Hum Ecol
DOI 10.1007/s10745-011-9450-7

Impact of Aquaculture on Commercial Fisheries: Fishermen's Local Ecological Knowledge

Melanie Gay Wiber · Sheena Young · Lisette Wilson

Abstract The Bay of Fundy along the southwest coast of New Brunswick, Canada is one of the most densely stocked finfish aquaculture areas in the world. An inshore multi-species fishery that dates back to the earliest European settlement shares these waters, and has been the economic mainstay of coastal communities. These inshore fishermen are increasingly displaced by the expanding aquaculture industry. A recent study conducted among fishermen in Southwest New Brunswick recorded their observations about the environmental impact of finfish aquaculture and the consequences for their commercial fishery. Fishermen all reported significant environmental degradation around aquaculture sites. Within 2 years of an operation being established, fishermen reported that gravid female lobsters as well as herring avoid the area, scallop and sea urchin shells become brittle, scallop meat and sea urchin roe becomes discolored. The use of chemicals to control sea lice on farmed salmon has also caused lobster, crab and shrimp kills. These and other concerns suggest that more comprehensive and detailed studies are required to establish the environmental and economic interactions of aquaculture and the inshore fishery, as well as on the stocks on which that fishery rely. The study also points to the need for more effective use of fishermen's knowledge in designing such studies.

M. G. Wiber (✉)
University of New Brunswick,
Fredericton, NB, Canada
e-mail: wiber@unb.ca

S. Young
Fundy North Fishermen's Association,
St. Andrews, NB, Canada

L. Wilson
Dalhousie University,
Halifax, NS, Canada

Keywords Aquaculture · Local ecological knowledge · Fisheries

Introduction

In the winter of 2009, a community newspaper reported that a large number of lobsters were found dead from pesticide poisoning in several locations in Southwest New Brunswick (SWNB) (Rayner 2009). It was subsequently reported that tests found cypermethrin in these lobsters, a pesticide not approved at that time for marine use in Canada, but used elsewhere to control sea lice (*Lepeophthierus salmonis* and *Caligus elongates)* in salmon aquaculture (French 2010a, b; Trotter 2011). Lobster deaths had been linked to chemicals for sea lice control in the past and several similar reports followed in 2010 (Gustafson 2011; Rayner 2010a). These problems heightened existing tensions between fishermen and aquaculture operators. In this region, inshore fishermen hold multiple licenses for several commercial stocks, operate boats under 45 feet in length, fish the waters close to shore and rely mainly on day trips. As a consequence, their fishing grounds overlap with aquaculture production areas. In 2008, the provincial and federal governments attempted to address conflict between the two industries by forming a local planning organization called the Traditional Fisheries and Aquaculture Working Group. The working group included local fishermen's organizations and aquaculture operators in the area, as well as federal and provincial government representatives.

During subsequent working group meetings, it rapidly became obvious that little was known about the interactions between aquaculture and commercial fish stocks. In order to gain some understanding of the fishermen's perspective and to suggest future directions for research to address this gap, a small study of fishermen's knowledge on recent ecological change near aquaculture sites was undertaken. This paper

Published online: 10 January 2012

reports on the findings of that study. Fishermen reported changes in: indicators of environmental degradation, distribution of commercial species, health of commercial species, and location and timing of fishing. They also reported specific concerns with aquaculture management. The paper concludes that fishermen's knowledge can provide vital direction for future research into the interaction between aquaculture and capture fisheries.

Since 2006, some members of the Coastal Community University Research Alliance (CURA) had been examining the interaction of finfish aquaculture and the capture fisheries in SWNB. One of these was the Fundy North Fishermen's Association (FNFA), which represents approximately 75 inshore fishermen in SWNB. Two academic team members of the Coastal CURA, together with the support staff for the FNFA, designed and conducted the study to compare two areas where aquaculture has long existed with one area where it has recently been introduced (Fig. 2).[1] The study relied on active fishermen who are on the water at all times of the year and use various types of fishing gear, including scallop draggers, lobster traps, and urchin diving equipment. During focus groups, fishermen were asked about their fishing licenses, fishing locations and years of experience. They were asked about the changes they had observed in the marine environment over their career and how these changes had affected fishing patterns. Finally, they were asked about any concerns they had with aquaculture in their area. The focus groups took place over a two-week period in October 2010. This short time frame was dictated by the time constraints of a multi-species fishery, and in particular by gearing up for the winter lobster season, which begins in mid-November.

The Economy and Management of the Inshore Coastal Zone in Southwest New Brunswick

The SWNB area of the Bay of Fundy (Fig. 2) is a rich marine area containing significant habitat for key commercial species, including spawning areas for cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and pollock (*Pollachius virens*) (Graham *et al*. 2002). It contains at least two important spawning grounds for herring (*Clupea harengus*), and many pockets of scallop (*Placopecten magellanicus*) and sea urchin (*Strongylocentrotus droebachiensis*) beds. Most importantly, it supports important spawning and nursery areas for lobster (*Homarus americanus*), which currently form the backbone of the inshore fishery.

The inshore fishery in SWNB began when Europeans first settled the area in the mid-eighteenth century and it continues to be the principal economic driver for most coastal communities. Many inshore fishermen are fifth and sixth generation fishermen. The earliest recorded herring weir was in 1797 (Doucet and Wilbur 2000: 5) and herring and groundfish dominated the fishery until the introduction of new fishing technology (draggers) decimated the groundfish stocks (Wiber and Kearney 2009). After the groundfish collapse, lobster stocks rebounded; today the lobster stocks in this region of New Brunswick are at an all-time high. There are presently 175 lobster licenses issued for this region of New Brunswick (Lobster Fishing Area 36). The fishermen who hold these licenses usually also hold additional licenses for scallop, shrimp, herring, groundfish, sea urchins or sea cucumbers.

Salmon aquaculture began in SWNB in 1979 with a single experimental lease (Walters 2007: 144). Deer Island was an early growth area (Fig. 2), and had 21 aquaculture sites by 2000. Aquaculture began with small local operators, many of them on sites previously operated as herring weirs (Anderson 2007). However, fierce international competition and provincial policies and incentives soon led to greater concentration of ownership in the hands of multinational corporations (Marshall 2001; Walters 2007: 145). Problems with disease and sea lice infestations led to increased government regulation, including the recent introduction of the "three bay policy" that requires each aquaculture operation have a different site for the three stages of growth and that each site gets a regular fallow period in rotation. This created additional demands for marine space devoted to aquaculture, so sites were allocated for the first time in the Maces Bay area.

Several recent reports (Desjardins 2007; Gardener Pinfold 2010; New Brunswick 2009) provide figures on the total value of the seafood industry in New Brunswick, as well as comparative figures for fishing and aquaculture. Between 2000 and 2008, the total value of the fisheries, aquaculture and seafood processing sectors in the province rose from 912 million to 1,184 million Canadian dollars (Gardener Pinfold 2010: 28). In southwest New Brunswick, lobster accounts for the majority of landed value in the fisheries sector (ibid: 7) while salmon is the dominant product in aquaculture (ibid: 9). However all seafood exports have been affected by the recent rise in the Canadian dollar and by market declines. Both the fishery and aquaculture weathered sharp declines in exports in 2006 and recovery has been slow (ibid: 6). For example, between 2008 and 2009, the total value of farm-raised salmon dropped from 201 million to 164 million (New Brunswick 2009). The 2008 employment figures for the fisheries sector average around 7,000 persons (Gardener Pinfold 2010: 6-7), while the 2009 figures for aquaculture are about 2000 persons province wide (New Brunswick 2009).

