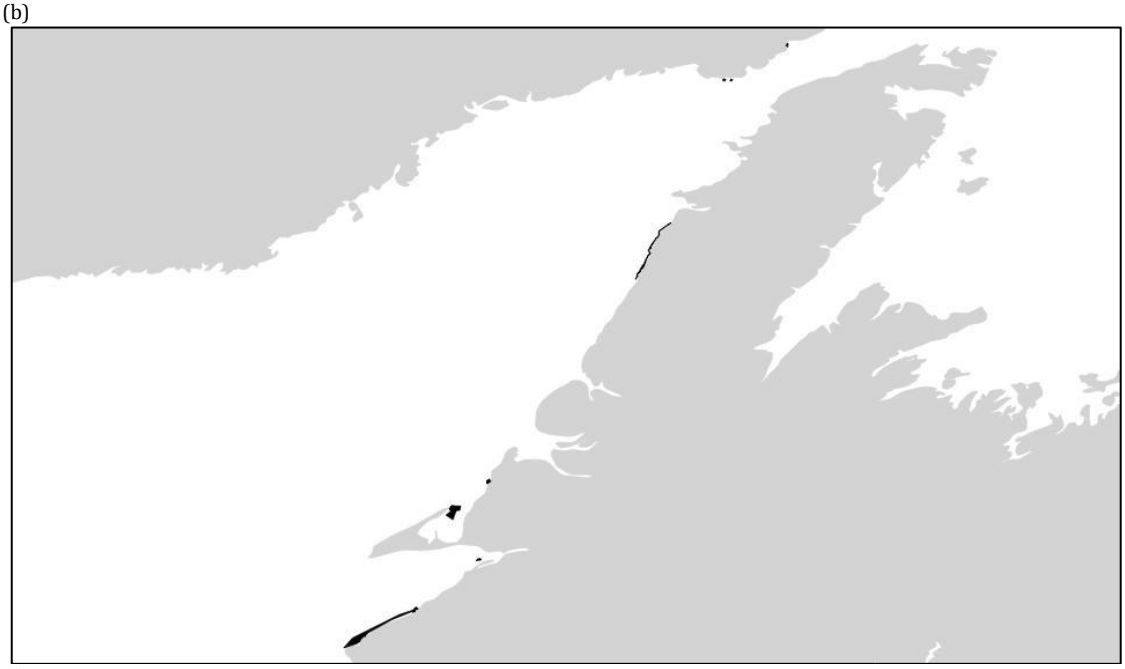
Table 5 Area covered and scale of nautical charts used during interviews. All charts published by DFO

Area	Chart no	Scale	Type
Bay of Islands	4653	1:50,000	paper & electronic
Bear Head to Cow Head	4661	1:146,000	paper & electronic
Cow Head to Point Riche	4663	1:145920	paper & electronic
Port au Port	4659	1:43,500	paper & electronic
Strait of Belle Isle	4020	1:150,000	paper & electronic
Bonne Bay	4658	1:40,000	paper
Cabot Strait/Port au Port	4022	1:340,000	paper & electronic

(a)



(b)



(c)

Figure 2 GIS data indicating fishing areas marked in black for (a) herring, (b) mackerel and (c) capelin reported by harvesters during interviews

Results and Discussion

Herring

Biological characteristics of the 4R Herring stocks

Herring (*Clupea harengus harengus*) are small pelagic fish that prefer cold waters. In Canadian waters, the distribution of Atlantic herring extends from Georges Bank and the Nova Scotia coast to Newfoundland and Labrador (DFO 2010a). Herring undergo extensive migrations between spawning grounds, feeding grounds, and over wintering areas (ibid). Herring stocks are not

homogenous, but have a complex population structure and are commonly referred to as “stock complexes” that are made up of several discrete subpopulations, which may mix at various times during their life history (Stephenson et al. 2009).
Herring in the western Atlantic are managed as several stock complexes according to NAFO management divisions (Figure 3). There is general agreement that all divisions contain complex populations, with several discrete subpopulations, but the attention paid to subpopulation integrity, especially at small spatial scales varies between divisions and authorities (Stephenson et al. 2009).

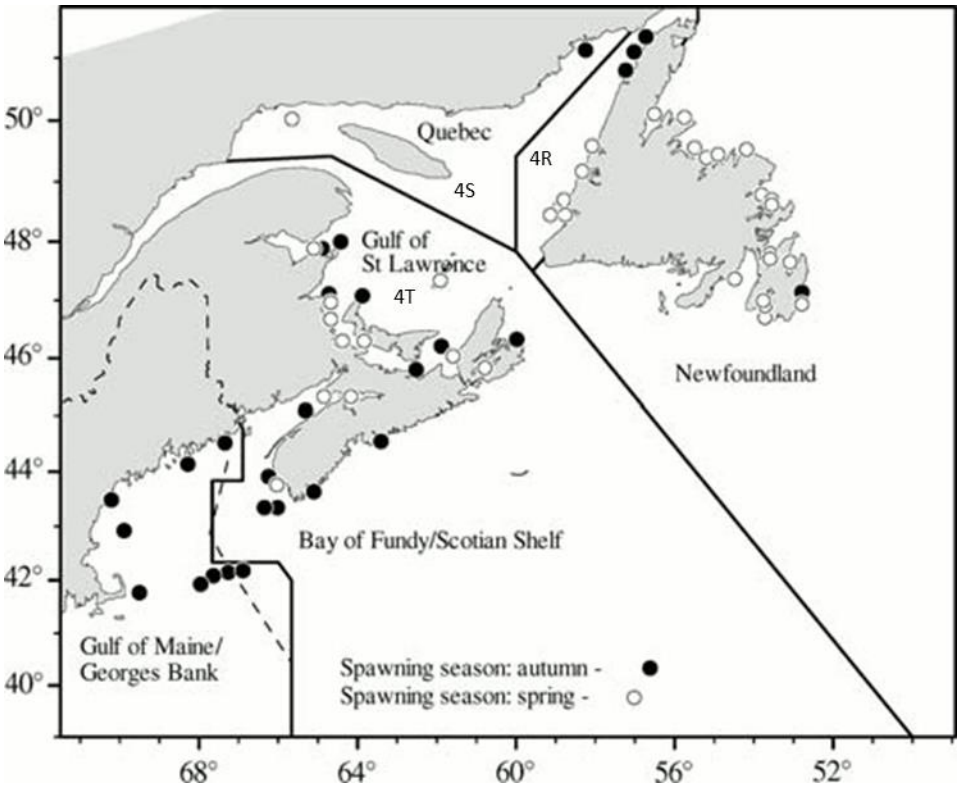


Figure 3 Spawning areas and seasons (dots autumn; open circles, spring), and NAFO Divisions used for herring in the western Atlantic (source Stephenson et al. 2009)

The 4R herring scientists and managers distinguish two stocks of herring, which they refer to as the spring spawning and the fall spawning stocks (DFO 2010a). These categories serve to separate herring that spawn during April-May (spring spawners) from herring that spawn during August-Sept (fall spawners). DFO analyses catch samples from various landing sites and identifies spring spawners and fall spawners based on otoliths and gonad analysis (NC29). Thus fish from the samples that show sign of spawning before 15 July are spring spawners, those that spawn later are fall spawners.

The biological basis for the notion of herring as stock-complexes is based on eight observations and assumptions discussed by Stephenson et al. (2009): (1) herring spawn in multiple, discreet locations within a stock distribution area; (2) Spawning takes place once a year, but there may be multiple waves of spawning

on spawning grounds; (3) herring larvae remain aggregated in predictable patterns (larval retention areas); (4) herring undertake extensive annual migrations between spawning, overwintering, and summer feeding areas; (5) herring return to the same spawning grounds from which they originated ("homing"); (6) different subpopulations show different trends in abundance and growth; (7) although herring from different spawning grounds mix outside spawning season, within these mixed aggregations fish of the same origin tend to remain in clusters; (8) herring subpopulations may show genetic differentiation (e.g. between different spawning waves), which suggests that herring are both spatially and temporally structured.

The management of the SW Nova Scotia/Bay of Fundy herring fishery is based on several small management units that are defined by individual spawning grounds (Stephenson et al. 1999). A decline of herring in 4R has been observed in the spring spawning stock and more recently also in the fall spawning stock. A decline was also observed in 4VWX, and a collapse was avoided with the introduction of smaller management units.

Scientific Advice and stock status

Fishery independent scientific information about 4R herring abundance is derived from acoustic surveys that were conducted every two years from 1989 until 2002, discontinued between 2002 and 2009 and started again on an annual basis between 2009 and 2011 (Figure 4).

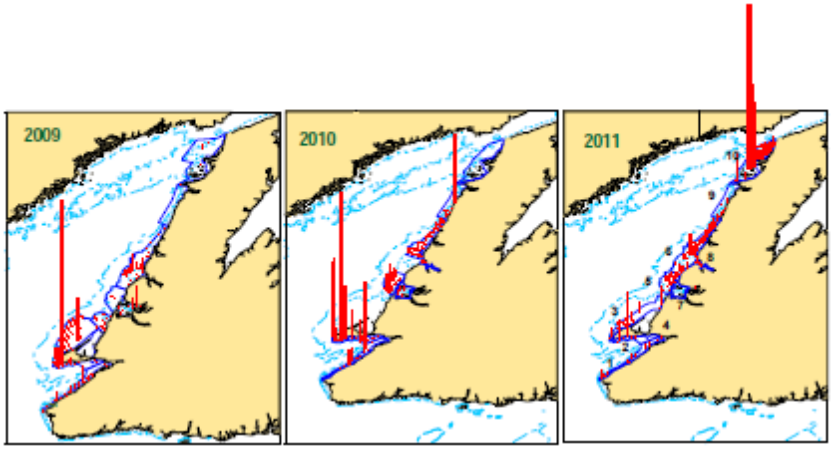


Figure 4 Herring density distribution (kg/m^2) along the west coast of Newfoundland in the fall of 2009, 2010 and 2011 (DFO 2012)

A second index of abundance was derived from the gillnet catch rates of an index fishermen program. This index was discontinued due to the lack of resources at DFO and lack of participation from the industry (F. Gregoire pers. comm.). Fishery dependent data is also collected by DFO resource management, and made available to the stock assessment scientists. Catch rates are not calculated from logbooks because their return is too low. Although submission of logbooks is mandatory according to the management plan, none were submitted in 2004 (DFO 2005a) and the rate of return is generally very low, with only about 5 out of 200-300 fishermen submitting logbooks (F. Gregoire pers. comm.). All landings by purse-seiners are weighed in the presence of a dockside monitor. In the case of fixed gear harvesters (i.e. trap, gillnet and tuck seine fishers) who sell

their landings to a processor or buyer, landings data are calculated from purchase slips. Logbook data are the only potential source of data from the spring bait fishery, as these catches are not sold and thus not captured in the dockside monitoring programme. Scientific data for use in abundance estimates of the spring spawning stock is therefore limited and incomplete making it difficult to establish trends. The former acoustic survey indicates a dramatic decline in spring spawners biomass followed recently by a slight recovery (DFO 2010b).

In addition "worrisome biological indications" such as evidence of a decreasing mean age in the landings over the last 30 years and declining condition in both spring and fall spawners, as well as evidence spring spawners are maturing at a younger age have been observed (DFO 2005a).

Current catches consist overwhelmingly of fall spawning herring (Figure 5). Although fall spawning herring seem to have increased in abundance since 2009, the 2011 biomass was mainly composed of a single year-class and there is a high degree of uncertainty associated with the abundance estimate. The 2012 assessment states clearly that it is unlikely that current catches can be sustained (DFO 2012). Thus the status of the fall spawning stock is also of concern.

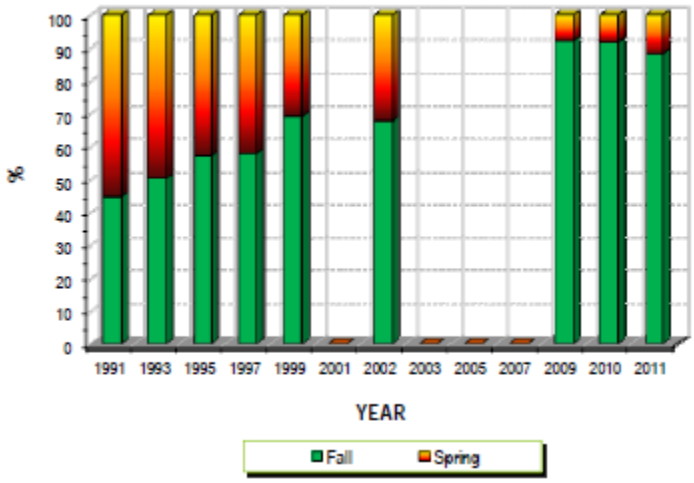


Figure 5 Percentage of spring and fall spawning herring observed in the biological samples used to calculate the biomass indices from the acoustic survey results (DFO 2012a)

Management

Prior to the 1960s, the 4R herring fishery was primarily a gillnet fishery. In 1960 four purse-seiners were operating on the west coast of Newfoundland between Bay St. George and the Bay of Islands. Following the collapse of the purse-seine fishery in British Columbia and the observation of a strong 1958 year-class of autumn spawners and a strong 1959 year-class of spring spawners, the Newfoundland Industrial Development Service (IDS) concluded in the early

1960s that the local herring stocks were underutilized (Mowat 2004). In 1965 the first reduction plant was built on the south coast of Newfoundland and by 1969, 50 modern seiners were fishing on the south and west coast of Newfoundland with the herring processed in an additional six reduction plants (Mowat 2004, p. 162). Herring landings in NAFO area 4R, which had averaged less than 4,000 tonnes in the past, shot up to 25,000t in 1972 (Figure 7).

After the southern Gulf of St. Lawrence herring fishery collapsed due to overfishing, quotas were introduced in 1973. The Atlantic wide seiner fleet was restructured with Gulf-based seiners restricted to the Gulf of St. Lawrence and Scotia Shelf-based seiners restricted to the Scotian Shelf (Barry Group 2008). The fleet separation policy was first introduced in 1979, but made provision for the retention of licences held by corporations before 1979, including those involved in the processing sector (DFO 1996; DFO 2003a). This allowed the creation of the offshore mobile gear fleet to accommodate the large seiner fleet, some of which are corporate-owned. In 1981 the quota was split with 55% going to the large seiners and 45% to the inshore (fixed gear). By then there were only 6 large seiners left in the 4R mobile fleet and the large purse-seine quota allocation was divided between the vessels and transformed into transferable quotas as part of a rationalization plan (DFO 2010a ; McQuinn and Lefebvre 1996). In 2008 it was decided to move to a full ITQ system based on the following rationale:

"It was noted that there were no valid fisheries management reasons for continuing the temporary sharing arrangement. Moving toward a full ITQ program would not affect conservation or the orderly conduct of the fishery. Therefore, it was accepted that the ITQs would be allocated on the licence holder's individual quota share and that these quotas be transferable between licence holders." (DFO 2010a)

In 1989, fixed gear harvesters applied for licences to purse-seine in the < 65 foot category. Fifteen licenses were issued, each with a permit to catch 200 tons of herring. This allocation of 3,000 tonnes was taken from the fixed gear quota.