[1] For density of aquaculture in this area see the Province of New Brunswick Marine Aquaculture Mapping site at http://www.gnb.ca/0027/Aqu/masm-e.asp, last accessed October 26, 2011.

Management of valuable ocean resources is complex. Section 31 of Canada's *Oceans Act* (1996) states that the federal Minister of Fisheries and Oceans will collaborate with other ministers and bodies and shall lead and facilitate the development and implementation of plans for the integrated management of all activities or measures in or affecting estuaries, coastal waters and marine waters. Under subsequent agreements, the federal and provincial governments each hold responsibilities, the province managing aquaculture, the federal department of Fisheries and Oceans (DFO) supporting research and development for aquaculture, and managing the capture fishery. Management committees that include local fishermen exist for all commercial stocks. Integrative planning, which links all fisheries, aquaculture and other uses of marine space such as tourism and shipping, has been supported largely by the Southwest New Brunswick Marine Resources Planning Process, which was jointly launched by the provincial and federal governments in 2004 as part of a wider planning effort for the Bay of Fundy. This committee produced a work plan entitled: "Preferred Future of the Bay" in 2010 (available at http://bofmrp.ca/home/ last accessed October 24, 2011). To date, however, the recommendations made in this work plan have not been implemented.

The Study Area

The study area is located at the mouth of the Bay of Fundy, includes fishing areas along the coast from the port city of Saint John to the U.S. border, but excludes Grand Manan Island (Fig. 2). It includes areas containing long-term aquaculture sites (Deer Island, Campobello) as well as areas where aquaculture was recently introduced (Maces Bay). The fishermen who participated in the study had experience with the waters of Passamaquoddy Bay, Deer Island, Campobello Island, Letete, Back Bay, the Wolves, Maces Bay, Dipper and Saint John Harbours. The westernmost stretch of this coastline has a heavy concentration of finfish aquaculture, primarily salmon (*Salmo salar*), while the easternmost stretch is relatively free of aquaculture operations.

Framing Local Ecological Knowledge (LEK)

Following the work of Berkes (1999) and others, a number of scholars have called for better integration of fishermen's knowledge into resource policy and management planning (Felt 2010; Neis and Felt 2000). Recent literature suggests that fishermen's knowledge can be useful in both data-poor and data-rich contexts (Hill *et al*. 2010), particularly where multiple users may be leading to deleterious interactions (Heaslip 2008). Fishermen's knowledge is "dynamic as it responds to changing circumstances" and is "time sensitive, location specific and holistic" (Hill *et al.* 2010: 659). As a result, LEK can be used to "prioritize and focus limited scientific resources in the form of a knowledge partnership" (ibid. See also Felt 2010).

But as Hill *et al*. (2010) point out, there are pitfalls to LEK studies that are not appropriately designed and it is important to distinguish between fishermen's observations and their theories about those observations, as well as to acknowledge when fishermen diverge in observations or in explanations (see also Palmer and Wadley 2007). We argue that it is also important to revisit what is meant by *knowledge*. A dictionary definition is "a result or product of knowing; information or understanding acquired through experience; practical ability, or skill" (Avis 1989: 749). Knowledge also includes the contribution of the mind in understanding data, perceiving relationships, elaborating concepts, formulating principles and making evaluations. Individuals create knowledge and use it to direct future behaviour. But at some point, individual knowledge becomes widely shared and may become collective knowledge, to be passed down through generations, or it may be contested and lost through political processes. A fisherman's knowledge directs his behaviour; widespread changes in fishing behaviour can reflect how widely distributed new environmental observations are among fishermen, can tell us when individual knowledge has become local knowledge, and can suggest when that knowledge has affected practice. As with any other type of knowledge, local knowledge can be situational, contested, and contingent (Curtis and Wiber 2010.; Maurstad *et al*. 2007), thus it is important to recognize the many pathways through which knowledge is shared and disputed.

In this study, we adapted the Hill *et al*. characterization of LEK (Fig. 1) to acknowledge the complex relationship between types and sources of fisher knowledge, the theories they generate about on-the-water observations and resulting changes to their behaviour. Fishermen are not only knowledgeable about the resources on which they rely and the environment in which they work, but also about the fishing behaviour of others in their community. In addition, they are knowledgeable about the management regimes that affect them and many scientific findings that are discussed at stakeholder management meetings in support of various management measures. Finally, in developing their theories, they test much of this information against their ethical guidelines for appropriate behaviour with respect to the environment. In this complex characterization of LEK, research design must take into account the many diverse sources of information that contribute to fishermen's knowledge. Separating theory from direct observation and experience, as Hill *et al.* advise, is an important first step to contextualizing LEK. But we also ask how fishermen's knowledge has changed their fishing behaviour.

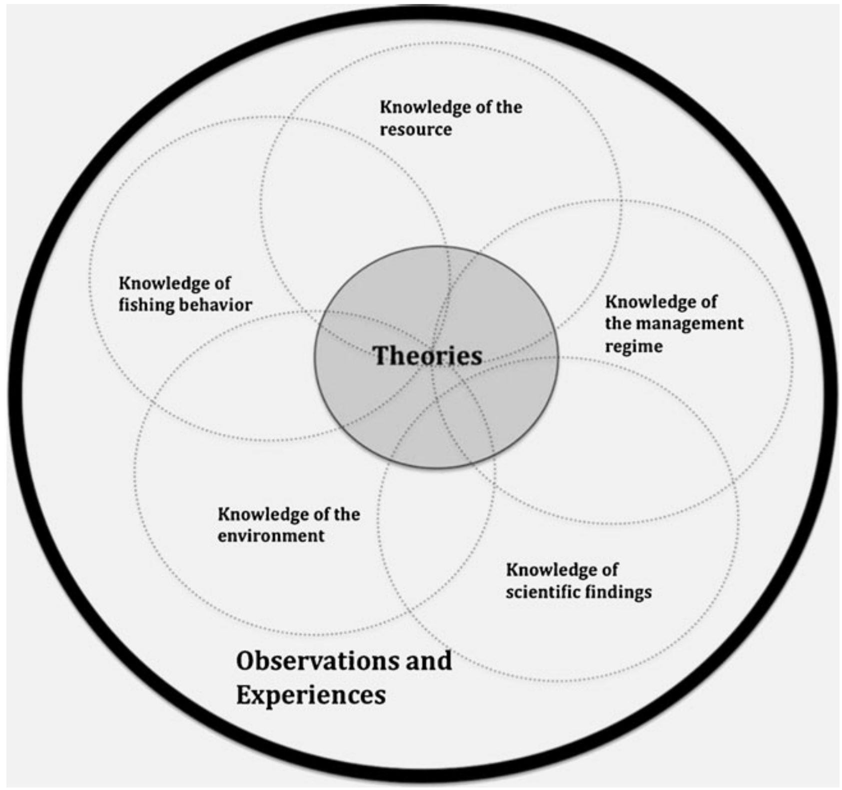

Fig. 1 Characterization of local ecological knowledge (adapted from Hill *et al*. 2010:664). Theories are based on observations and experiences, but components of LEK have various sources. LEK in turn affects fishermen's behavioral choices

The Study Methodology

Focus groups are used to gain in-depth qualitative data (Morgan 1997), particularly where participants may have divergent views and the aim is to generate "rich understanding of the participants' experiences and beliefs" (Morgan 1998: 11). In this study, a semi-structured interview schedule was developed to solicit fishermen's observations and to allow room for clarification, explanations, and disagreement. The aim was to suggest directions for further natural science research to better understand and address the potential impact of aquaculture on commercial fish stocks.