> *"Well, we were give 200 tonnes each and then [name] went to the Fisheries cause it was caught quick, right, and the guy that was the head over Fisheries in Corner Brook at that time gave him another 100ton [for] the whole fleet, right? And then after time went on we established that we … owned half of that fixed gear portion, the 15 of us, and then just turned into a license, permit transfer and all that stuff, right* (NC 20)?"

As a result, today the large seiner fleet is managed through ITQs and the small seiner fleet through individual quotas (IQ) that are not supposed to be transferable. The fixed gear quota for tuck seines, gillnets and traps is competitive. In 2009 a sharing agreement was introduced that allocates different proportions of the fixed gear quota to two fishing areas: fixed gear harvesters in area 13 have access to 35% of the quota and fixed gear harvesters in area 14 have access to 65% of the fixed gear quota allocation in 4R (Figure 6).

The different fleet sectors also have different fishing areas. Large seiners are allowed to fish herring in 4R and 4T[1], small seiners are allowed to fish anywhere in 4R, and fixed gear harvesters are allowed to fish in area 13 or 14 within 4R only, depending on their the home port. Thus for instance, fixed gear harvesters residing in Bonne Bay and north of Bonne Bay are allowed to fish in area 14 and those residing south of Bonne Bay can fish in area 13 (Figure 6).

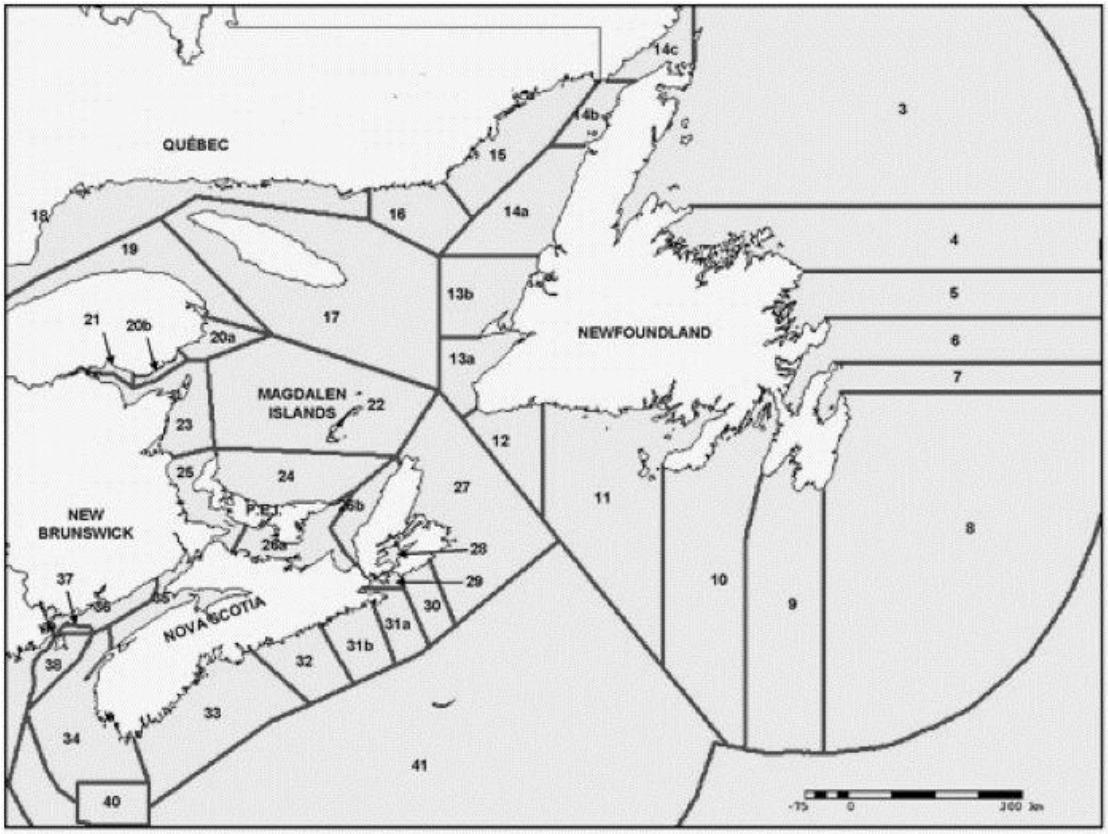


Figure 6 DFO fishing areas

The recommended total allowable catch for herring in 4R was set at 20,000 metric tons in 2010, 2011 and 2012. The mobile fleet has access to 77% of the herring TAC (55% for 6 vessels in the over 65 foot fleet and 22% for 20 vessels in the under 65 foot sector) while the fixed gear sector (680 licenses, an estimated 180 of which are active) has access to 23%.

TACs were first set in 1977 at 12,000 tonnes and peaked in 1989 at 37,000 tons. The TAC remained high (35,000 tonnes) in the early 1990's but was never caught and was reduced in the late 1990s to 22,000 tonnes and further decreased to 13,000 tonnes in 1999. The TAC was then increased again and has been at 20,000 metric tonnes since 2003 (Figure 7).

[1] Large seiners are allowed to fish mackerel in 4S, but they do not have the right to catch herring in that area.

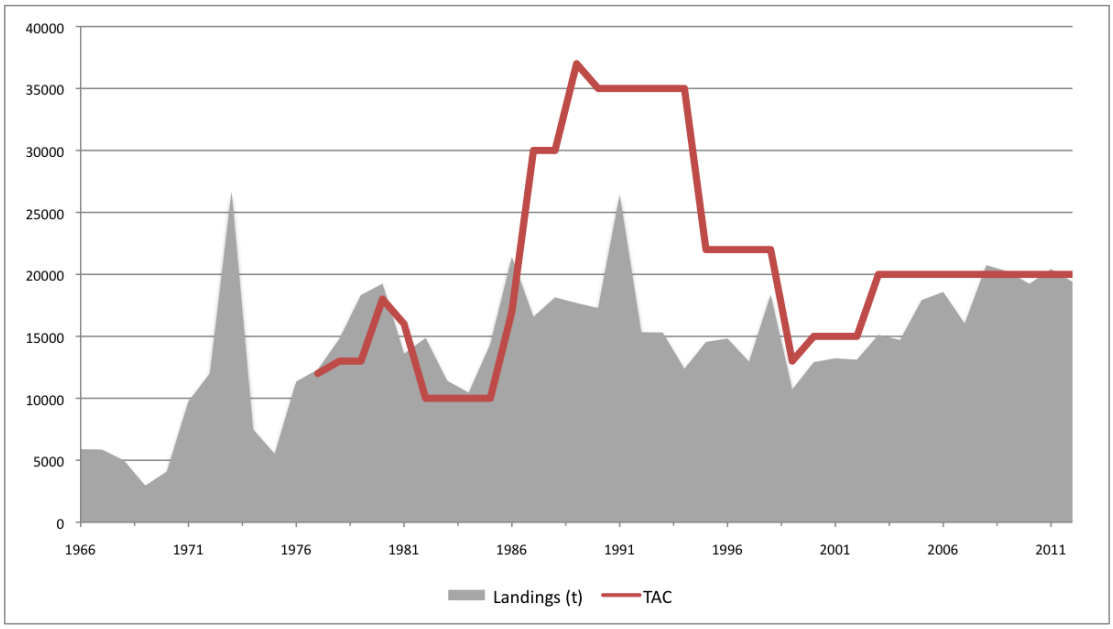


Figure 7 Herring commercial landings (t) and TAC (t) for unit areas of NAFO division 4R, 1966-2012 (source: DFO herring stock status report 2010)

There is a limited spring fishery of 2000 metric tons in the Bay of St George and Port au Port Bay, which are considered the primary spring spawning grounds. This spring bait fishery takes place during the lobster fishery and involves between 200-300 fixed gear harvesters (DFO 2005a; F. Gregoire pers. Comm.). Management measures were put in place with the aim to protect the spring spawning component by limiting fishing effort on spring spawners.

Protecting the spring spawning component

Because Bay St. George and Port au Port Bay are considered the main spawning grounds for the spring spawning stock, management measures to protect that stock have focused on these areas, which were closed all year for two years beginning in 1995. The scientific advice proposed these conservation measures and recommended to monitor the spring bait fishery closely to monitor catches and to disperse the fishing effort of the purse-seine fleet along the entire coast to avoid uneven fishing pressure (DFO 2003b; DFO 2004a; DFO 2005a; DFO 2010b; DFO 2012a).

However, the closure was partially lifted in 1997 and since 1999 the wider area has been closed during the spring (no fishing before 1 July) but open to herring fishing the rest of the year. In 2001 a catch limit of 1,000 metric tons was implemented for the wider area. The catch limit was increased to 2,000 tons in 2002. The reasons for this partial opening of the closed area given in the management plan include: a "positive outlook for spring spawners" and to produce additional data for science (herring IFMP). In 2004, the closure at the bottom of Bay St George (Figure 8), which had been closed all year, was changed to a spring closure and the northern boundary of the closed area in Port au Port Bay was moved slightly southward (Figure 8) following requests from the industry (NC 29) and "based upon the view that catches in the more northern area were primarily autumn spawners" (DFO 2010a). However, scientific recommendations have continued to state clearly that there is a need to maintain

these conservation measures (DFO 2003b; DFO 2004a; DFO 2005a; DFO 2010b; DFO 2012a):

> *The abundance of the spring component continued to decrease even though management measures have been introduced since 1999 to protect this stock's spawning activities. Considering the lack of reconstruction of the reproductive component, it is recommended to maintain these management measures* (DFO 2010b).

Despite this advice, the management measures that were introduced in the late 1990s in Bay St. George and Port au Port Bay have been eroded based on short term views regarding the improvement of the spring spawning stock that were not supported by data time series on herring caught in the spring fishery. DFO does not have data on how much herring is caught in this fishery because most fixed gear harvesters do not return logbooks and are not required to land herring for their own use in the presence of a monitor. Although logbooks are mandatory according to the IFP, resource management is not successful in ensuring that logbooks are returned.

Stakeholder involvement

Advisory meetings with the industry, including representatives of the fishing fleets and the processing sector, are held annually before the beginning of the season. The 4R herring Co-management Advisory committee is the principal body for the management of the 4R herring stock (DFO 2010b). On this committee harvesters, processors, DFO personnel from science, statistics, resource management, and conservation and protection come together to discuss the management of the fishery. During these meetings scientific data is presented to stakeholders, the previous years of the fishery are reviewed and management measures are discussed before being put in place. If necessary, the resource management section then formulates recommendations based on these discussions. These annual meetings are meant to provide a forum for stakeholders to raise issues and discuss problems. Additional meetings are seldom held (NC 26).

In 2010 this committee consisted of 23 members and 3 co-chairs, with the industry (harvesting and processing sectors) being represented by 15 seats and 2 co-chairs. Six seats represented processors' interests and another six seats represented the fishers' interests. There are two seats for each of the three fleet sectors, which seems like an equal distribution. However, a closer look reveals that the interests of the large seiner fleet were in fact represented by five individuals, i.e. two harvesters from the large seine fleet, and three processor representatives (including one of the co-chairs), who also operate large seiner vessels. On the other hand, fixed gear harvesters from either area 14 or 13 were represented by one seat each.

Table 6 Membership of the 4R herring co-management committee in 2010 (source DFO 2010a)

Co-Chairs	Organisation
Donald Ball	DFO (Co-Chair)
Bill Barry	Barry Group Inc.

	Prosessing Sector & >65' Harvesting Sector
Jason Spingle	FFAWU <65' Harvesting Sector (Co-Chair)
Fisher Representatives	**Number of seats**
>65' Large Purse-seine Fleet	2
<65' Small Purse-seine Fleet	2
<65' Fixed Gear Area 13	1
<65' Fixed Gear Area 14	1
Associations	
FFAWU Field Representative	1 (Vacant)
4T Based Seiner Representative	1 (Vacant)
L'Association des Seineurs du Golfe	1
Federation of Newfoundland and Labrador Inians	1
Processor Represenatives	
Barry Seafoods	1
Harbour Seafoods Inc	1
Allen's Fishereis Ltd	1
3Ts Ltd	
Labrador Fish Union Shrimp Co	1
New Brunswick Seafood Producers Association	1
Provincial Government	
NL Department of Fish Food & Aquaculture	1
NB Department of Fish Food & Aquaculture	1
DFO Representatives	
DFO	6

As in all meetings there is the danger that dominant participants may assert more influence than less assertive participants. "Interest groups lobby agencies for privileged access to resources The more energetic, powerful or privileged these interest groups are the more influence they tend to have" (Pinkerton 2007). A fixed gear harvester from are 13 confirms:

I've been going to the pelagic meetings the last few years, the meetings they've been having in Corner Brook in the spring and stuff. And like, when we got all the fisheries sat down, [..] all the guys from Corner Brook and St. John's and the union, [...], they might ask a question, like fishery related, if the fishery should get up and answer, [name] will get up and cut them off and answer for them cos they don't know what they're talking about right? It's just, he knows, he's a smart man, can just shut them up or leave them speechless.

Stakeholder participation can take many forms ranging from consultative meetings to active involvement in research activities. In the Bay of Fundy fishing industry involvement ranges from tagging studies in the Weir (DFO 2005c) and purse-seine fisheries (NC 1) to the collection of hydroacoustic data by fishing vessel captains (http://www.mar.dfo-mpo.gc.ca/Maritimes/SABS/popec/mf/Herring). These research collaborations are building on a long history of cooperation between DFO and industry. Two DFO scientists describe the level of industry involvement in research in the Bay of Fundy:

Scientist 1 — *I think we do more, more, certainly more with industry than other areas. Some areas are doing, are doing some but we do more. Part of it is because the industry is really engaged and has taken an active role in that research to the point of even of, of getting funding to do it or co-funding it [...] the industry did create um, their own research council. Pelagics Research Council at first it was called now it's called Herring Science Council.*

Scientist 2 — *Herring Science Council now basically coordinates all the acoustic surveys that we do because all the acoustic surveys are done by industry. The purse-seine fleet, or the gillnet fleet and the HSC coordinates all the purse-seine surveys in lines of what boats are gonna go and with consultation with me they'll decide what the survey plan is and what areas and what the survey lines will be. And then after the fact they'll, they even take care of all the downloading of the acoustic data and we get it to [name] for analysis and they pay [him] to do the analysis and provide the basic data to us.*

In the 4R herring fishery information from fixed gear harvesters was collected in the past via a questionnaire that was distributed to index fishermen. However, this collaboration was discontinued because DFO lacks the capacity to analyse the data but also due to lack of participation by the harvesters. Several larval surveys have been carried out in collaboration with the Barry Group on the southern part of the west coast of Newfoundland (Grégoire et al 2006a; Grégoire et al 2006b; Grégoire et al 2009; Grégoire et al 2011a; Grégoire et al 2011b).

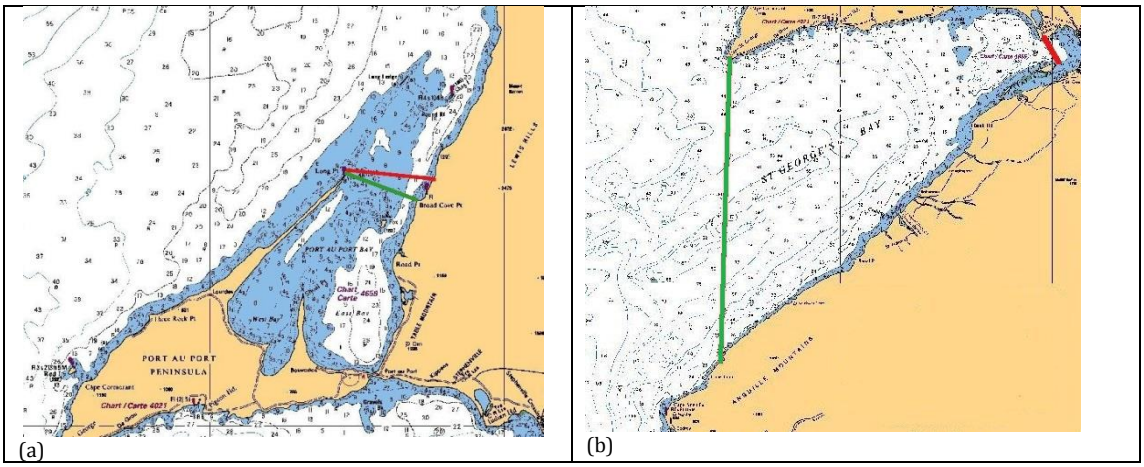


Figure 8. Closed areas in Port au Port Bay (a) and St Georges Bay (b). In 1995 and 1996 both bays were closed to commercial fishing. In 1997 there was a limited re-opening of both bays. This led to a spring closure (prior to July 1) for both bays and a year round closure of the bottom of St Georges Bay (red line) in 1999. In 2004 the closed area in Port au Port Bay was reduced, as indicated by the green line in (a); the closure of the bottom of St Georges Bay (b) was reduced to a spring closure (i.e. fishing is allowed from July 1).

Catches

Herring catch data for the past five decades show an increasing trend (Figure 7). Catch levels rose from 6,000 metric tonnes in 1966 to over 26,000 metric tonnes in 1973. From 1974 until 1990, catches were below or near 20,000 metric tonnes, but peaked again in 1991 at over 26,000 tonnes. Since then catch levels have remained below or close to 20,000 tonnes (Figure 7).
The decline of the southern Gulf herring stock in the early 1970s led to the development of a pre-spawning fishery in Bay St George and Port au Port Bay in the mid-1970s (Moores & Winters 1984). In 1973 12,000 metric tonnes were caught by large seiners (over 65 foot) in NAFO unit area 4Rd, which includes Bay St George (Figure 9). From 1984 until 1987 most of the purse-seine catches were taken from October to December (DFO stock status report 1997). In 1988 the development of a system of over-the-side sales to Russian vessels caused spring catches from 4Rd and 4Rc to increase dramatically. Landings reported for 4Rd rose from 1,000 metric tonnes in 1987 to 16,400 tonnes in 1991. Landings from 4Rc rose from 5,000 metric tonnes in 1987to 13,800 tonnes in 1989 (McQuinn & Lefebvre 1996, Figure 3). More than 95% of these catches were made by large seiners (Figure 9; McQuinn & Lefebvre 1996).

The pattern described by these statistics and in the DFO publications was corroborated by harvesters during the interviews. A purse-seine harvester (over 65 foot category) remembers:

> *One time that's where we caught all of our herring here, Bay St. George. (..) In the spring* (FE 58).

An older harvester (under 65 foot category) describes the period of over-the-side sales in Bay St George:

> *I had a little boat and then, when you take, when you take the hatches off the boat you know, the spawn would be running out, that much spawn all over the boat, you know, they spawned in the boat. I cried shame at the Fisheries for having her open at that time, at spawn time. … It was two or three, or four factory freezer trawlers out there in the bay, anchored, and that's where, that's where we were selling it, to them. … Could be 20 years ago, could be 15 years ago. … I only remember one year, one year put the clamps onto her. You know, one year, that was it, they never, there was no herring there after that (NC 11).*

The DFO commercial landings data for the past five decades indicate that the areas associated with the spring spawning component have at least twice been subject to severe fishing pressures, namely from the late 1960s to mid 1970s and again in the late 1980is and early 1990s (Figure 9). Although the DFO stock status report of 1997 states that the spring spawning stock has recovered, the 1999 report states the spring spawning stock is in danger of collapse. Harvester opinion is clear that severe fishing pressure resulted in the overfishing of the spring spawning stock in Bay St George and that stock has never recovered in spite of management measures.

> *They have her closed off now for a certain time in spring of the year. ... It's too goddamn late…There might be only, maybe two or three hundred you know, maybe a thousand ton left of them to come in and spawn, when they was finished maybe 500 ton left to spawn* (NC 11).

It may seem reasonable to suspect that these catches could be responsible for the continued decline of the spring spawning component. Moreover it might require only low catch levels to prevent this stock from rebuilding:

> *For instance we have no idea about how much is caught in the spring fishery, which targets the spring spawners. Is it possible that they catch too much?* (NC 29)

Recognising this data gap the scientific recommendations have routinely stated that the spring bait fishery needs to be closely monitored and that the close collaboration with fixed gear harvesters in the area that was initiated in the past should be maintained and enhanced (DFO 2003b; DFO 2004a; DFO 2005a; DFO 2010b; DFO 2012a).

Although observer and dockside monitoring programmes are in place for the commercial herring fisheries, these are not used to monitor catches or landings from the spring bait fishery in these areas or elsewhere as pointed out by the resource manager for the area: "we don't observe off-loadings from the gillnet or handline fisheries" (D. Ball, pers. com.), and only a handful of fixed gear harvesters are returning logbooks. "We send logbooks to the fixed gear fishers each year. But of the more than 200 harvesters only 5-6 returned logbooks." (F. Grégoire, pers. com.). Thus no catch rates are calculated for the fixed gear sector in either spring or fall (NC29 email).

Dispersal of fishing effort

In order to mitigate uneven fishing pressure the scientific recommendation to management is to distribute fishing effort along the entire coastline. Catch data for NAFO area 4R down to the subarea level are available until 2008. In the 1970s, the early 1990s and from 2002 to 2008, catch levels were highest in area 4Rd (Port au Port Bay and South), followed by area 4Rc (Bay St. George and Bay of Islands). In the mid 1980s catch levels were highest in 4Rb (Bonne Bay). In most years, catches have been higher in the South than in the North (Figure 3). Between 1966 and 1995 the large seiner fleet took the majority of catches in subareas 4Rb, c, d, whereas gillnetters took the majority of herring caught in subarea 4Ra (Figure 10).

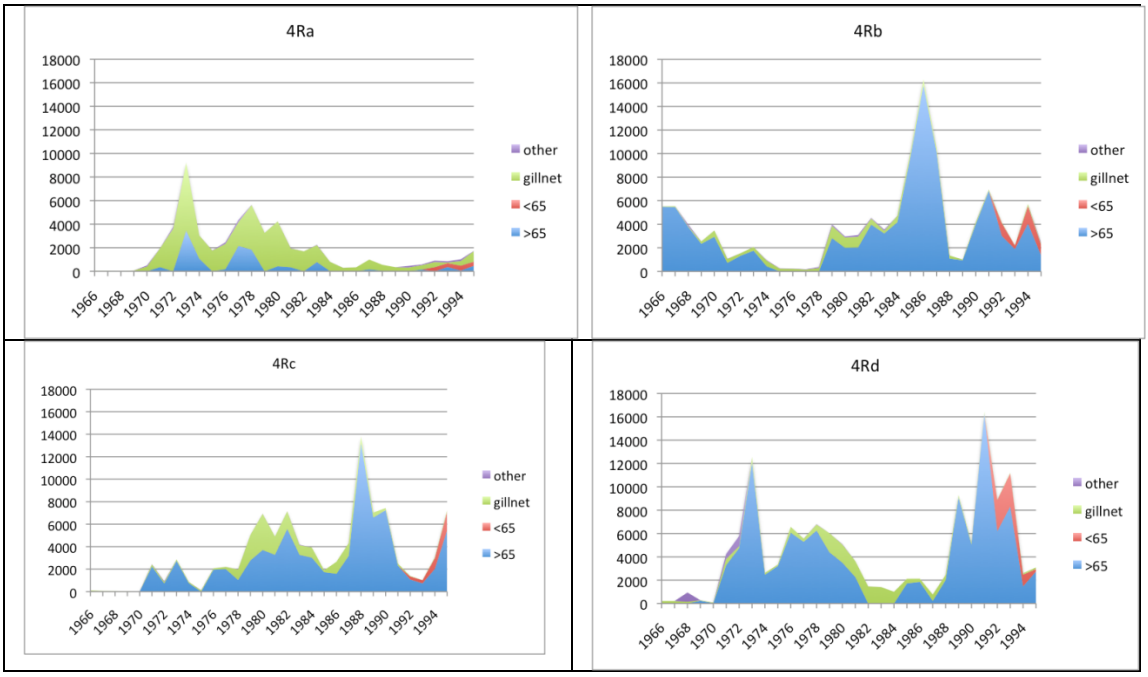


Figure 9 Herring catches (1966- 1995) per fleet sector in each of the four NAFO sub-divisions, data from Hourston (1969) and McQuinn & Lefebvre (1995)

According to the DFO stock status reports, the spring spawning and fall spawning herring stocks "are harvested separately during spawning gatherings or collectively when the stocks are mixed between April and December" (DFO 2005a). Their documents indicate that, "the herring purse-seine and 'tuck' seine fishery is practiced mainly in the fall. Spring fishing activities were strongly reduced following the implementation of management measures to protect the spawn of spring spawning herring" (DFO 2010b). As indicated above, there is no logbook or landings data for the spring bait fishery. Since this fishery takes place in areas associated with spring spawning, it has been suggested that these catches "could be considerable" and "that the spring bait fishery [should] be subject to more rigorous monitoring "(DFO 2010c). There is no evidence in the documents that similar concerns regarding overfishing of spring herring have been raised in relation to the much larger, mixed component fall fishery, which is now mainly composed of fall spawners and largely carried out by the mobile fleets. Landings in this fishery are now composed mainly of fall spawners, but used to also include spring spawners in the past.

The partial and temporary closure of Bay St George is the only spatial management measure that affects the mobile gear fleet sector, i.e. the large (over 65 foot) and small (under 65 foot) seiners. Otherwise purse-seiners (as opposed to tuck seiners) may fish herring anywhere in NAFO area 4R.

The following dialogue with a purse-seine harvester explains that if the market is profitable, seiners will not only catch herring in the southern bays during the fall but also in the spring.

Harvester: *Herring [season] is however long, you can squeeze it out like me, a lot of the guys in our fleet caught their fish this spring when the price was say twenty cents a pound versus now it's*

eight. But as the fall goes on, that price should rise again, so if I wanted to I should have taken it when it was a higher price, but … usually what I do is catch my mackerel [and] when the mackerel season's over on the way home I'll catch my fish. Last year I sat a hundred thousand I think it was, we landed that in three nights.

Researcher: *Okay, … [so] it doesn't matter if you catch it in the spring or in the fall, to DFO[regulations] it doesn't matter?*

Harvester: *No, a lot of guys caught their herring this spring when the price was there. Cos, Nova Scotia wanted it for lobster bait and the price was higher…*

The structure of the 4R herring stocks complex

Atlantic herring spawn at distinct locations and at particular times (Stephenson and Lane 1995) with, "populations which spawn either in the spring (April to June) or in the autumn (July to October)" (DFO 1997). In western Newfoundland (4R) spring and fall spawning herring abundance are assessed separately, but a single TAC is set and then allocated between the fleets.

Temporal structure

Whether a herring belongs to the spring or the fall spawning stocks depends on the time of year when it spawns. However, it does not seem to be clear what a spring or a fall spawner actually is. From a biological perspective *"the determination of a spawning group is based on the otoliths and the gonads and in theory you should get the same signal from both. But for some fish, the otolith signal says spring and the gonads says fall"* (NC 29).

Although harvesters are aware of herring spawning at different times of the year, the distinction between spring and fall spawners is perceived as arbitrary by some:

> *… the government got it labeled as fall spawners or spring spawners … And anything that spawns after July the 1st is considered an autumn spawner or a fall spawner, whatever. Anything that spawns before that is considered a spring spawner. So it's just Government policy or government regulation or whatever you want to call it. But, the herring probably don't know anything about it* (NC 6).

Spatial Structure

Although "several other spawning sites are known along the coast towards the north" (DFO 1997) DFO reports give explicit attention to only the two main spawning areas for the spring spawning stock, i.e. Bay St George and Port au Port Bay. It is further assumed that the main spawning areas associated with the fall spawning stock are north of Point Riche, in particular in St John Bay (DFO 2010a; e.g. DFO 1997, 1999, 2010b). The following statement by a DFO resource manager reflects this understanding:

> *We have two well identified inshore spawning areas for herring. One is right at the bottom of Bay of St. George … you'll notice they refer to two different stocks of herring that are involved in the Gulf and also in western*

Newfoundland. One is the spring spawning component, … I think it's a general rule to say that herring tend to spawn in the fall of the year, however, there is subcomponent in the Gulf of St. Lawrence that spawns in the spring. And right at the bottom of Bay St. George, an identified area, we close that all year to protect that and there's another one up here in St. John Bay, … which are fall spawning (NC7).

Because Bay St. George is considered the most important spawning area management measures to protect the spring spawning stock focus on this area. Nonetheless there are other areas where harvesters (small seiners and fixed gear), local residents and other key informants report that spring spawning has been observed (Figure 10):

… as the water warms up in the spring and I think they start moving out, out of [Bonne Bay] to the north, right, and they spawn near a little community called Sally's Cove, which is about ten miles north of here" (NC 3).

… a place there like Sally's Cove, she's just right white and green with spawn all the way along the beach. Up here in the bottom of this bay here where Port Saunders [is], Gargamelle Bay, they spawn there. Then down in the bottom of this St. John Bay, uh say from [this] river up a long ways, she was white with spawn there … in the spring of the year, in the spring. Cos I drive to Sally's Cove like when I'm travelling got to go up for a part or something. And you see them there, the herring, … the water is just moving for probably a couple of miles there, it's all the herring" (NC 9).

To further complicate the picture, one harvester reports having caught and observed herring that were spawning in the fall in the same areas that are associated with spring spawning events:

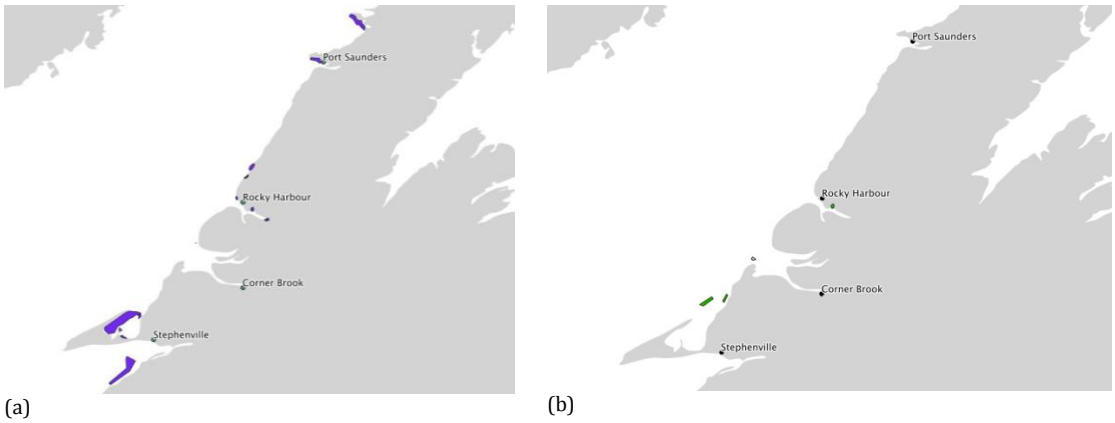
We were at the mackerel, yeah. And that's why we knew that they spawned there. We set our seine and … I had moss on my purse strings where I touched the bottom and took moss off the bottom and the spawn was on the moss (NC 11).