Recruitment was designed to capture active fishermen, all of them men, with experience in fishing waters both with and without aquaculture sites. The Fundy North Fishermen's Association facilitated recruitment. The total population of all commercial license holders in the inshore sector in this area is difficult to estimate as most fishermen are engaged in a multispecies inshore fishery and hold multiple licenses, so that numbers of licenses are misleading. The Federal Department of Fisheries and Oceans most recent statistics list 340 core fishermen for the Scotia-Fundy region of New Brunswick.[2] The most important species for this inshore fishery, however, is lobster. A more accurate estimate for the total universe of relevant fishermen in our study area, then, can be based on the approximately 176 lobster licenses for Lobster Fishing Area (LFA) 36, which covers the study area.

Aquaculture in this area of SWNB has primarily been developed in several distinct areas and through several phases of development. Deer Island (and the adjacent Letete and Back Bay areas on the mainland) has the longest history and the heaviest concentration of sites. Campobello Island, in the middle range of site impact, has a number of sites on the northwestern side of the island. The Maces Bay area has only recently been allocated aquaculture sites (Fig. 2). Two focus groups were held on Deer Island, two on Campobello Island and one in the Maces Bay area. Fundy North Fishermen's Association announced these focus groups through phone mail messages to all members, and through phone calls to long-time members in key harbours, asking them to attend and to encourage others to do so.

A semi-structured interview schedule covered the following topics: background information on the fishermen; general ecological changes fishermen have observed; the impact of salmon aquaculture on commercial stocks; the spatial effects of aquaculture; the recent sea lice chemical problems and any other issues fishermen wished to discuss. Where possible, fishermen were asked to locate their observations on our research map. Following Krueger (1998: 100), the researchers took notes and tape recordings were also made of the sessions in order to check the accuracy of notes.

[2] See http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/fishers-pecheurs/fp07-eng.htm, last accessed January 27, 2011. The statistics listed are for 2007.

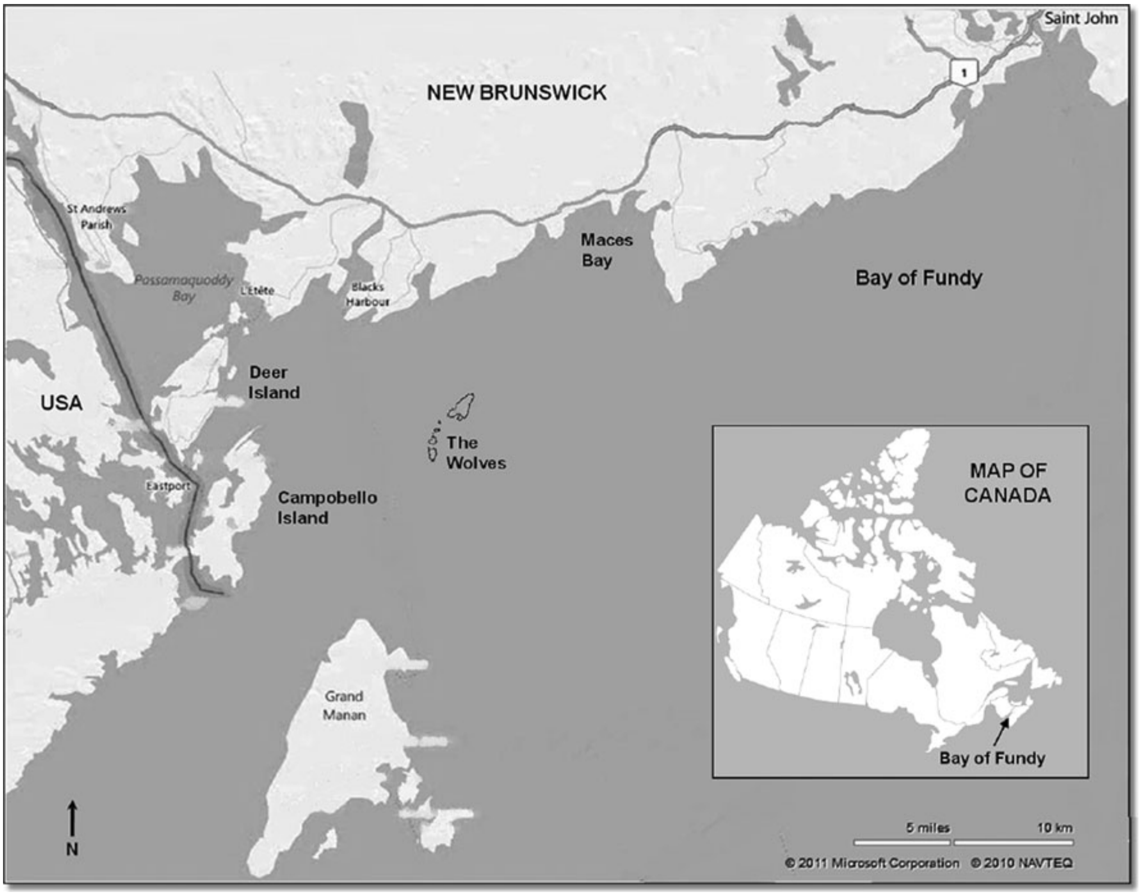

Fig. 2 Southwest New Brunswick: showing the three focus group areas

Fifteen fishermen participated in the five focus groups; all were holders of multiple licenses: fourteen held lobster licenses, ten held scallop, six held herring, three held sea urchin and two held active groundfish, quahog, or crab, while one held a shrimp license. The average years of fishing experience among the fifteen men was 31 years. Two men had over 50 years of experience, four men had over 30 years, four men had over 20 years, three men had over 10 years, and two did not report their years of experience. In each focus group a mix of license holders and years of experience were represented. All participants fished in the study area and had experience in fishing both areas with and without aquaculture.

Following the focus groups, all research notes were collated and subsequent analysis was undertaken using qualitative methods that focused on common themes (Krueger 1998; Palys 1992). Several themes emerged including: significant environmental problems and their indicators; loss of species habitat; changes to health of commercial stocks; loss of fishing ground; poor management of aquaculture sites; and the impact of the management of aquaculture operations on local communities. The last topic is not addressed here. Where appropriate, fishermen's observations were then compared to ten maps that had been produced by the Province of New Brunswick Department of Agriculture, Aquaculture and Fisheries to support the SWNB Marine Resources Planning exercise. For example, several maps traced the development of aquaculture over time and allowed us to compare fishermen's observations with aquaculture site locations and stocking dates. Other maps gave historical data on changing patterns of fishing in this area. This step provided important corroborating evidence both for fishermen's observations and for changes in their fishing patterns.