One harvester, the skipper of one of the large seiners, expressed a strong belief that the distinction between spring and fall spawners is incorrect; that there is only one population of herring and the decline in so-called spring spawners is of no consequence.

P2: You know, [the fish] don't know that they're spring or fall you know, and in most cases here what we've found since, uh, well since the 60's anyway, that the herring … they start spawning in the early spring and really in a lot of cases don't finish spawning till late November sometimes.

P1: Because years ago they tried to get a roe fishery going here, right? Fish the roe. But they never could get the work 'cos it was too much mixed up. (NC 6)

He also said that there is no genetic difference between these fish, and that therefore they must be part of the same stock. However, with the technology applied in herring genetics today it is impossible to prove sameness (R. Stephenson, pers. Com. 7 10 2011). Moreover, it is clear that spawning aggregations of herring have been observed in the spring as well as in the fall at various locations along the west coast by fishers and local residents. This suggests that the 4R herring does consist of several subpopulations.



(a) (b)

Figure 10 Localities where harvesters and a local resident have observed herring spawning in the spring (a) and fall (b)

Environmental factors contributing to spring spawner decline

Another factor that may be contributing to the decline of the spring spawners is the changed temperature regime (DFO 2010c), because environmental conditions favour either spring or fall spawning and the recently observed higher temperatures favour autumn spawners (Melvin et al. 2009).

> *Gary's paper talks about the relationship between water temperature and spring/fall spawners. We have warmer springs now, maybe that's why there are less spring spawners. If the temperature goes up more, maybe the spring spawners will disappear or change to fall spawners. … So perhaps it is not that they are being fished too hard but something else. Possible it's the water temperature"* (NC 29).

Although in recent years environmental factors may have been more favorable for fall spawning than spring spawning (Melvin et al 2009), the underlying question is whether these herring are all part of the same stock. This suggestion implies that 4R herring are one single stock. It is based on the assumption that the population dynamics of 4R herring are different from those of herring elsewhere in Atlantic Canada as described by Stephenson et al (2009).
A more reasonable explanation is that as spring and fall spawning have been observed on the west coast, these stocks are separate. Both harvesters and scientists are aware of several different locations where herring spawn in the spring and others where they spawn in the fall. Thus it is reasonable to assume that there are some different spawning grounds and that a combination of fishing and environmental conditions can lead to the decline or even extinction of local populations (R. Stephenson, pers. comment, 7 10 2011).

Herring migrations

Some harvesters told me about fishing for herring in winter through the ice (in the Bay of Islands as well as St Pauls Inlet – the latter was reported to Kurt Korneski, a CURRA postdoctoral fellow). This is an important and very interesting feature of these locations, because herring undergo complex migrations between winter areas, summer feeding areas and spawning grounds. Herring tagged in the Bay of Fundy have been observed on the coast of Cape Breton Island, very close to the shore and in dense aggregations of up to 500,000t of fish (R. Stephenson, pers. Comment, 7 10 2011).

Conclusion

Over the years 1976-1995 catch levels and TACs have been increased and spatial management measures to protect spring spawners have slackened in response to positive interpretations of short-term abundance trends. Stock status reports for 4R herring present catch data for the last 10 years. But when looking at the catch data for the last 50 years it is clear that catch levels have increased considerably and are now four times higher than they were at the beginning of the data series (Figure 7). This in itself is of course not enough evidence to signify overfishing; however, attention also needs to be paid to the negative abundance trends for both spring and fall spawning stock components (based on stock assessment surveys) and the "worrisome biological indications" suggesting that fishing pressure is too high. It is thus important to note that the current catch levels (20,000 tons) are approaching those of peak exploitation levels in the past (27,000 tons) and as catches are now dominated by fall spawners are concentrated on only one of the two spawning stocks.

The two herring stocks in 4R are defined temporally, based on the time of year that spawning takes place. In the Bay of Fundy the individual spawning stocks are defined spatially, by the spawning location, which means that each stock component is linked to a particular location. As a consequence in 4R the priority is to protect the main spawning ground that is associated with spring spawners and less attention is given to other spawning grounds. While it makes good sense to focus initially on the area that is identified as a major spawning ground, the lack of attention given to protecting other spawning aggregations of spring spawning herring may have contributed to the erosion of these subpopulations and consequent loss of genetic biodiversity, which may be further hindering the recovery of the spring spawning stock.

Catch data indicate that there has been extreme fishing pressure on 4R herring in the past, including a foreign fishery that operated in the main spring spawning area. Furthermore, purse-seiners are likely to pulse fish on aggregations, which may unevenly affect different sub-populations. In the autumn, fishing effort by "mobile" seiners is linked to the mackerel migration and therefore concentrated in the South (see section 'Interactions between the 4R mackerel and herring fisheries', p. 43). In the absence of dedicated tagging projects there is no knowledge about the movement of spring spawners throughout the year. The amount of herring caught by the bait fishery from the spring spawning aggregations in Bay St George is unknown, thus it is possible that these help to prevent the rebuilding of the spring stock component. But, although no gear type

is incapable of overfishing, mobile gears tend to be "hungrier, especially when there is an unlimited market" (R. Stephenson, pers. Comment, 7 10 2011). Of course the markets for herring, like all small pelagic fish, are based on high volumes.

Clearly, the lack of catch data from the spring bait fishery needs to be addressed. However, an allocation of 10% of the total herring TAC to a spring fishery quota on the primary spawning ground seems high for a threatened stock. In order to determine who is fishing where and when, it would be necessary to map fishing locations by month and gear type. This information together with the reported landings would help us determine the impact of each gear type on the fishery. There is of course the problem that DFO does not have data for the bait fishery. So this is potentially an area where additional interviews with harvesters could contribute valuable information.

The important knowledge contribution fixed gear harvesters can make regarding stock structure is not always recognized by science and tends to be overshadowed by other explanations for reduced catches:

Regarding the fish distribution, the purse-seiners are the best to talk to …. However, if you are interested in the relationship between water temperature and catch then you must talk to the trap fishers. They don't move, the fish either come or don't come. And this is due to the temperature of the water rather than the stock abundance or both. The fixed gear fishers think that when their catches are down one year that this indicates that the stock is low. It is a challenge to show them that the fish are there, they are just somewhere else and therefore not being caught in the traps. Water temperature is the reason for this. (NC 29)

Surveys along the west coast have ben intermittent. Co-operation between fisheries biologists and harvesters has been limited to stakeholder consultation through advisory meetings. DFO's index fishermen project with gillnetters was discontinued due to lack of resources and lack of collaboration from fishermen. It is interesting to note that during consultations held by the Fisheries Resource Conservation Council (FRCC) the representative of Barry Group Inc. strongly advised to discontinue collecting information from gillnetters and to re-channel resources from the index fishermen project towards "better" and more "important" activities (Barry Group 2008). Recent scientific collaboration with industry has taken the form of larval surveys funded by Barry Group Inc., one of the main processing companies, who also operate large purse-seiners in the area (NC29).

Focusing on information from seiners alone, ignores the fact that fixed gear harvesters can potentially provide highly pertinent information regarding the spawning grounds of herring. Herring have a strong drive to return to spawning grounds, thus if they don't return this would be a strong signal of a potential problem with overfishing on particular stock components. Fixed gear harvesters are more likely to observe this than seiners because their gear stays in the water at a fixed location for several weeks and are often set at those same locations in several seasons. The greater mobility of the purse-seiners enables them to follow

the fish, which can easily mask spatial changes in the distribution of spawning herring that could be an indication of the erosion of local spawning aggregations. In the Bay of Fundy close collaboration between fishermen and scientists has led to several innovative management practices in that area (Stephenson et al 1993, Stephenson et al 1999).

It seems that an innovative approach would be useful for the 4R herring fishery. However, development and implementation seem impossible because the team responsible for the assessment of 4R herring is understaffed and has to address four fisheries.

Mackerel

Biological characteristics

The Atlantic Mackerel (*Somber scombrus*) is a small pelagic fish that occurs on both sides of the North Atlantic, from Norway to Morocco and from Labrador to Cape Hatteras, North Carolina. Two spawning stocks of mackerel are recognized in the North Atlantic, one associated with the Gulf of St Lawrence the other with the waters off the US coast (DFO 1997b). In Atlantic Canada, the Atlantic mackerel is most abundant around Newfoundland, in the Gulf and estuary of the St. Lawrence, off the coast of Nova Scotia and in the Bay of Fundy (Figure 11). Mackerel are very sensitive to the surrounding water temperature regime (NC 29). In addition, the absence of a swim bladder forces mackerel to swim continually and enables them to change depth rapidly. Mackerel travel in dense schools of equally sized individuals that swim at the same speed and conduct long annual migrations. In spring and summer they are found in coastal waters and in winter in the deeper, warmer waters along the continental shelf (DFO 2007a).

Mackerel Migration Patterns

According to DFO, mackerel of the northern spawning stock migrate northwards in spring, arriving along the coast of Nova Scotia in May. They then continue around Cape Breton usually in June. The spring migration usually ends at the end of July. In the fall the mackerel migrate out of the Gulf. The fall migration usually starts in September (DFO 2007a). In the spring and summer mackerel are caught by fixed gear harvesters in Nova Scotia, PEI, New Brunswick and Quebec. In the fall mackerel are also caught in Newfoundland by fixed gear and purse-seine harvesters.

The most important factor that influences the migratory behaviour of mackerel is water temperature (DFO 2007a). Mackerel are believed to enter the Gulf of St Lawrence during the spring migration in order to spawn and to leave the Gulf during the fall migration. The spawning of mackerel is concentrated in the southern Gulf of St Lawrence in June and July, but also occurs along the coast of Nova Scotia and on the west coast of Newfoundland in water temperatures between 10-12° C. But not all mackerel migrate along the same routes. Mackerel that are caught in the fall along the east coast of Newfoundland are believed to have left the Gulf of St Lawrence during their spring migration through the Strait of Belle Isle. Harvesters who catch mackerel starting in September along the west coast of Newfoundland, report that these fish move southwards along the coast.

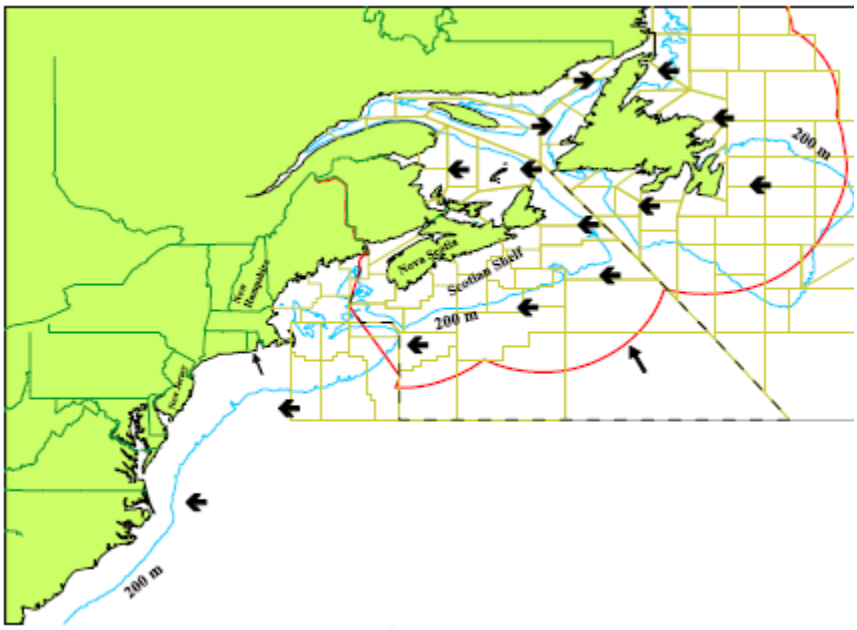


Figure 11 Distribution of Atlantic Mackerel (←) in the North-west Atlantic (source DFO 2012b)

All interviewed harvesters agreed that the arrival of mackerel on their fishing grounds has been happening much later in recent years than when they first started fishing for them.

> *And see, years and years ago, okay, we'll go back 20 years or even 25… mackerel say 30 years ago was fished here and it started probably the first week or two of July, purse seining mackerel, right? So July and August were your two months that you'd probably be fishing mackerel. Now there's none around in July and August, we fished last year September, October and November* (NC20)

Stock Structure

Although two spawning stocks are recognized, Atlantic mackerel are treated as a single shared stock between the USA and Canada (DFO 2012b). The fishery management unit in Canada spans NAFO subareas 2, 3 and 4. There seem to be contestations among harvesters as well as between scientists and harvesters regarding whether there is one body of mackerel in the Gulf or several. For instance, one small (under 65 foot) purse-seine harvester expressed the opinion that the mackerel that are caught along the coast of western Newfoundland are a separate group of mackerel from the shoals that are observed along the Quebec shore, and that the two groups are separated by a body of colder water in the middle of the Gulf. Related to this, he says the fact that there are apparently large volumes of mackerel in the Gulf is irrelevant because the local fishery only catches those that migrate along the west coast.

Harvester: *Right. I told Bill Barry, he said, the Gulf is full of mackerel, [name]. I said listen, it's not the west coast of Newfoundland mackerel, no, I said, they stays on the Quebec shore, they haven't got to come. I said, our mackerel comes in Bonne Bay, comes up from Port au Choix, … comes up and goes up on this shore, and I said they're fished night and day. …*

I said we're fishing the west coast of Newfoundland mackerel and, I said, they're fished too heavy. You think so? I said, I'm goddamn well sure, I knows and…one of these days I'm going to run into him, he's going to say, you knew what you was talking about…There been mackerel boats left here, they was at the mackerel, being that scarce here, there were boats [that] left right across, to the Quebec shore. [They] was looking, eh? And there was mackerel seen half ways across. There was mackerel seen 45 mile off here.

Researcher: *When was that?*

Harvester: *Maybe 20, maybe 15 years ago?*

Researcher: *And it was the big seiners that*

Harvester: *Big seiner, yes…and so if-if-if, you know if there's mackerel seen 45 mile off here, there could be mackerel seen 60 miles off here. They're not, that's not the mackerel seen here in Bonne Bay. They're out there, late in the fall, later you know, 45 mile off here, they're not going to come back [across] the cold water and go up to Bonne Bay, no, no, that's not the mackerel that comes here, eh? Oh yes. I hope I'm wrong, for the boys' sake and for other fishermen's sake. I hope they do keep up, but it's iffy my dear, it is iffy* (NC11A).