The results of our analysis are presented below. Within each theme, we present the most commonly reported or the consensus response. Generally there was consensus in the focus groups, but sometimes only one or two fishermen reported an observation and in those cases we make note of it. We also note any differences in observations recorded in the three focus group areas, Maces Bay (least affected), Campobello Island, and Deer Island (most affected).

Results

In what follows, we outline the reported general environmental changes, including changes in distribution of commercial species (summarized in Table 1), move on to changes in the health of commercial species (summarized in Table 2), and then address specific concerns with aquaculture operations (summarized in Table 3). It is important to note that we have no direct data either to support or to reject fishermen's hypotheses, but where possible we cite scientific research that relates to specific problems, whether or not it agrees with fishermen's observations.

General Environmental Change

The marine ecosystem has undergone significant degradation for the past several centuries, and fishermen were aware of declines or collapse in commercial fish stocks and environmental degradation that predated the introduction of aquaculture (see Bavington 2010; Lotze and Milewski 2004). Nevertheless, there was consensus among all fishermen interviewed that further environmental degradation follows on the introduction of aquaculture (see also Black 2010; Cubitt *et al*. 2010; Felt 2010; Milewski 2001). Indicators of such degradation include: foul odours of "sewage" or "rotten fish" near aquaculture sites, discoloured "plumes" of water flowing from aquaculture cages, changes in species commonly found in the area, and transformation of ocean "bottom" around cages. In all five focus groups, fishermen reported observing sequential changes in those species found near aquaculture sites. In the first year of stocking a salmon cage, commercial species are still found close to the cages; in the second year, commercial species begin to fall off and crab and starfish increase; in the third year, starfish dominate and commercial species become scarce. Fishermen in all five focus groups reported that aquaculture changes the "bottom." "Good bottom" is "hard bottom" or gravel areas that are preferred habitat for commercial species such as lobster, scallop and sea urchin. In the Deer Island and Campobello focus groups, fishermen reported that aquaculture bottom becomes "mildewed or mouldy" – whitish in colour and largely a "dead zone" as nothing else is found there. There was some variation in observations about how quickly dead zones recover; a few fishermen theorized that a one-year fallow is sufficient, others suggested that this depended on various factors such as length of cage site operation and frequency of fallow. Cubitt *et al*. (2010: 149) report varied recovery times for aquaculture bottom, ranging from one to over seven years. Felt (2010: 180) notes that Newfoundland fishermen refute recovery time claims made by the aquaculture industry in that province.

Fishermen in the Deer Island and Campobello focus groups made references to changes on the ocean bottom by referring to those earlier observed in Passamaquoddy Bay. Many fishermen from this area characterized Passamaquoddy as a previously rich fishing ground that is now a "marine desert," a conclusion supported by Lotze and Milewski (2004). As one fisherman put it: "[Passamaquoddy] Bay was a rich fishing ground in the 1950s. Now it's all gone. Pulp and paper mills killed that bay. Now the aquaculture industry is doing the same thing on a larger scale."

Fishermen from all three locations expressed concern that aquaculture is destroying habitat for commercial species. All fishermen reported that lobsters are now more likely to be found in mud bottom areas, further off shore (see also Rowe 2002). Among other causes, they theorized that aquaculture has had an affect on lobster distribution (see Chang *et al*. 2007 on lobster habitat and Fogarty and Gendron 2004 on lobster recruitment and environmental change). Respondents from Deer Island and Campobello reported that after lobster nursery areas were leased to aquaculture operators, lobster larvae and egg bearing females were no longer observed in those locations. Fishermen on Deer Island and Campobello were also concerned about loss of scallop habitat.

Table 1 Summary of fishermen's environmental observations

Environmental Degradation	Aquaculture sites associated with the smell of "sewage" or "rotten fish"
	Bottom around aquaculture cages is "mildewed", "moldy", "whitish", a "dead zone"
Habitat Loss	Loss of species habitat for lobster, scallop and sea urchin through placement of aquaculture sites on "good bottom" (ie. hard gravel substrate)
	Aquaculture impacts important spawning, feeding and/or nursery grounds for commercial stocks, including herring and groundfish such as pollock
	Declines of specific kelp (brown, apron) affect sea urchin roe production
	Declines of rockweed affect habitat for juvenile lobster
	Loss of zooplankton, krill and other copepods
Change in Predator/Prey Relationships	Starfish "blooms" observed around aquaculture sites
	Whales no longer feeding close to shore
	Herring no longer driven or attracted into near shore areas
	Krill no longer washing up on beaches
	Seabirds less frequently feeding on mud flats

Table 2 Summary of fishermen's concerns by commercial species

Lobster	Displacement of fishermen leads to increased pressure on healthy stocks
	Sea lice chemicals are killing adult lobster and may be affecting juveniles
	Lobster pounds adjacent to aquaculture sites experience more "shrink" (ie. dead lobsters among those held for market)
	Lobster gear is cut by aquaculture boats or fouled by aquaculture waste
	Potential for adverse affect on markets given traceability
Herring	Loss of productive herring weirs/ shut off coves
	Lights, odors and noise from aquaculture sites may deflect herring schools
	Herring did not reach normal size or fat ratios over the 2010 season
Scallop	Displacement of fishermen leads to increased pressure on healthy stocks
	Loss of fishing flexibility, especially in winter conditions
	Meat to shell ratios are lower near aquaculture operations
	Scallop show thin shells and "mildewed" meats near aquaculture operations
	Starfish "blooms" near aquaculture sites may affect stocks
Sea Urchins	Loss of kelp beds resulting in less healthy roe
	Shells are brittle and thin near aquaculture sites
	Roe is discolored and unmarketable from beds adjacent to aquaculture sites
	More dead urchins in beds adjacent to aquaculture sites
Crab/Shrimp	Dead shrimp and crabs observed near well boat operations in summer 2010

Herring fishermen from all three locations uniformly reported that herring distribution has been affected (see also Felt 2010: 180). Where aquaculture sites have been placed near pre-existing herring weirs or "shut off coves," those weirs and coves no longer catch herring. This was reported for the SWNB fishery as early as 1990 (Stephenson 1990). Fishermen in two separate focus groups mentioned groundfish. In both discussions, groundfish problems were viewed as predating aquaculture. But two fishermen raised concerns about groundfish recovery, mentioning for example that young pollock entered aquaculture cages and were unable to escape once they reached adult size.

In all focus groups, there were observations about krill and other small crustaceans, and theories that change in krill could be related to aquaculture. Fishermen in three separate focus groups on Campobello and Deer Island reported that in the past when the tide and winds were right, large numbers of krill would wash up on the beaches, but this has not been observed for years. Two additional focus groups discussed changes in the behavior of a number of marine species, particularly those such as herring that feed on krill or small copepods. One focus group discussed how high concentrations of zooplankton accompanied by feeding schools of fish are less frequent. Another focus group discussed the observation that whales are less often found feeding close to shore, and gulls and other birds are not observed feeding on shrimp. Fishermen in all focus groups reported that starfish are much more common in many areas. Sea urchin divers and scallop draggers uniformly reported areas of starfish "blooms" and called these a sign of "the end of the fishery" as they are associated with poor water quality and "bad bottom."

Fishermen from the focus groups on Deer Island and Campobello reported that several species of seaweed are

Table 3 Summary of concerns with aquaculture operations

Poisoning the waters	"Blood water" from salmon processing dumped at sea
	Dead salmon dredged up by scallop gear
	Chemicals used to control sea lice flowing away from cages in "plumes" (visible due to die used in chemical baths)
	Aquaculture garbage (feedbags, net, ropes, plastic) foul beaches, fishing gear and weir sites
	Abandoned nets that sink to the bottom kill everything on the ocean floor, while those abandoned on the beach kill the beach
	Disinfectants used on aquaculture infrastructure is washed into ocean
	Fish feces "fouling" or "mildewing" good bottom
Impact on Fishing	Gear is lost or entangled by aquaculture boats
	Aquaculture sites expand beyond their boundaries
	Sites are not cleaned up after abandonment
	Marine dangers (snagging on or entanglement in abandoned nets or anchors)

less common and theorized that seaweed is impacted by aquaculture, including rockweed, which is a preferred habitat for juvenile lobster. Supportive evidence is found in Lotze and Milewski (2004: 1437), who report 40% declines of perennial rockweed cover in some sites with eutrophication. Fishermen noted that green kelp and brown apron kelp are also less common in aquaculture areas; sea urchin fishermen observed that in areas without these kelp beds, sea urchin produce less roe, and less roe of marketable quality.

Impacts on Commercial Fisheries

Spatial Problems

All fishermen reported the displacement of commercial fishing by aquaculture with resulting pressure on adjacent fishing grounds. One example of displacement comes from the herring industry. Herring weir fishermen on Deer Island and Campobello claimed that herring weirs and aquaculture could not coexist in the same waters. They listed many herring weirs that are no longer productive; one fisherman said he could personally list over 67 such weir sites. Herring fishermen blamed much of this loss on aquaculture, and were able to identify on our map the many locations where aquaculture sites were placed near pre-existing weirs. Provincial maps confirm the numbers of aquaculture sites that are adjacent to current herring weirs but do not record weir sites that have since been abandoned. Fishermen theorized that herring are sensitive to light, to noise and to the scent of dead fish, that herring schools are deflected by the smell of aquaculture feed or of dead salmon, by lights, noise or oil slicks associated with aquaculture, or by changes to the way the tide flows around cages (see also Friends of Port Mouton Bay 2011; Milewski 2001: 171). Fishermen also reported that many coves that were once useful herring "shut off" locations are no longer used due to detritus left by aquaculture operators, including "nets left lying on the bottom." In two separate focus groups, fishermen theorized that without krill to attract them into the inshore waters, herring are staying further offshore.

Lobster fishermen on Deer Island and Campobello reported that they now fish further offshore, which increases costs for steaming time and requires more costly gear, engines and boats and puts increased pressure on specific fishing areas. The fishermen from Maces Bay also noted that there was more crowding on fishing grounds that are free from aquaculture. All lobster fishermen reported gear conflicts, including propellers from aquaculture boats entangling with lobster gear or cutting traps, as well as lobster gear "fouled" by aquaculture waste. Scallop fishermen from all three areas reported that aquaculture has displaced the many small scallop beds that they formerly relied on to relieve harvesting pressure or to provide safe winter conditions. Two fishermen from Campobello and one fisherman from Maces Bay reported that they no longer drag for scallop in the months of January and February given the lack of sheltered locations. Provincial maps support this claim, indicating that in 1997 scallop were fished in many areas around Passamaquoddy Bay, Campobello and Deer Islands and near Maces Bay; none of these were harvest areas in 2008.

Changes in Health of Commercial Species

Observed changes in commercial species could be due to any number of environmental factors, including climate change, other contaminants and overfishing. However, fishermen uniformly reported that areas with high concentrations of salmon aquaculture have characteristic changes in commercial stocks that fishermen say are not common in areas free from aquaculture. Fishermen also routinely reported that they have been forced to change their fishing practices as a result of such changes.

Lobster

For several years now, according to the fishermen from Deer Island and Campobello, dead lobsters have been pulled up in traps, found in lobster holding facilities (pounds), observed on the bottom by sea urchin divers, and washed up on beaches. In the fall of 2010, several dead lobsters were tested and found to contain the toxic chemical cypermethrin, probably used to control sea lice (French 2010a; Rayner 2009, 2010a, b; Williams 2011). The SWNB experience challenges recent studies that find no significant effects of such chemicals on non-target species (Ernst *et al* 2001; Telfer *et al* 2006; Willis *et al* 2005). In our study, two fishermen reported owning lobster pounds located near aquaculture sites. They reported that lobster mortalities in pounds have increased dramatically in recent years. One owner reported that in 2007, he experienced a total loss of 4% of stored lobster over three months. In contrast, in November 2008, the same operator lost his entire holdings (2,400 pounds). He reported that all lobster pounds located in the same bay sustained similar losses that November. In 2009, this owner did not risk operating his pound. Both lobster pound owners were concerned that chemical use in nearby aquaculture sites was destroying returns on investments made in lobster marketing infrastructure.

In three focus groups, concerns were expressed about the impact on lobster markets if traceability requirements result in reports of Bay of Fundy lobsters being contaminated by aquaculture or poor water quality. Harmful algae blooms due to water quality problems have been linked to toxins in lobster (Sephton *et al* 2007). Market problems occurred in the past when trace elements of paralytic shellfish poisoning, associated with poor water quality, closed Asian markets to Bay of Fundy lobster. A recent European study advocates research into such potential transfer of contaminants to commercial marine species, which suggests that European markets may also become sensitive to this issue (Swartenbroux *et al* 2010).

Finally, fishermen theorized that the sea lice chemicals that kill adult lobsters must also affect juvenile lobsters, and studies on the effects of chemicals on lobster lifecycle and reproduction are suggestive (Abgrall *et al* 2000; Boudreau *et al* 1993; Fairchild *et al*. 2010). While lobster landings are doing well now, fishermen fear that future year classes could decline rapidly as a result of the combination of chemical use and loss of nursery areas.

Scallop

The ten scallop fishermen in this study uniformly reported a concern for the health of the scallop stocks. They reported that scallops are no longer found in areas with long-term aquaculture and that adjacent areas have noticeable problems; indicators are the appearance of meat and shells. First, the meat to shell ratio appears to be adversely affected. Fishermen reported that previously they would obtain "six to seven pounds per basket" but now scallops are smaller, with less meat per shell and there are many more "clappers" or empty shells. Second, the quality of meat and the general appearance of shell are affected. Near Friar's Bay, for example, where there is an aquaculture site, fishermen reported that scallop shells are thin and appear to have been eroded from the outside. Fishermen reported that they would not eat scallops from this site, as a black or "mildewed matter" is sometimes found inside the shell and that thin shells are "hard to shuck" as they "shatter" and "leave bits of shell in the meat". Fishermen uniformly theorized that aquaculture sites lead to water quality problems that adversely affect scallops.

Herring

The herring weir fishermen on Deer Island and Campobello reported that in the summer of 2010, herring did not fattening up, nor achieve their normal length of six inches. Fat content on harvested herring normally averages around 12% but in 2010 it was around 3% (lean fish are called "slinks"), while length was said to average four inches. Herring caught in weirs did not have to be held in the weir to empty their digestive tracts before going to market for canning or freezing, and fishermen theorized that this is because they have not been feeding. Fishermen theorized that aquaculture may be adding to cumulative effects that impact herring food sources.