Cause they're fished night and day and, like I told you my dear, the equipment, the equipment they got, the gear they got on the boats today, it's unbelievable…And if one miss 'em, there's another feller there to grab 'em and if he miss 'em, there's another fella there …

A younger harvester also expressed concern that if there is indeed one distinct body of mackerel that is targeted by the local fishery then the fishing pressure might be too hard:

> *If the last two years now … nobody knows [if] it's the same body of mackerel that comes here that we fishes. Is it the same body of mackerel that goes around to the south west coast? And if it is, now you got all the boats from around Newfoundland, from the Northern Peninsula right up through the other side coming down there now starting to fish them in the last two years. So if it is well, it won't take too many years and you'll probably notice a difference, right?* (NC 22).

Management

Since 1987 there has been an Atlantic wide total allowable catch (TAC) for mackerel, which is divided between the USA and Canada. Between 1987 and 2000, the total allowable catch (TAC) for the Northwest Atlantic was 200,000 tonnes.

The Canadian fishery is competitive and no quotas or caps are set. There is, however, a sharing agreement which allocates 40% of the Canadian TAC to the large purse-seine vessels in the over 65 foot fleet and 60% to the vessels in the

under 65 foot category. According to the mackerel IFMP (2007a), one of the management objectives is to give priority access to the inshore (under 65 foot) fleet. There is, therefore, a management provision to allow the small seiner fleet (under 65 foot) to continue fishing if they reach their share of the TAC before the large seiner fleet allocation has been reached.

Following the low biomass estimates from the 1996, 1998 and 2000 Canadian egg surveys, Canadian stock status reports since 2001 have recommended that the Canadian TAC be reduced. The combined TAC was lowered to 150,000 tonnes (Canadian portion 75,000 tonnes) between 2001 and 2009. Canadian landings peaked in 2005 at 55,454. Since then landings have dropped to an average of 43,161t between 2006 and 2010 and in 2011 less than 9,000 tonnes were landed in Canada (NAFO data). The combined TAC was lowered to 80,000 tonnes following the 2009–2010 joint Canada-US assessment, and to 60,000 tonnes following the 2010 Canadian Advisory Committee. The 2011 landings of less than 9,000 tonnes were a historical low and indicate a rapid decline from the 55,000 tonnes that were landed in 2005. The landings data, egg surveys and population analysis all give the same signal: that the biomass is declining due to unsustainable fishing levels.

Finally, following the 2012 Canadian Advisory Committee, the TAC for subareas 3 and 4 was set at 36,000 tonnes to equal the US TAC despite scientific advice that recommended annual catches not exceeding 9,000 tonnes (DFO 2012b).

Catches

During the 1970s, mackerel were fished heavily by foreign fleets (Figure 12). These catches dropped when the exclusive economic zone came into effect in 1977 (Figure 12). However, an agreement between the USA and the USSR led to increased foreign landings in the 1980s. In 1992 the foreign fleet fishery was closed.

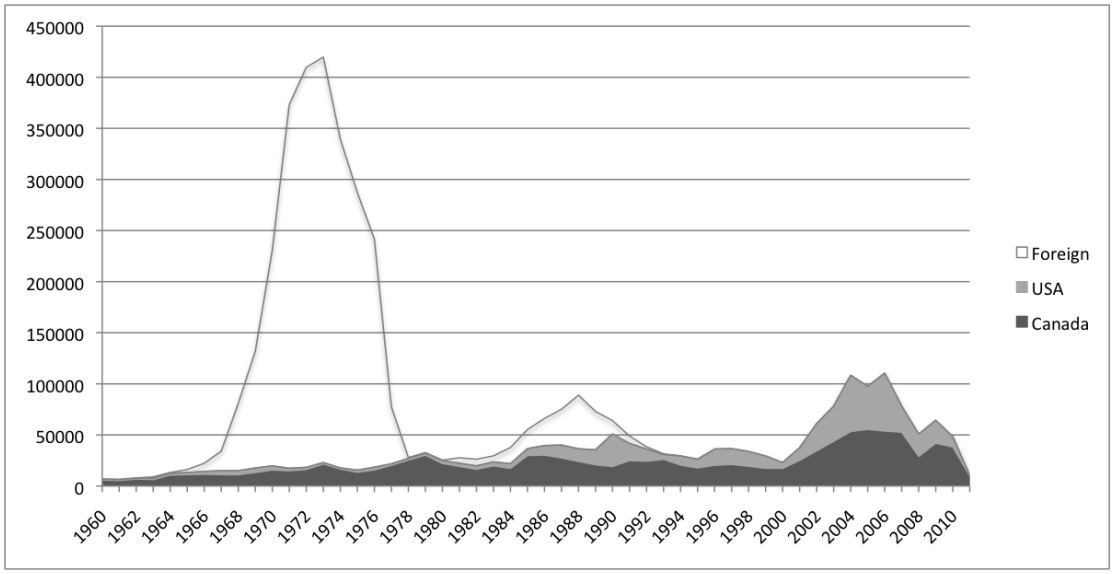


Figure 12 Canadian, USA and foreign catches (metric tonnes) of mackerel in the North West Atlantic from 1960 until 2010, Source: NAFO data

Prior to 1987 hardly any catches of mackerel were reported from NAFO area 4R (Figure 13). Since then catches in area 4R have increased in proportion to other areas and since 2007 have accounted for the majority of Canadian landings. This increase in landings after 1987 coincided with the presence of USSR vessels fishing for mackerel in Canadian waters. So-called "over the side sales" created a lucrative market for mackerel for local harvesters. Nonetheless, until 1990 the highest landings of mackerel were reported in Nova Scotia, Prince Edward Island and Quebec (DFO 2007a). Then the concentration of landings shifted and since 2000 landings from fish harvesters in Newfoundland and Labrador have increased dramatically and accounted for up to 82% of total Canadian landings in 2008 (DFO 2007a, 2008). Landings in the USA increased from 5,649 tonnes in 2000 to 56,640 tonnes in 2006, then decreased from 25,547 tonnes in 2007 to 9,891 tonnes in 2010 and reached a historical low of 500 tonnes in 2011.

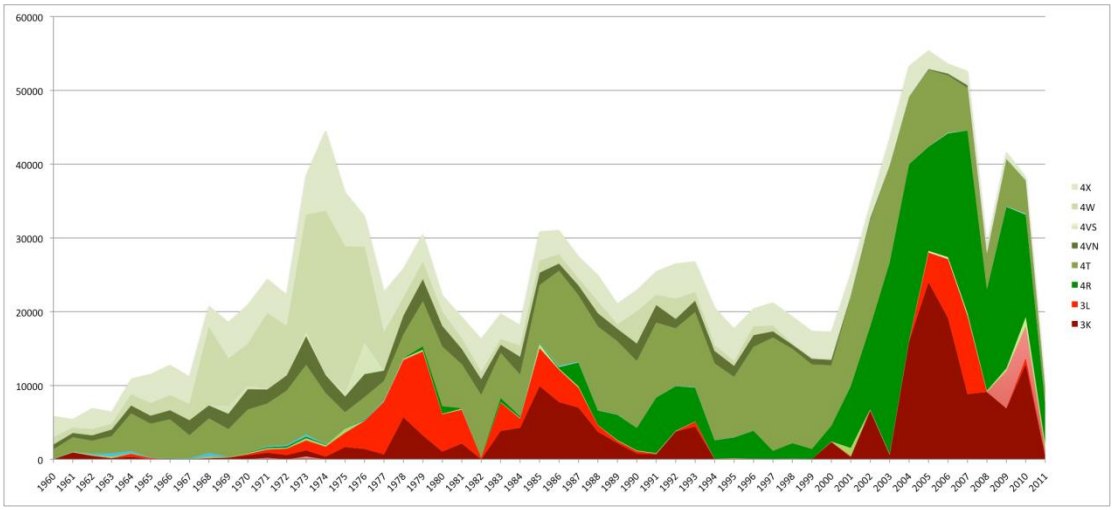


Figure 13 Canadian Mackerel Landings (mt) by NAFO area from 1960 until 2010. Source: NAFO data

The pattern of mackerel landings in Newfoundland has been highly variable over time (Figure 13). These fluctuations are associated with several factors such as changes in market demand as well as intensification of fishing effort related to the introduction of new fishing methods such as the advent of purse-seining and sonar – the latter makes it much easier to detect mackerel – on the seiner vessels during that time. Landings in particular zones are also subject to the effects of fluctuations in year class strength (abundance) and changes in migration routes.

Efficiency Increase

Larger boats

As often happens with relatively high value competitive fisheries, there has been a dramatic increase in fishing capacity in recent years.

Harvesters in the under 65 foot seiner fleet have invested in larger boats that can catch more fish per trip and in new fish finding equipment (Table 6). Thus although the number of mackerel licenses hasn't changed, harvesting capacity

has increased substantially. One part of this increase is the shift to tuck seiners in the fixed gear fleet. Vessels in the large seiner fleet have also increased in capacity (Table 7).

Table 7 Three examples taken from career history interviews with individual owner operators of small seiners (<65ft vessels) who increased catching capacity over time by investing in larger boats

Port aux Choix	**Years owned**	1986-1989	1990-1997	1998-2000	1998-2003	2003-2005	2005-2011
	Length (ft)	55	55	55	65	56	65
	Loading capacity (p)	80,000	150,000	140,000	140,000	115,000	250,000
	Engine power (HP)	350	540	462	720	48	620
Bay of Islands	**Years owned**	1971- 1984	1985-1993;	1993-2004	2005-2011		
	Length (ft)	35	40	45	65		
	Loading capacity (p)	30,000	45,000	100,000	230,000		
	Engine power (HP)	120	210	311	597		
Stephenville	**Years owned**	1982 -1986	1987-1991	1991-2011			
	Length (ft)	45	45	65			
	Loading capacity (p)	30,000	50,000	120,000			
	Engine power (HP)	265	170	429			

Table 8 Examples of boat capacity increases in the large seiner fleet taken from two career history interviews with an active skipper (a) and a retired skipper (b).

a) Active skipper

Years fished	1974-1975	1976-1978	1979-1992	1992-2004	2005-2011
Owned by	National Sea	BC Packers	Barry's since 1990	Barry's	Barry's
Length (ft)	140	76	104	114	114
Loading capacity (t)	1,322,760	440,920	496,035	815,702	815,702
Engine power (HP)	500	500	800	1000	1000

b) retired skipper

Years fished	1965	1966	1967	1970	1970 - 1972	1973 - 1974	1975 - 1978	1978 - 1980	1980 - 1990	1990	1991 - 2004
Length (ft)	89	89	107	65	70	137	137	89	107	107	115
Loading capacity (t)	286,598		551,150	198,414	209,437	352,736		573,196			793,656
Engine power (HP)	365	500	800	365	365	900	900	565		800	1125

A skipper in the under 65 foot fleet expressed concern that the effort in the mackerel fishery is unsustainable:

Harvester: *The boats is getting bigger and more people getting into it so obviously you knows what's going to happen to it, it's only a matter of time.*
Researcher: *Some people were saying it's impossible to fish [mackerel] down because the window is so small, and the weather.*
Harvester: *Well some people probably think so but I don't know.* (NC22).

The result of this capacity increase is not only more pressure on the fish but also increased dependency of harvesters on this fishery because of the investment costs:

You know, you got people with million dollar boats, you got to have something to pay for it, right? If the mackerel fails, you know, we're finished. We'll never make a living. I'm okay because I own my boat, but the young guys starting out, with a million dollars in the hole, if the mackerel fails, we're finished. You can't even make a boat payment. The herring and capelin, there's no money in that, you might make yourself a hundred thousand dollars a year, a hundred and fifty thousand, but how in the hell are you going to live on that, with a bunch of men to pay and fuel and the cost of fuel today, you know (NC 12).

This dependency creates pressure on harvesters, in particular the under 65 foot seiners and tuck seiners who have invested heavily in vessels, gear and equipment on the promise of a lucrative mackerel fishery. But their profitability relies on a strong market for mackerel, a healthy mackerel stock and suitable environmental conditions to ensure the majority of mackerel migrate along the west coast.

The result of the open access nature of the fishery is capacity increase as well as "a race to fish". A purse-seine harvester told us how he damaged his engine trying to reach the fish as fast as he could:

Harvester 1: *I changed the motor to 360, yeah. I almost melted her.*
Reseracher: *What does that mean, you almost melted her?*
Harvester 1: *Oh, just running her hard, trying to get where you're going, chasing them.*
Harvester 2: *Someone saw mackerel one day, and we were all out around and everybody shoved their boats and their motor down cause when someone sees mackerel we're going.* (NC20)

Many of the smaller seiners, both under 65 foot purse-seiners as well as some tuck seiners expressed concern about the increasing number of participants in the purse-seine fishery, which is created by fixed gear harvesters changing to tuck seining, and the absence of catch limits.

Harvester: *And they're allowing the boats to get bigger and bigger and bigger, if they just left the boats as they were, everybody with the same size*

boats, but now the guys are carrying fifty thousand pounds are three hundred now and they won't put a stop to them. I wrote to the fisheries minister a letter five or six years ago and asked him to try and keep it a hundred thousand pounds per boat, you know, per trip. He never even called me back. (NC21)

Improved fish finding technology

The increase in catches since the late 1980's is partly due to improved fish finding technology. The lack of a swim bladder not only causes mackerel to be constantly on the move, it also renders them invisible to certain kinds of fish finding equipment which were the ones used before the 1990s.
Without the high frequency sonar, harvesters could catch mackerel only opportunistically, whenever the fish were "ringing" on the surface of the water:

I'm sure there was plenty of years that there was plenty of mackerel here but everyone was saying there was none because they couldn't see 'em because they didn't come to the surface. The only years we figured we had mackerel before that was when they were on the surface (FE 58).

The large seiner captains report that some of them were sent to Europe to find out about mackerel seining because, "if not us, someone else would catch them" (FE 58). In Europe they learned about the high frequency sonars. One skipper told us that he was one of the first to use the new technology.

Starting in the 1990s, new, high frequency sonars were introduced that made mackerel much visible and thus improved the catchability of mackerel in the seiner fleets dramatically. Prior to the 1990s and still for some years, the fish could only be caught when seen on the surface. Now they can be targeted and followed by the fleet. A harvester who has been fishing on large seiners for many years explains:

Herring and capelin, both those species had an air bladder in them, right. And that's what the sonar picks up…like 45 kilohertz…would pick up capelin or herring. To pick up mackerel, you need at least a 150 to a 200 kilohertz [sonar] to pick up that species fish because they don't have a swim bladder. So if we didn't see them on the surface you wouldn't know they were there. But, when the high frequency gear came on stream, well then you could see 'em, and I think that's why we're catching more mackerel now than we did" (NC6).

Local harvesters started to use high frequency sonars in the late 1980s and early 1990s. As the interest in mackerel grew, more and more harvesters invested in this technology. The owner of a small seiner (under 65 foot) relates how he changed to high frequency sonar about 10 years ago:

I went fishing with somebody else in [the] company, and they were seeing fish that I couldn't see. And I started losing. 'Cos I was leaving places where the fish was. Wasn't really, you know, like the bays weren't full, but there were a lot of fish there. And I couldn't see. So that's when I changed to this kind of gear (NC9).