Sea Urchins

Three divers from Deer Island and Campobello all reported that they frequently find thin shells and poor quality, unmarketable roe ("diseased," "cancerous," "mildewed," or "discolored") among sea urchins close to aquaculture sites. They theorize that the quality of sea urchin roe is affected by aquaculture feed or by proximity to chemical applications. One diver recalled that this discoloration was first noticed in the Letete area, which used to produce up to 30% of urchin roe for the market. He theorized that disinfectants used in the 1990s to keep aquaculture gear and boats clean after an infectious salmon anemia (ISA) outbreak destroyed the roe industry in the Letete area.[3] His fear is that sea lice chemicals may be having the same effect.

Shrimp and Crab

Two fishermen from Deer Island and one fisherman from Campobello reported seeing "drifts" of dead shrimp and crab after the operation of well boats to control sea lice over the summer of 2010. As opposed to tarp treatments, where chemicals are applied to fish in the aquaculture cages and tarps are used to contain the chemical application for the duration of the treatment, well boats are used to pump fish out of the cages and into the hold of a boat for application of the chemical. After the treatment, fish are pumped back into the cages and the wastewater from the treatment can be disposed of. When the well boats were discussed as an alternative to tarp treatments, fishermen were told that hydrogen peroxide would be used, as it is not as toxic as the alternative chemicals. As a result, they signed petitions to support well boat treatments. However, aquaculture operators applied to have two other chemicals approved and this allowed operators to change the expected protocol just before the well boats were put to use. The chemicals approved under "emergency registration" were Salmosan® and Alphamax® (see Rayner 2010b). Other "therapeutic" chemicals are common in aquaculture (see Black 2010: 103; Cubitt *et al.* 2010: 132; Saner 2010: 118). Fishermen reported that when the well boat chemicals were disposed of at sea, dead shrimp and crab were observed in the water and washed up onto nearby beaches.

Management of Finfish Aquaculture

All fishermen expressed the view that aquaculture is here to stay, but members of the focus groups on Deer Island and

[3] ISA is a viral disease of Atlantic salmon. Outbreaks have affected salmon aquaculture operations all over the world, most recently in Chile in November 2010 (see Zarnikow 2010, http://en.mercopress.com/2010/11/11/isa-virus-outbreak-detected-on-salmon-farm-in-southern-chile, downloaded January 27, 2011).

Campobello argued that it needs to be better managed to control practices that they believe harm the marine environment. Some problems fishermen class as "irritants" (gear fouling), others they view as more serious ("poisoning the waters"). Several fishermen referred to the federal *Fisheries Act* (Government of Canada 1985, R.S., 1985, c. 4-14, Sec. 35–43) and restrictions on putting substances in marine waters that can adversely affect fish habitat. Many reported hauling up gear that is fouled with nets, rope, feed bags, or garbage from aquaculture operations; finding beaches littered with the remains of former aquaculture operations; seeing aquaculture boats dump 'blood water' from processing salmon into coastal waters; finding dead salmon hauled up in their scallop gear. Some fishermen reported on several coves with layers of abandoned aquaculture cage nets laying on the bottom or "smothering beaches." Fishermen theorized that these practices might lead to spread of disease and pests as well as destruction of viable habitat for other species.

In three separate focus groups, fishermen also reported that some aquaculture operations exceed their lease boundaries (taking up additional marine space) and/or run compensatory lines hundreds of yards past their grid systems. Fishermen discussed marine hazards such as fishing gear snagging on abandoned concrete anchorage. They believe that abandoned aquaculture sites are sometimes retained under lease, as the lease fee is cheaper than the clean up costs, a practice that prevents fishermen from making use of that area.

Future Research Needs

As with the Norwegian fishermen described in Maurstad *et al*. (2007), we heard a wealth of detail from fishermen about ecosystem relationships, changes over time and impacts on commercial fisheries, detail that was "grounded in everyday practice." There was very little disagreement among fishermen in the focus groups. The only variation in fishermen's observations occurred between the Maces Bay focus group, where aquaculture is relatively recent, and Deer Island and Campobello, where aquaculture has a longer history. As one Maces Bay respondent said: "It's early days here yet."

Fishermen's concerns highlight the lack of information about the interactions between salmon net cages and the inshore fishery, but are consistent with published findings on broad ecosystem degradation (Cabello 2006; Carroll *et al* 2003; Findlay *et al*. 1995; Haya *et al*. 2001; Heaslip 2008; Lotze and Milewski 2004; Milewski 2001; Wu 1995), changes in the adjacent inshore fisheries (King and Pushchak 2008; Lane *et al*. 2010), and changes in adjacent coastal communities (Costa-Pierce 2008; Wiber and Turner 2010). Other environmental degradation as reported by fishermen have not been reported in the literature, including the impact on sea urchin of the loss of specific species of seaweed and kelp, starfish blooms, the adverse effects on scallop and sea urchin shells, discoloration of meats and roe, lobster kills and kills of other marine species (crab and shrimp). The literature has also generally been silent on how these changes have affected the fishing patterns of the capture fishery.

A review of the literature thus illustrates that research is needed to better understand the environmental impacts of finfish aquaculture and its interaction with other commercial species (DFO 2010; Lane *et al*. 2010: Maurstad *et al*. 2007; Milewski 2001). Little is known about how the effects of aquaculture are mitigated by currents, seawater temperature, season, and storm events as existing studies have limited scope (Findlay *et al*. 1995; Fisheries and Oceans 2003; Telfer *et al*. 2006; Willis *et al*. 2005). Given this, future science should be targeted to address specific concerns. This study suggests that future research on the environmental impact of aquaculture should include input from fishermen. In SWNB, fishermen suggested the following research: the long-term impacts of aquaculture measured through comparison of long-term sites with more recent sites; eutrophication rates and remediation times; the cumulative impacts of multiple, large-scale aquaculture operations on lobsters, scallop, sea urchin, crab, shrimp, and zooplankton; changes in habitat for berried female lobsters, in lobster mortality, reproductive success and in growth rate and development (following on Haya *et al* 2001); patterns of growth in scallop and sea urchin and how this affects shells, meat and roe; dye dispersion tests (following Ernst *et al*. 2001) to establish how sea lice pesticide plumes move through the water column under differing conditions; impact of consumption by non-target species of infeed pesticides. In sum, this study suggests that more scientific study should be undertaken into the environmental changes around aquaculture sites (Black 2010; Cubitt *et al*. 2010; Wu 1995). More comprehensive and detailed studies are required to establish the environmental and economic costs of aquaculture, especially the affects on the adjacent industries that make a significant contribution to local economies.

Conclusions

The SWNB inshore fishery has proven resilient despite dramatic downturns in key commercial stocks such as groundfish. Fishermen in this study reported that two key things were necessary to create better management and continued resilience of the inshore area. First, fishermen and their local knowledge should be consulted in the development of targeted research into the consequences of aquaculture on the productivity of the marine environment, on nursery or spawning grounds, and on the effects of the loss of key habitat for commercial stocks. Many fishermen reported feeling a distrust of the federal department of Fisheries and Oceans, which they believe is in a conflict of interest situation, in that it both supports research to expand aquaculture and also regulates impact of aquaculture on marine ecosystems.