Table 9 Changes in fish-finding equipment reported by harvesters in the large seiner fleet harvesters N=4

Years	1960s	1970-1972	1973-1975	1975-1978	80ies	90s	2000
Type of sounder	Dry paper & needle display	Dry paper & needle display	Dry paper & needle display	Dry paper & needle display	Dry paper & needle display	Screen display	Screen display
Type of sonar	Wet paper & needle display; 50 kHz	Wet paper & needle display; 50 kHz	Screen display; 50 kHz	Screen display; 50 kHz	Screen display; Dual system: 50 kHz (herring, capelin); 120 kHz (mackerel)	Screen display; Dual system: 50 kHz (herring, capelin); 120 kHz (mackerel)	Screen display; Dual system: 50 kHz (herring, capelin); 120 kHz (mackerel)
Sonar range	250 m	250 m	500 m	1000-1500 m	1000-4000m	1000-4000m	1000-4000m
Species caught	herring	herring	herring	herring & capelin	herring; capelin; mackerel	herring; capelin; mackerel	herring; capelin; mackerel
Number of vessels described in sample	3	4	2	3	3	3	3

Table 10 Changes in fish-finding equipment reported by harvesters in the small seiner fleet (N=8)

Decade	70ies	80ies	90ies	2000
Type of sounder	paper	paper	paper	Screen
Type of sonar	none	50 kHz	50 kHz	Dual system: 50 kHz (herring, capelin); 200 kHz (mackerel)
Species caught	capelin; herring; mackerel	capelin; herring; mackerel	capelin; herring; mackerel	capelin; herring; mackerel
Number of vessels described in sample	2	6	5	14

The following dialogue illustrates how dramatically the high speed sonar improved fishing for small pelagic fish:

Researcher: What kind of difference does the sonar make, having the sonar?

Harvester: Sonar is a big difference… you try to put your seine around the fish instead of getting in among 'em. And with the sounder you had to get in on top of 'em, we'll say. Before you could see 'em…

Researcher: What difference did it make, though, when you didn't have to get in among the herring?
Harvester: Well like if it's a real large school it's not so bad but, say, if it's small schools, like small 100 ton schools, and 50 ton schools and stuff like that, if you're in on top of it and you sought you'd probably as soon as you shoved her in gear and dropped the skiff...and they still do it yet too, you don't always catch 'em but you got a better chance if you can be ready and stand off clear of 'em like, and watch 'em on the sonar. And then you drop and try to put your seine right around it without touching, eh?...But if you're in on top of it and you start up and you shove your motor in gear and drop the skiff well the noise...they're gone eh, before you get around.

Researcher: So you went through a big change there.

Harvester: Oh it's a big advantage, yeah. Big advantage.

Researcher: What kind of, I mean I know it's hard to estimate but what percentage of improvement would you say that would have been?...

Harvester: Yeah, there would be 70 to 100 increase, I would say.

Researcher: In your efficiency?

Harvester: Yeah. And on mackerel of course I would say it's 100%... Like this past couple of years we haven't seen any [mackerel] hardly on the surface, but the past year we landed, pretty near landed our share of the mackerel quota here. (FE 58)

Night fishing and the use of lights

Being able to see mackerel in the water using sonar technology rather than only on the surface also means that harvesters are no longer dependent on daylight to locate the fish. At night, mackerel are attracted to light and purse-seine and tuck seine harvesters use this behavioural propensity to draw the fish together and trap them in the seine. The use of lights makes it much easier to catch mackerel. Some boats, mostly smaller tuck seiners, tow a light boat in addition to the skiff they use to set the seine around the shoal of fish. A tuck seiner describes how the light boat is used:

> *Well, we draw the fish up with the big lights on the boat…and when we start fading out the big lights on the big boat…we'll drop one person in the light*

boat to haul the anchor so we'll go back in the darkness and the big boat will be black, there'll be one light on in the washroom just so you can see the winch on the deck of the boat and when we come back around, when we start to set the seine around the little boat, cause all the fish is come into the small boat, under the light, right, and you make a circle and it makes the air, the bubbles in the water, right, same as a whale would do and, you know, drive the fish together… and next time when you come around you let the seine go and all the fish'll take off in under the boat, in the dark, they figure they're hiding away... The small boat, he got to hide, he stays in the seine. He'll haul his anchor and just rows back to what we call the bunt end of the seine (NC4a).

Other boats have lights on the main boat and fish in pairs taking turns using their lights to attract the mackerel so the other boat can seine them more effectively.

Researcher: *And do you use lights when you fish?*
Harvester: *Yeah, yeah. You can see, if you have any mackerel around and if they're scattered you draw them closer to the boat and, say, my brother will set around me and when he gets his seine put together and haul[s], I'll just shut off the lights.*
…
Researcher: *So then, if your brother and you do that together then do you both then pump out of that seine?*
Harvester: *If there's more to load.*
Researcher: *And if it's not then you take turns?*
Harvester: *Let's say I fish here and he's loaded, then I'll let him come in and if I've got fish around my lights I'll let him come in and get close to me and I'll gradually start shutting off so many lights at a time and let them go to him. And I'll get ready to go around.*

Towing a light boat can be safety hazard as purse-seine skipper explains:

Harvester: *Well some fellows use the light boat. I think its torture trying to tow that around. And you're caught in the wind and everything else. In the bays now, they can manage it 'cos the weather's always like the harbor here, but we're on a rocky coastline, say a straight coastline you've got to fish out some twenty, thirty miles away. It's no place for a small boat.*

Night-fishing and the use of lights are not regulated in any way, and another harvester suggested that either DFO or the Department of Transport could bring out regulations for night fishing as some boats do take chances by driving along the shore with just the pit lamp:

They got little boats going around along the shore with lights on, just, you know, no port, no port light, no starboard light, just the light, just the pit lamp saying, if the mackerel is chasing 'em, chasing 'em and he's taking all

the mackerel along the shore and then the seiner comes and sets around him (NC 11).

This practice was confirmed by a gillnetter, who told us how he occasionally would act as a light boat for another harvester:

Harvester: *I was just a light boat, I have four lights on the boat …I just take [the mackerel] up and haul them up with the lights … and he set around me and got mackerel*

Researcher: *So do you do that a lot?*

Harvester: *Oh yeah, everybody does that, every boat goes out takes another goes around the cove and finds the cove and finds the mackerel and figures the mackerel is going to be in the light and just leaves that boat there and goes around turns the generator on and goes back and goes on turns off and gets the mackerel. …*

Researcher: *But now you say you were the light boat?*

Harvester: *I was just on my own, and when I get a load and then he gets a load he loads me up.*

Researcher: *They don't want you to...*

Harvester: *Nope, you're not allowed to give it to no one else.*

Researcher: *but everyone does that.*

Harvester: *Oh yeah.*

Researcher: *So, if you get a load of fish out of that arrangement, because the guy your buddy seined it, and then you know the seiners, how do you report that fish?*

Harvester: *I report it as hand line or whatever (NC 17).*

Fishing Methods

The majority of mackerel landings are caught by purse-seines. In 2011, only 4 or 5 harvesters were known along the west coast of Newfoundland to be handlining for mackerel commercially (NC5) and these harvesters were all based in the area around Port Saunders. Individual harvesters who handline for mackerel land much smaller quantities of fish than seiners and their catch is mostly sold for use as bait. They also use some of their catch for subsistence purposes (NC 3; NC 17). Thus, handlines and traps (Figure 14) account for "a very small percentage of the catch. Mackerel is almost ninety-nine percent purse-seine…there's probably only two or three crews trapping pelagics" (J. Spingle NC5).

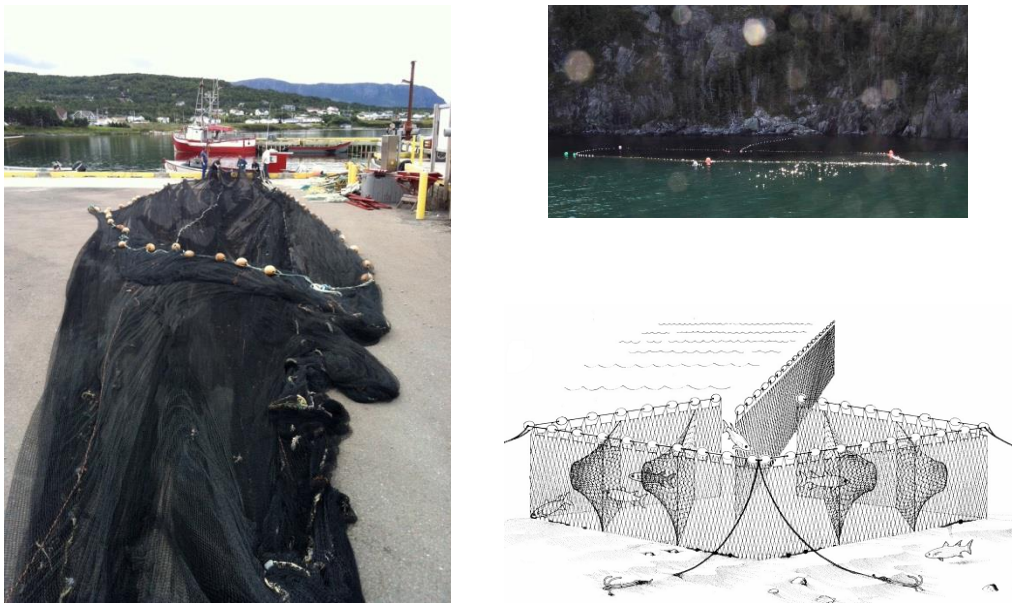


Figure 14 Left: A crew is loading a mackerel trap in Rocky Harbour (photo: John Paterson). Top right: a mackerel trap in the water (photo: John Paterson). Bottom right: Buoys and anchors are used to set the net into a box shape in shallow water (http://njscuba.net).

Tuck seining

Since the early 2000s a new type of gear has appeared in the fixed gear fleet, the so-called "tuck seiner". The different name obscures the fact that tuck seiners are basically purse-seiners. By regulation the only difference between them and the purse-seine fleets lies in the size of the seine. By regulation, tuck-seines may only be 80 fathoms long whereas purse-seines have no limitation (IFMP 2007). However, this limit on the size of tuck seines does not seem to be enforced. All tuck seiners who participated in our research stated that their seines are 120 fathoms, the same length as the purse-seines used in the under 65 foot fleet.

According to an under 65 foot purse-seine skipper:

> *They're all purse-seiners… Then they went around and the fisheries, people complained that their seine was too long, [a tuck seiner is] only allowed 90 fathom, [but] there was people using 130, oh they was, they was. Anyhow they complained, inspectors coming and saying 'run the seine on the wharf,' and six foot in a fathom, they count the rings, the purse rings on 'em. I could have a seine, 120 fathom long with only 12 purse rings on it. They count the rings, they said the rings two fathom apart, nothing wrong with the seine, only come out 70 or 80 fathom, eh?* (NC 11).

For fixed gear harvesters who use tuck seines, the mackerel fishery is the longest fishery in their annual cycle:

> A*t the lobsters we do get six to seven weeks…, but once that's over then you've got the turbot and you only get three or four days and the corners*

are so sharp, you've got to take everything out of the water, same thing with the halibut, you've got a one day fishery and then it's out of the water and the longest fishery we got right now is the mackerel (NC8).

In 2005 tuck seiners landed 6,393 tonnes of mackerel.

A young tuck seiner expressed concern at the fishing capacity increase in the mackerel fishery due to more and more fixed gear harvesters changing to tuck seining:

Harvester: *But myself personally, I am concerned about too many boats getting involved and fishing and I mean I think it will affect the mackerel fishery… there's only so much fish and they can only reproduce so fast* (NC 22).

Scientific Advice and stock status

The stock status of Atlantic mackerel is uncertain. According to the emerging species profile sheet of the Department of Fisheries and Aquaculture (DFA no year), "Mackerel resources in the northwest Atlantic appear to be declining". In 2010, "the [Transboundary Resource Assessment Committee] consider[ed] the status of Atlantic Mackerel to be 'unknown'" (TRAC 2010).

Since 1972 estimated spawning biomass of Atlantic mackerel has declined. Apart from occasional large year-classes in 1967, 1982 and 1999 recruitment has generally been decreasing. Relatively low recruitment estimates since 1982 may indicate that the productivity potential of Atlantic mackerel may be less than previously believed. Similarly a lack of older fish in the USA and Canadian landings since 1990 may indicate low productivity and high mortality.

DFO stock status reports from 1999 to 2010 indicate there is a lot of uncertainty around the biomass estimates for the Canadian portion of the Atlantic Mackerel stock. Furthermore, methods to determine biomass estimates have been changed several times and there have been problems with their implementation. For instance, the scientific stock size estimation for Atlantic Mackerel is based on an annual egg survey in the Gulf of St Lawrence and on an annual bottom trawl survey along the US coast. The egg surveys conducted in 1989, 1996, 1998, 2000 and 2006 did not take place at the optimum time to match the ideal spawning period resulting in deficiencies in "the theoretical model used to calculate the proportion of eggs laid daily and over the entire spawning season" (DFO 2002b). However, a correction is now applied and the SSB of those years were updated (NC 29). Since 2001 a new method has been used to determine daily egg production, which is based on mean daily gonadosomatic index values. The new biomass estimates based on this model are considered to be more accurate, and they differ from the early ones but are close to those determined based on the DFRM. Nonetheless environmental variability and uncertainties still affect confidence in the biomass estimates.

In addition to the annual egg survey conducted by DFO, larval surveys were conducted in 2004, 2005, 2007, 2008, and 2009 on the west coast of

Newfoundland (Grégoire et al 2006a; Grégoire et al 2006b; Grégoire et al 2009; Grégoire et al 2011a; Grégoire et al 2011b). The area from southern Bonne Bay to Bay St George was sampled with plankton nets. These surveys were carried out on a commercial vessel and funded by Barry Group Inc. who controls most of the large purse-seiners. Unexpectedly, mackerel eggs and larvae were found at almost every station (NC 29 notes). The annual egg surveys indicate that mackerel are spawning less in the southern Gulf, which used to be the main spawning ground for mackerel in Canadian waters. The results from the egg and larval surveys and the distribution of landings suggest that the mackerel stock is slowly moving to the North, a phenomenon that is also observed in Europe (NC29 notes).

There seems to be a general lack of understanding of the dynamics and stock status of mackerel. Landings from the bait fishery are unrecorded and the DFO perspective seems to be that this may potentially be a factor impacting on the Canadian mackerel stock. Mackerel are sensitive to environmental variability and changes in the temperature regime have been observed so this could also be playing a role in influencing Mackerel migration abundance (NC 29).

Key issues from the scientific assessments

Notwithstanding the uncertainties around the mackerel assessment and the overall rapid and substantial decline in actual landings the investments made by harvesters reflect confidence in the abundance of mackerel.

Harvester: *A boat could be carrying four, five, no seven hundred thousand pounds. The big black one you're talking about in Bonne Bay? Seven hundred and fifty thousand. And I've seen that thing load twice a day. Crazy. No need for that, especially those big boats… But still our scientists is telling us there's no danger, they're seeing the mass of [mackerel] spat in the gulf, it's unreal (NC 12).*

Nonetheless many of the harvesters we spoke to, especially older fishers but also some of the younger people, expressed concern about the Mackerel stock. Harvesters referred to a recent downward trend in catches and that the mackerel arrive later every year:

Harvester: *This here is the first time in a long time that we never caught mackerel yet [in September], and nobody seen signs of mackerel yet this year, right? Last year [2011] we fished them in September and the year before last in September we had a lot of fish for mackerel. I don't know if got anything to do with being caught or if some people thinks it's the water temperature is too warm and they're not here so, hopefully that's the case. In reality nobody knows; it's only just guessing* (NC 22).

Harvesters also report that mackerel "don't come to the surface anymore or, [not] very often" (NC6). One explanation for this change in behavior is a possible change in the temperature regime. Warmer water temperatures may keep the

plankton at deeper levels and because "the plankton stayed down the mackerel stayed down" (NC6).

Although it seems to be generally known that the scientific knowledge on mackerel is limited, many people we spoke to said that mackerel are not being overfished because the landings thus far have been well within the TAC (Figure 13). However, as shown above, the Canadian TAC has been set above scientific recommendations, which explains why, despite intense effort and increased technological efficiency, the fleets have not been able to land the TAC.

Range expansion

In addition to improving their technological efficiency, purse-seine harvesters have also expanded their fishing range towards the south: "We used to go, we used to go down the southern side of Bay St. George, that's the furthest we go, eh?... We wouldn't chase them any further. Last year and this year, we chased them to La Poile (NC11A)" as well as further offshore.

Researcher: *Are you worried about the mackerel at all?*
Harvester: *Oh yes, I am worried about it. Last year was down a lot from the year before so, I don't know if it's just the weather doing it or, I mean they got to get caught up after a while. And the mackerel we used to catch we caught it as it was going back across the gulf, we're going further now and catching more of that again* (NC12).

Data fouling – bursting of seines leads to unrecorded fishing mortality

One of the older and now retired harvesters told us that seines often break, either because the mesh tears on rocky ground or corals or because the net bursts from the sheer weight of the fish. I have heard similar accounts in Namibia from purse-seiners who target sardines and anchovy, that the load of fish becomes very heavy when the fish die, because the dead fish don't float up but sink. Since mackerel lack swim bladders, a net full of mackerel might become heavy even before the fish "dries" up simply because they are prevented from swimming. Several harvesters mentioned that mackerel become heavy once caught.

After we started asking about this it became clear that seines break frequently and need constant maintenance. Since the mackerel fishery is a competitive fishery, harvesters will catch as much fish as quickly as they can. Since mackerel seem to turn into a "dead weight" soon after they are caught, the likelihood of bursting nets seems to be higher in this fishery. The practice of towing a full seine alongside the vessel towards the wharf increases the risk of breaking the net as well. Harvesters will do this when the catches are good and the boat is already full of fish. Again, the competitive nature of the mackerel fishery likely encourages this practice. One harvester explained that he used stronger twine overall and especially in certain parts of the seine to prevent breaking. But many other harvesters were very vague on the twine they used or only seemed to use one kind and not the strongest. Thicker twine is likely to be more expensive than thinner twine.

Although harvesters report that giving a load to another harvester is common practice, it seems that regulations prohibit this. Thus regulations seem to encourage the practice of transporting surplus fish in the seines. This practice is highly questionable for several reasons: dragging a heavy weight alongside the vessel is dangerous and if the seine breaks the catch will be lost. Furthermore, the lost fish will not be reported thus contributing to the uncertainties around the actual fishing mortality.

The value of mackerel

Along the west coast of Newfoundland local purse-seiners started to target mackerel in the 1980s. Initially mackerel were processed into fishmeal and oil. A local fish processor explained that smaller sized mackerel are used as bait by local fish harvesters but that the majority of mackerel landings today are sold for human consumption as a

whole frozen product...our pelagic species are generally landed in large quantities…And it's not just…put in a box and sold but it's quite a complicated process of grading and sorting and from the fresh state to quality, to feed conditions, to fat content. You got to put your product in proper form or package form for countries that will be buying it…especially mackerel has quite a range of markets in terms of size and price. And it's a bit more global (NC 14).

Mackerel are in high demand. Since 2009 the minimum price for mackerel has increased between 19% and 35% depending on the size class (Table 6). On a provincial scale both the volume and value of mackerel landings have increased dramatically since 1990 (Figure 15). The increase in value combined with the shift in Newfoundland catches from the east coast to the west coast (Figure 12) has created a situation where buyers from elsewhere in the province and other parts of Canada are seeking to buy from west coast harvesters creating a highly competitive environment for local buyers and processors.

Processor: *Most prices are negotiated, because every fisherman is part of the union…and there is a negotiation that takes place for mackerel and herring and capelin, it's a minimum price.*
Researcher: *Do you end up paying more than the minimum price?*
Processor: *Well yeah, I mean, it's not much different than anywhere else, I mean it's an auction; it's an auction at the wharf.* (NC 14)

The following dialogue with the skipper and owner of an under 65 foot purse-seine vessel describes the situation from the perspective of the harvester:

Harvester: *We got three different companies combined that takes our fish and shares it, freeze it for us, and all…So they're all calling us, calling us everyday, wondering where's the mackerel? When are you going to get some mackerel? So when I get the mackerel I'm going to start calling them and say, who wants to pay fifty cents? If you don't then, okay, I'm going to make another few calls now and if you don't hear from me I got [it] sold. And they're all, oh, just a second just a second, we can go up to forty-five. Oh yeah, I'm not going to give anything*

away but the demand is there, so be it for bait and food. It's unreal the demand….And they're getting over two dollars a pound for it, so why… shouldn't we be getting at least fifty cents for it. I know they got a lot of work to truck it and freeze it and get it to market. I got a broker in Montreal that looks after me. He does all, gets all my sales in for me.

Researcher: *So how does that work?*

Harvester: *Well he's in with the companies and he finds the market for the companies and, like last year, they were paying me less than what I could have gotten from another place so I goes and sells a load of fish to another company. And he called me up on the phone and he says - I don't know how the hell he found out I was only there for fifteen, twenty minutes unloading - and he says, what are you doing unloading fish there? I said, how do you know what I'm doing? Well I know, he said. From Montreal! He said, well, you could have called me and given me a chance and I said well I'm getting more money from this guy. So he said well what is he paying you? And I told him what he was paying me. And he said well you could have given us a chance, we could have paid that. So, well, why didn't you pay me that then? Why are you just waiting for someone else? Well I can't blame them they're just business people. I do the same thing. I said, well now, I need another five cents a pound if you want the fish. So, okay, he said. Well from now on whenever you're going to move, give me a call first and make sure.*

Researcher: *So when you telephone you actually speak to this guy?*

Harvester: *Yeah.*

Researcher: *And he works with the three [companies]?*

Researcher: *Yes, and he'll get the pumps set up for me and make sure whatever I need is there. We got three pumps and five tractor-trailers and nine men crew on the dock to unload the boat. And wherever we go they chase us. And they stay in the hotels there.*

A fixed gear harvester who handlines for mackerel told us:

Harvester: *There's three or four buyers in the area; some around Port au Basque…*

Researcher: *So that is all for the herring?*

Harvester: *Yeah.*

Researcher: *and then for mackerel, is it the same?*

Harvester: *yeah, same guys. Except for the seiners, they got buyers coming in from the east coast, one buyer here now that he sells.*

Researcher: *He's here already.*

Harvester: *Yeah.*

Researcher: *So he drives up.*

Harvester: *Yeah, he has a crew and stays in the motel for two weeks, three weeks till we finish here and he chases them all up the coast. He goes over to Bonne Bay and Port au Basques and goes on around.*

Researcher: *So you say he has a crew and they drive around trucks to buy the fish or?*

Harvester: *Yeah he brings all the truck drivers and brings them… He's not from around here. But he bought from those same seiners since he started buying, five or six years. And he just goes up the coast and next stop is Bonne Bay. Then he goes to Port au Basques… Somebody come all the way and stay in the motel and somebody got to pay for it. The fish pays for it…everybody eats, all the truck drivers, all coming out of that fishery. (NC 17)*

High demand for mackerel and the fact that a major proportion of the landings has shifted to the west coast of Newfoundland have altered the character of the fishery. Harvesters have additional bargaining power because there are more buyers who are prepared to pay better prices. This competition creates pressure on local processors. Local processing plants provide local employment but fish that are trucked away to be graded and packed elsewhere do not create any further benefits for the area. Thus these landings only create benefits for the harvesters. What is not clear, however, is whether this practice takes fish away from local processors. Two of the local processing plants source fish from their own large seiners (over 85 feet in length) and are unlikely to not meet their requirement for raw material, provided that mackerel are being caught. The third processing plant sources mackerel from local harvesters, most of which are based in the same area.

Table 11 Negotiated Prices for mackerel (http://www.ffaw.nf.ca)

Size class (g)	2009	2010	2011	Increase
200-399	8.5 cents	10 cents	11.5 cents	35%
400-599	14.5 cents	15 cents	17.25 cents	19%
600 plus	19 cents	20 cents	24 cents	26%

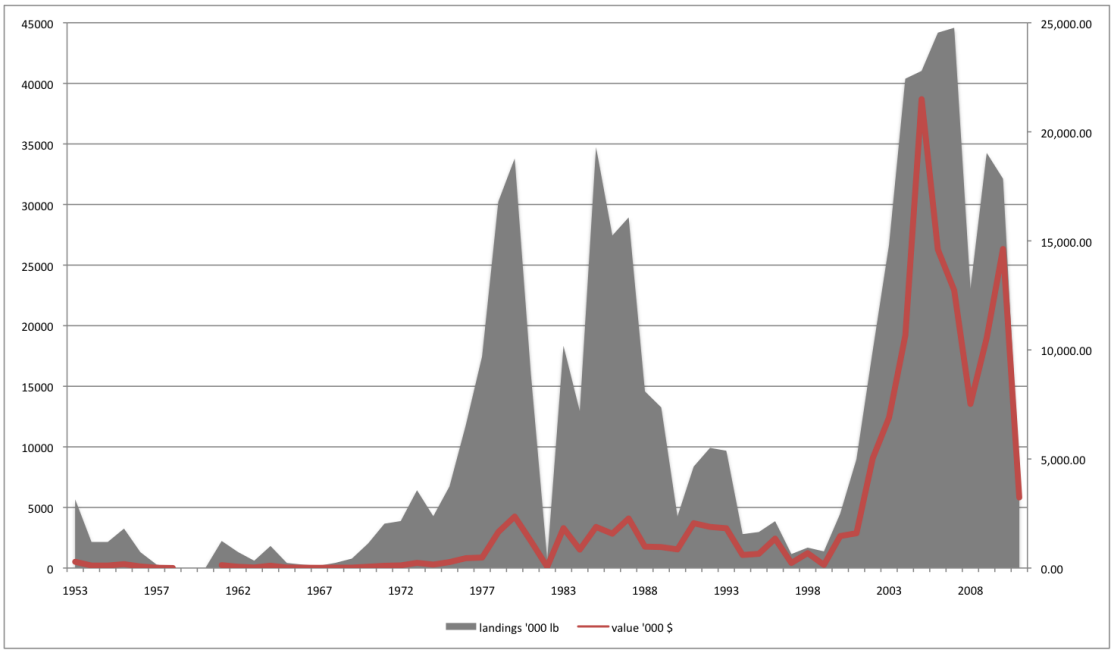


Figure 15 Mackerel landings and value of landings in Newfoundland from 1953 until 2011. Source: 1953-1975 statistics Canada, Fisheries Statistics Newfoundland; 1990-2011 DFO, Ottawa, Ontario K1A 0E6 (http://www.dfo-mpo.gc.ca/stats/stats-eng.htm)

Conclusion

Apart from the overall TAC, there are no quotas or catch limits for mackerel caught in Canadian waters making this a competitive fishery. Add to this that the mackerel price is far higher than the price for herring or capelin and it is clear that small pelagic harvesters focus on the mackerel as an important target species.

Harvesters we interviewed considered the mackerel fishery to be the most exciting of the fisheries. This is likely linked to the fact that there is a high price for the fish and no quotas or output controls for mackerel, apart from the overall Canadian TAC, which they haven't reached in years despite increased effort and efficiency. Consequently harvesters can potentially make a lot of money during the mackerel season. But when they spoke of excitement in the interviews, they were really referring to the competitive nature of the fishery and the fact that the mackerel are a fast fish that is not easy to catch. Seeing the seine full of mackerel gives them a great feeling of excitement and satisfaction, having outwitted the fish and done well. In the context of generally declining fisheries I could not help but feel that it was nice to see a fishery where fishers are making a good living and find the fishery challenging and engaging. However, along with this same thought goes the concern that unless the multispecies, small pelagic fishery is well managed, this will have huge impact on many harvesters. Some expressed concern that the situation may very well get worse over the next 10 years and that the next generation will not be able to make a living from fishing. Others, however, seem quite happy about the fact that their children are as involved in the fishery as they are.

Interactions between the 4R mackerel and herring fisheries

The previous sections of this report provide strong evidence that both herring and mackerel stocks are declining. Despite high levels of uncertainty about the landings the fact remains that effort and efficiency have increased substantially in recent years. However, despite high prices, mackerel fishermen have been unable to catch the mackerel TAC.

In the case of herring, the spring spawning population(s) in particular are in need of rebuilding but the fall spawning stock is also unlikely to sustain current catch rates (DFO 2012a).

Unlike in Nova Scotia, the 4R herring management system does not take the spatial structure of herring subpopulations into account. However, some management steps have been taken to protect what is considered to be the main spawning area for spring spawners in Bay St. George. The southern bays from Bonne Bay to Bay St George have seen intense fishing effort in the past and even in recent years the majority of herring landings have been made there. Scientific advice to management has been to disperse fishing effort to avoid intensive fishing in these areas (DFO 1997). Nonetheless, fishing pressure has been spatially disproportionate and more fishing pressure is exerted by herring seiners in the Southern bays including Bay St. George where the closure is only seasonal (Figure 10).

Pulse Fishing

West coast Newfoundland harvesters catch mackerel during their fall migration. Fixed gear harvesters who jig mackerel in the Port Saunders area are usually the first to land mackerel in July and August. They catch mackerel while they are still scattered (NC17). When the mackerel start to "bunch up", i.e. larger, tighter shoals of mackerel appear, they are pursued by seiners, which tend to postpone the herring fishery until the mackerel season is over. During the interviews, we asked harvesters to mark fishing locations for mackerel and herring on a map:

Researcher: *So where did you catch the mackerel last year?*

Harvester: *the whole coastline back and forth… we had some in St. John's Bay and then up in Bonne Bay and … we had some in the Bay of Isles.*

Researcher: *So do you follow the mackerel?*

Harvester: *Yes, yes try to. We try to work to the west, cos they're supposed to head for warmer water, later in the fall.*

Seiners from Port au Choix and Port Saunders follow the mackerel migration southwards. Tuck seiners can only fish as far south as Bonne Bay. Several harvesters who were recalling past fishing locations commented that "the entire fleet" or "20 boats" had been fishing in the same spot simultaneously both while targeting mackerel and also during the herring fishery.

An older skipper of an under 65 seiner uses the metaphor of 'a city of lights' to describe this very intensive, multi-vessel fishing that takes place in Bonne Bay places along the coast:

> *(The mackerel) goes in Bonne Bay, eh? And it's so nice and peaceful and quiet in Bonne Bay. The first thing there's lights on here, there's lights on there, there's lights on there, lights coming from everywhere, eh? Sometimes you drive 'em right out of the water. It's only natural, my dear, it's only natural to understand that fish are not used to a city. It's just like a city. You take 25 or 30 boats with lights on 'em, that's just a little city my dear. A little city out in the middle of nowhere; that city wasn't there last night, eh? And that happens all the once, within a half hour… And here she is, a city* (NC 11).