Second, we heard from some fishermen that local input into resource management is vital to improved management systems. They had tried to work with the aquaculture industry and had relied on the working group on fisheries and aquaculture to develop solutions to their mutual problems. For some problems, this working group facilitated solutions. For example, fishermen developed, built and tested propeller cages for aquaculture boats to reduce lobster gear entanglement, and some aquaculture companies adopted these propeller cages. However, recent events have discouraged this cooperation, particularly the change in protocol for use of chemicals in the well boats in summer 2010 (see French 2010b) without discussing this with fishermen in the working group. All fishermen associations in SWNB then withdrew from the working group in protest.

Government support for grassroots management institutions is vital. The consistent message we received from all involved in this study is that aquaculture can be a part of viable coastal communities, but that better targeted research, as well as better management institutions, are required to ensure the sustainability and successful co-existence of aquaculture and the capture fishery.

Acknowledgements This research was facilitated by the Coastal CURA (see www.coastalcura.ca), a five-year project that investigated the role of communities in integrated management. The authors thank the Coastal CURA for research funding, and the Social Sciences and Humanities Research Council of Canada for supporting the Coastal CURA.

References

Abgrall, P., Rangeley, R. W., Burridge, L. E., and Lawton, P. (2000). Sublethal Effects of Azamethiphos on Shelter use by Juvenile Lobsters (*Homarus americanus)*. Aquaculture 181: 1–10.

Anderson, J. M. (2007). The Salmon Connection. The Development of Atlantic Salmon Aquaculture in Canada. GlenMargaret Publishing, Tantallon, Nova Scotia.

Avis, W. S. (ed.) (1989). Funk and Wagnall's Canadian College Dictionary. Fitzhenry and Whiteside, Toronto.

Bavington, D. (2010). Managed Annihilation. An unnatural history of the Newfoundland Cod Collapse. UBC Press, Vancouver.

Berkes, F. (1999). Sacred Ecology. Taylor and Francis, Philadelphia, PA.

Black, K. (2010). Environmental aspects of aquaculture. In Culver. K., and Castle, D. (eds.), Aquaculture, Innovation and Social Transformation. Springer. Pp. 97–114.

Boudreau, B., Bourget, E., and Simard, Y. (1993). Behavioural Responses of Competent Lobster Postlarvae to Odor Plumes. Marine Biology 117: 63–69.

Cabello, F. C. (2006). Heavy use of Prophylactic Antibiotics in Aquaculture: A Growing Problem for Human and Animal Health and for the Environment. Environmental Microbiology 8(7): 1137–1144.

Carroll, M. L., Cochrane, S., Fieler, R., Velvin, R., and White, P. (2003). Organic Enrichment of Sediments from Salmon Farming in Norway: Environmental Factors, Management Practices, and Monitoring Techniques. Aquaculture 226: 165–180.

Chang, B. D., Page, F.H., Losier, R.J., Lawton, P., Singh, R., and Greenberg, D. A. (2007). Evaluation of Bay Management Area Scenarios for the Southwestern New Brunswick Salmon Aquaculture Industry: Aquaculture Collaborative Research and Development Program final project report. Canadian Technical Report of Fisheries and Aquatic Sciences 2722, Biological Station, St. Andrews, New Brunswick.

Costa-Pierce, B. A. (2008). Epilogue: Aquaculture, innovation and social transformation. In Culver, K., and Castle, D. (eds.), Aquaculture, Innovation and Social Transformation. Springer. Pp. 315–326.

Cubitt, F., Butterworth, K., and McKinley, R. S. (2010). A synopsis of environmental issues associated with salmon aquaculture in Canada. In Culver, K. and Castle, D. (eds.), Aquaculture, Innovation and Social Transformation. Springer. Pp. 123-162.

Curtis, D. G., Wiber, M. G. n.d. (2010) Fishermen's information versus fishermen's knowledge: The perspective from governance. Paper presented at the Fishermen Dependent Information Conference in Galway, Ireland on 23–26 August

Desjardins, P-M. (2007). Economic Impact of Lobster Sector - Province of New Brunswick and Its Counties. Government of New Brunswick. Accessed online at http://www.gnb.ca/9999/Publications/lobster.pdf on January 27, 2011.

DFO. (2010). Pathways of Effects for Finfish and Shellfish Aquaculture. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/071.

Doucet, R., and Wilbur, R. (2000). Herring Weirs: The Only Sustainable Fishery. Quebecor World Atlantic, Saint John.

Ernst, W., Jackman, P., Doe, K., Page, F., Julian, G., MacKay, K., and Sutherland, T. (2001). Dispersion and Toxicity to Non-target Aquatic Organisms of Pesticides used to Treat Sea Lice on Salmon in Net Pen Enclosures. Marine Pollution Bulletin 42(6): 433–444.

Fairchild, W.L., Doe, K.G., Jackman, P.M., Arsenault, J.T., Aubé, J.G., Losier, M., Cook, A. M. (2010). Acute and Chronic Toxicity of Two Formulations of the Pyrethroid Pesticide Deltamethrin to an Amphipod, Sand Shrimp and Lobster Larvae. Canadian Technical Report of Fisheries and Aquatic Sciences 2876.

Fisheries and Oceans Canada. (2003). A scientific review of the potential environmental effects of aquaculture in aquatic ecosystems. Volume 1. Far-field environmental effects of marine finfish aquaculture (B.T. Hargrave); Ecosystem level effects of marine bivalve aquaculture (P. Cranford, M. Dowd, J. Grant, B. Hargrave and S. McGladdery); Chemical use in marine finfish aquaculture in Canada: a review of current practices and possible environmental effects (L.E. Burridge). Canadian Technical Report of Fisheries and Aquatic Sciences 2450.

Felt, L. (2010). "It all depends on the lens, b'y": Local ecological knowledge and institutional science in an expending finfish aquaculture sector. In Culver, K., Castle, D. (eds.), Aquaculture, Innovation and Social Transformation. Springer. Pp. 167-190.

Findlay, R. H., Watling, L., and Mayer, L. M. (1995). Environmental Impact of Salmon Net-pen Culture on Marine Benthic Communities in Maine: A Case Study. Estuaries 18(1): 145–179.

Fogarty, M. J., and Gendron, L. (2004). Biological Reference Points for American Lobster (*Homarus americanus*) Populations: Limits to Exploitation and the Precautionary Approach. Canadian Journal of Fisheries and Aquatic Sciences 61: 1392–1403.

French, E. (2010a). Lobster Deaths Raise Questions After Traces of Pesticide Found. The Quoddy Tides, February 26, 2010: A1 and 34.

French, E. (2010b). Fish Farmers Challenged by Sea Lice Outbreaks. The Quoddy Tides, September 24, 2010: A1.

Friends of Port Mouton Bay. (2011). Trace metals in sea-surface microlayer (Sampling 2010 and 2011). Available at http://www.friendsofportmoutonbay.ca/documents.html, last accessed October 27, 2011.