Several harvesters suggested that this practice of pulse fishing has negatively affected the availability of mackerel in Bonne Bay.

So, you got the lamps on [in Bonne Bay] one night, [the mackerel] are not there tomorrow night. That's what they're not, they're not there the next night (NC 11).

Two skippers of large company-owned vessels suggested that light fishing tends to drive the fish away:

1st Harvester: *You know it's just the same as down in Bonne Bay. When it was only a few small boats at it, Bonne Bay was a good place for a few mackerel. And you could probably go back a second night and get 'em there. Sometimes, but you don't do that now. You got a job, about two hours. It's… different. I guess they adapted to it. Got to do what they had to do to survive.*

2nd Harvester: *Well we do think that it is it is a good way to catch them it slows down the mackerel and then say I'll put on the lights, [*name] will come and set around me, set around the boat (..). But in most cases that's all you'll get, they're gone then. And that's why I'd sooner not use 'em [lights].* (NC 6)

A Port au Choix based under 65 foot purse-seiner agrees:

Harvester: *Generally years and years ago [the mackerel] would go [into Bonne Bay] and stay three, four days even a week. But now, you get a night or so that's it. There's too many lights now. Everybody is lighted up and trying to fish.*

Although the two large seiner skippers suggest that the lights are disturbing the mackerel and causing them to shift away, the implication is that more often than not there are many boats fishing at the same time in the same place. This raises

questions about the effect of pulse fishing on fish aggregations. Are the fish being driven away by lights or fished out of the water?

Another issue arising from competitive fisheries that target aggregations of fish is that of safety when boats fish in close proximity to each other. There is an informal rule among seiners to keep a quarter of a mile distance between each other. This also speaks to question of who has the right to which "piece" of fish. An under 65 foot seiner skipper explains:

> *Sometimes you'll hear 'em my dear, they gets on the radios calling one another everything. They gets into a row (…) he's blackguarding and cursing and swearing 'you got your goddamn seine out too handy to me. I got me lights on, you're too handy to me'…. They're saying, 'okay we'll stay a quarter of a mile [away from each other]'. Some feller puts his lights on, buddy sets around 'em, he jumps out over the cork line again and got the lights on again, he wants this whole goddamn thing to hisself, eh. He's saying 'stay away [name], I got the lights on'. He just had his lights on and got a load of fish for one feller, eh, he got his lights on again, you know…I could be fishing up in this bay, small bay say half a mile wide, I could be fishing there half the night. Buddy comes and puts his lights on, drives me out of it, you know…. I can't go there and set because he's saying 'you're not a quarter of a mile away from me there'…. But I was there fishing before he come there. He come there and put his goddamn lights on and stop me from fishing. It's a racket.* (NC 11)

Spatial distribution of fishing effort

There are 26 seiner licenses in the mobile gear category. Most of these vessels are based in the Bay St George, Port au Port and Bay of Islands region. One large seiner is based in Bonne Bay, and several small seiners are based in Port au Choix and Port Saunders. We interviewed seiners from both the southern and the northern part of the coast and all report that they catch herring in the South, from Bay St George to Bonne Bay. Although there is abundant herring in the north very few herring are caught along the northern part of the west coast. "Like St. John Bay, Port aux Choix, all down that coast, there's very little herring taken these last 20 years. Not worth mentioning what's taken" (NC 20). This means effort is not evenly distributed across the fall spawning aggregations increasing the risk of localized overfishing. This raises the question why the purse-seine effort is concentrated on the southern bays when fishing close to one's homeport seems to be more cost efficient than fishing further away as it requires less fuel and less in the way of accommodations, food and other costs.

During the most recent acoustic surveys most of the herring in the northern part of the west coast were found on or near the bottom, whereas in the southern part herring were found in the water column and near the surface (NC 29).
It is thus possible to assume that the skewed catch distribution is simply a consequence of the fact that herring in the northern part are unavailable to the purse-seine fleet.

However, it is interesting to note that none of the fishers from the northern area cited lack of catchability as the reason why they catch herring in the south. In fact seiners from Port au Choix and Port Saunders report that in the fall herring is indeed available close to their homeport.

Seiner: *…Round here, I would say if you went out here [around Port au Choix] at night you wouldn't be gone no more than an hour in the evening time and you'd get to see the herring.* (NC9)

Seiner: *But there was lots of it here [near Port au Choix] and we see it every morning when we're going out shrimping.* (NC10)

Rather harvesters make an economic argument for the unevenly distributed fishing effort, namely that due to the higher value of mackerel they prefer to focus on that fishery first. Thus seiners follow the mackerel migration south and once this fishery is over they catch their herring quota on the way back. The following dialogue with a seiner captain (under 65 foot category) from Port au Choix describes how the herring and mackerel fisheries are linked:

> *Seiner: Yeah, we fish herring in Bay St. George. And uh it doesn't matter we go anywhere, wherever the fish is at, in Bay of St. George, in Bonne Bay. Bay of Islands is an excellent place for herring and anywhere outside on the outside route or in the bay…*
> *Researcher: Okay, and where do you prefer to catch it?*
> *Seiner: You like to be in the bay somewhere*
> *Researcher: Okay, so if it's in Bonne Bay, it's good?*
> *Seiner: Oh yeah it's good, and it's on the way home and whatever for us 'cos like we usually catch [herring] on the way home.*
> *Researcher: …from the mackerel.*
> *Seiner: and uh, round here, I would say if you went out here [around Port au Choix] at night you wouldn't be gone no more than an hour in the evening time and you'd get to see the herring.*
> *Researcher: Okay, so why do you catch the mackerel first?*
> *Seiner: It's global. Where my quota is individual.*
> *Researcher: So you save your [herring] quota?*
> *Seiner: Sure. And go after the one that's there for the open, open season. What we call open season. It means that the more you can get, the better for you.* (NC9)

This practice of catching herring on the way home from catching mackerel by the northern fleet, in combination with the concentration of the large seiners and a substantial proportion of the under 65 foot purse-seiners in the south, means that very few herring are caught along the northern part of the west coast:

"*Like St. John Bay, Port aux Choix, all down that coast, there's very little herring taken [by Purse-seiners] these last 20 years. Not worth mentioning what's taken*" (NC 20).

It has been suggested that the reason why seiners catch mackerel before they catch herring is because "herring are offshore when mackerel are inshore" (NC 29). However, the seiner captains we interviewed reported that this practice is linked to the increased value of the mackerel and the different quota regimes. Because mackerel is a competitive fishery the seiners want to catch as much as they can while the mackerel are available. The herring is available longer and the individual quotas determine the amount of fish each seiner is allowed to catch. Thus the seiners prefer to leave the herring in the water while the competitive mackerel TAC is being fished:

Researcher: *Okay, so why do you catch the mackerel first?*
Seiner: *It's global. Where my quota is individual.*
Researcher: *So you save your quota?*
Seiner: Sure. *And go after the one that's there for open, open season. What we call open season. It means that the more you can get, the better for you.* (NC9)

The value of mackerel increased dramatically between 2000 and 2010 (Figure 15; Table 6). It is not clear why this has happened but it may be linked to the opening of a new Chinese market for mackerel in 2003 and associated increased exports of Canadian mackerel to China (DFO 2007a).

As a result the landing price for mackerel is far higher than the price for herring or capelin. In 2011 the price per pound of fish was up to 24 cents for large mackerel, 14 cents for herring, and 10 cents for capelin.

Moreover, many of the harvesters have agreements with fish buyers, for whom cold storage space is a constraint. Many of these agreements are based on mackerel:

> *We spend all fall trying to avoid [herring] because [of] our buyers. The mackerel fishery is that lucrative to them that they don't want to put any herring in the cold storage until the mackerel fishery is finished* [NC10].

In light of these combined factors it is no surprise that harvesters focus on the mackerel as an important target species.

Competitive mackerel fishery has led to efficiency increase in the herring fishery

The west coast purse-seine fishery expanded during the 1980s (DFO 2007a). Many of the under 65 foot seiner harvesters interviewed either started seining for mackerel in the early 1980s or switched to larger vessels as part of their seine fishery. In response to increased commercial landings "and uncertainties related to both unreported catch (bait and recreational) and to the scientific information concerning the level of biomass, DFO in 2007 introduced some effort control measures in the form of "a freeze on authorizations for new mobile gear activities for fishing Atlantic mackerel" (DFO 2007a, p. 15). By then capacity in the fishery had already increased substantially. Besides the company-controlled large seiners, most of the independent seiners are operating vessels close to 65 feet in length. In addition, several fixed gear harvesters have switched to tuck

seining using 40-50 foot vessels. These investments in larger vessels have been supported (if not encouraged) by an unusual abundance of mackerel along the west coast of Newfoundland between 2000 and 2010, combined with an increase of the value of mackerel. In the absence of quotas and individual catch limits the larger boats and efficient fishing gear enable harvesters to catch larger volumes of fish when they are available.

These developments have affected the herring fishery in as much as the same fishers participate in both fisheries. For fishers operating in the mobile gear sector vessels have become larger while individual quotas have remained the same. As a consequence some successful harvesters who have the financial means to do so, have sought to increase their individual quota by obtaining additional licenses.

Seiner 1: *Everybody in our fleet, like our size boats, like us and [name removed] had the same herring catch, the only ones got more were if someone bought extra quotas*

Researcher: *mm-hmm, another person's license, yeah*

Seiner 1: *Yeah, we bought out a guy the other year, us and [name removed], see. So. Us and [name removed] we bought out the, well*

Seiner 2: *My brother-in-law*

Seiner 1: *And my first cousin's license the other year [...] We had to buy him out then and so we've got extra capelin and extra herring. Most people now in our fleet got the same amount of herring; the only people who got more are people who bought and combined.*

Seiner 2: *The regular quota for herring for the small seiners is 630,000. We got 960,000 now because we bought a feller out between us, right?* (NC 20)

The number of licenses in the fixed gear fleet has not changed but as many have changed to tuck seining there is now a highly efficient and mobile gear being used within that fleet that is contributing to increased landings. While the use of traditional fixed gears has declined, in 2005 tuck seiners landed more than 6,000 t of mackerel. In 2011 there were about 20 tuck seiners fishing both herring and mackerel on the west coast. Before tuck seining started the fixed gear herring quota share was never caught. But in recent years tuck seiners in area 13 have caught the full fixed gear quota for that area, whereas in 2010 and 2011 gillnetters in area 14 caught the entire fixed gear quota in the spring due to an unusual demand for herring as lobster bait. This left for tuck seiners only enough quota to cover the bycatch of herring that came with the mackerel fishery (Jason Spingle FFAW).

Conclusion

Fishers on the west coast of Newfoundland have historically caught small pelagic fish using multiple gear types including traps, gillnets and purse-seines, but more recently traditional gears are used by fewer and fewer harvesters and in 2011, only 20% of fixed gear licenses were active. Of those that were active, roughly 18% were using tuck seines which are actually a form of purse-seine. Thus there are three fleets using purse-seines: large seiners in the over 65 foot category, smaller purse-seiners in the under 65 foot category and so called tuck seiners in the under 45 foot category. Purse-seine fishers catch herring in the spring, followed by capelin, and then mackerel and herring in the fall. I was told that this is the only place in eastern Canada where the same fleet of purse-seiners catches three species of fish (NC 29). Historically herring landings used to be dominant but more recently mackerel have become important. Although the same participants are involved in each case, each fishery is managed separately under different management regimes. This management approach assumes that because the three fisheries take place at different times of the year there is no interaction between them (Don Ball, email comm. 24 9 2012). This stovepipe approach to fisheries management (Pinkerton 2007) that treats these fisheries as temporally and spatially distinct and ignores that from the perspective of the fishers this distinction is much less clear. A social-ecological lens brings to the surface the social and economic connections that lead effects across fisheries and target species.

Due to spatial changes in mackerel migration patterns the 4R mackerel fishery has benefitted from high abundance of mackerel in recent years. This abundance coupled with an increase in mackerel value and the absence of local catch limits have made this fishery the most profitable of the small pelagic fisheries in this area. Consequently harvesters concentrate on catching as much mackerel as they can while the fish are available, and postpone the herring fishery. The highly mobile purse-seiners follow the mackerel shoals south along the coast as far as they are permitted. As a consequence and in the absence of any spatial management measures they catch their herring quotas in the southern bays rather than along the northern part of the coast.

This fishing behaviour contradicts the scientific recommendation to disperse fishing effort on herring to prevent uneven pressure on the spring spawning component. It should be investigated if the continued uneven effort distribution is linked to the decline of the spring spawning stock.

Moreover, until recently the herring quota allocation for harvesters fishing with traditional fixed gear was more than sufficient as was evident in a surplus of quota at the end of every season. But in recent years these allocations are caught up through the coupled effects of increased efficiency (tuck seining) and the opening of new markets for herring as bait.

The result is not only strong pressure on both mackerel and herring but also an increased dependency of harvesters on the mackerel, which creates pressure on harvesters, in particular the under 65 foot seiners and tuck seiners who have invested heavily in vessels, gear and equipment based on the promise of a

lucrative mackerel fishery. Their profitability relies on a strong market for mackerel, and an abundance of mackerel long the west coast. However, mackerel biomass is declining due to unsustainable fishing levels and TACs that were set above scientific recommendations.

Thus changes in mackerel migration (which may be temporary), improved prices and an open quota management regime for mackerel have inadvertently created a situation that is detrimental for both herring and mackerel as well as the people who fish them – particularly those in the fixed gear sector. It is clear that the management of these complex fisheries requires more thought. To manage these fisheries according to separate management regimes with no regard to the interactions that affect both the fish stocks as well as the harvesters whose livelihoods depend on them is clearly not appropriate or practical. Instead, management needs to take into account that the 4R small pelagic fishery is a complex multi-species fishery.

In the case of the herring fishery it is important to note that although scientific reports repeatedly stress the need for better fishery dependent data, and notwithstanding the fact that logbooks are required in the management plan, no logbook data are returned. In addition the scientifically recommended spatial management measures for the herring fishery have been eroded and in the mackerel fishery TACs have been set that far exceed the scientific recommendations. It is clear that the 4R small pelagic fishery would benefit from a more innovative and interactive management approach.

There is an urgent need to work with harvesters and local communities and mobilise their knowledge. Only through the participation of local people can fisheries management hope to capture the complex interactions between these three fisheries. As fish stocks decrease so does our margin for error. We need to remember that different fishing methods require and generate different kinds of knowledge and all need to be heard on equal terms.

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Appendix 1: Videos showing seining along the west coast

http://youtu.be/66pI1fu45Bg
Herring seining part 1

http://youtu.be/28twNUe1ofM
Herring seining part 2

http://youtu.be/6HMdtfaJMLM
Herring seining part 3

http://youtu.be/hl1iaahq9NQ
On Gemini 1, Barry Fleet

http://youtu.be/YAXWRcipZSY
Setting the seine, viewd from the perspective of the skiff

http://youtu.be/yXEpjFxN-oY
Outside Bonne Bay, trying to drive the mackerel off the beach, a lot of boats around with seines set already

http://youtu.be/r0vSWjjetg8
Steaming to port