Gardener Pinfold. (2010). Economic Impact of the New Brunswick Ocean Sector 2003-2008. Report prepared for the Government of New Brunswick and Fisheries and Oceans Canada. Last accessed online on October 17, 2011 at http://www.gnb.ca/9999/publications/ocean.pdf.

Government of Canada. (1996). *Canada Oceans Act*, RSC (1996). Bill C-26, Chapter 31.

Government of Canada. (1985). *The Fisheries Act*, R.S. c. F-14, s.1.

Graham, J., Engle, S., and Recchia, M. (2002). Local Knowledge and Local Stocks. An Atlas of Groundfish Spawning in the Bay of Fundy. The Center for Community Based Management, Antigonish, Nova Scotia.

Gustafson, R. (2011). Are salmon pen pesticides killing lobsters? The Working Waterfront February/March, Vol. 24, No. 1, page 3.

Haya, K., Burridge, L. E., and Chang, B. D. (2001). Environmental Impact of Chemical Wastes Produced by the Salmon Aquaculture Industry. ICES Journal of Marine Science 58: 492–496.

Heaslip, R. (2008). Monitoring Salmon Aquaculture Waste: The contribution of First Nations' Rights, Knowledge, and Practices in British Columbia, Canada. Marine Policy 32: 988–996.

Hill, N., Michael, K. P., Frazer, A., and Leslie, S. (2010). The Utility and Risk of Local Ecological Knowledge in Developing Stakeholder Driven Fisheries Management: The Foveaux Strait Dredge Oyster Fishery, New Zealand. Ocean & Coastal Management 53: 659–668.

King, S., and Pushchak, R. (2008). Incorporating Cumulative Effects into Environmental Assessments of Mariculture: Limitations and Failures of Current Siting Methods. Environmental Impact Assessment Review 28(8): 572–586.

Krueger, R. A. (1998). Analyzing & Reporting Focus Group Results. Focus Group Kit 6. Thousand Oaks, California and London: Sage Publications.

Lane, D., Michalowski,W., Stephenson, R., Page, F. (2010). Integrated systems analysis for marine site evaluations and multicriteria decision support for coastal aquaculture. In Culver, K., Castle, D. (eds.), Aquaculture, Innovation and Social Transformation. Springer. Pp. 255-264.

Lotze, H., and Milewski, I. (2004). Two Centuries of Multiple Human Impacts and Successive Changes in a North Atlantic Food Web. Ecological Applications 14(5): 1428–1447.

Marshall, J. (2001). Landlords, Leaseholders & Sweat Equity: Changing Property Regimes in Aquaculture. Marine Policy 25: 335–352.

Maurstad, A., Dale, T., and Bjorn, P. A. (2007). You Wouldn't Spawn in a Septic Tank, Would You? Human Ecology 35: 601–610.

Milewski, I. (2001). Impacts of salmon aquaculture on the coastal environment: a review. In Tlusty, M. F., Bengston, D. A., Halvorson, H. O., Oktay, S. D., Pearce, J. B., and Rheault Jr., R. B. (eds.), Marine Aquaculture and the Environment: A Meeting for Stakeholders in the Northeast. Cape Cod Press, Falmouth, Massachusetts. Pp. 166–197.

Morgan, D. L. (1997). Focus Groups as Qualitative Research. Sage Publications, Thousand Oaks.

Morgan, D. L. (1998). The Focus Group Guidebook. Focus Group Kit 1. Thousand Oaks, California and London: Sage Publications.

Neis, B., and Felt, L. (eds.) (2000). Finding Our Sea Legs: Linking Fisheries People and Their Knowledge with Science and Management. St. John's, NFLD, ISER Books.

New Brunswick. (2009). Aquaculture Sector In Review 2009. www.gnb.ca/aquaculture.

Palmer, C., and Wadley, R. (2007). Local Environmental Knowledge, Talk and Skepticism: Using 'LES' to Distinquish 'LEK' from 'LET' in Newfoundland. Human Ecology 35: 749–760.

Palys, T. (1992). Research Decisions. Quantitative and Qualitative Perspectives. Harcourt Brace, Toronto.

Rayner, B. (2009). Lobster Fishermen Concerned About Pesticide Use. Courier Weekend, June 12, 2009, page A2.

Rayner, B. (2010a). Officials Checking Dead Lobsters. The Saint Croix Courier, January 12, 2010, page 6.

Rayner, B. (2010b). Health Canada Approves Continued Use of Salmosan. St. Croix Courier, November 2010. Accessed online at http://stcroixcourier.ca/fullnews.php?view=406 on January 26, 2011.

Rowe, S. (2002). Population Parameters of American Lobster Inside and Outside No-take Reserves in Bonavista Bay, Newfoundland. Fisheries Research 56: 167–175.

Saner, M. A. (2010). Ethics, governance and regulation. In Culver, K., Castle, D. (eds.), Aquaculture, Innovation and Social Transformation. Springer. Pp. 115-122.

Sephton, D. H., Haya, K., Martin, J. L., LeGresley, M. M., and Page, F. H. (2007). Paralytic Shellfish Toxins in Zooplankton, Mussels, Lobsters and Caged Atlantic Salmon, *Salmo salar*, During a Bloom of *Alexandrium fundyense* off Grand Manan Island, in the Bay of Fundy. Harmful Algae 6(5): 745–758.

Stephenson, R. (1990). Multiuse Conflict: Aquaculture Collides with Traditional Fisheries in Canada's Bay of Fundy. World Aquaculture 21(3): 34–45.

Swartenbroux, F., Albajedo, B., Angelidis, M., Aulne, M., Bartkevics, V., Besada, V., Bignert, A., Bitterhof, A., Hallikainen, A., Hoogenboom, R., Jorhem, L., Jud, M., Law, R., Licht Cederberg, D., McGovern, E., Miniero, R., Schneider, R., Velikova, V., Verstraete, F., Vinas, L., and Vlad, S. (2010). Joint Report of the Marine Strategy Framework Directive Task Group 9. Contaminants in Fish and Other Seafood. JRC Scientific and Technical Reports. European Commission Joint Research Center, Ispra Italy.

Telfer, T. C., Baird, D. J., McHenery, J. G., Stone, J., Sutherland, I., and Wislocki, P. (2006). Environmental Effects of the Anti-sea Lice (Copepoda: Caligidae) Therapeutant Emamectin Benzoate under Commercial use Conditions in the Marine Environment. Aquaculture 260: 163–180.

Trotter, B. (2011). Pesticide use, lobster deaths probed in Down East waters. Bangor Daily News 1/7. Page 11.

Walters, B. (2007). Competing use of Marine Space in a Modernizing Fishery: Salmon Farming meets Lobster Fishing in the Bay of Fundy. The Canadian Geographer 51(2): 139–159.

Wiber, M., and Kearney, J. (2009). Learning communities and legal spaces: community-based fisheries management in a globalizing world. In von Benda-Beckman, F., von Benda-Beckmann, K., and Griffiths, A. (eds.), The Power of Law in a Transnational World. Berghan Press, New York, pp. 137–155.

Wiber, M., Turner, B. (2010). Moral Talk: The Ontological Politics of Sustainable Development. Max Planck Institute for Social Anthropology Working Paper 123. Haale/Saale, Germany.

Williams, T. (2011). Fundy Feedlots. Atlantic Salmon Journal (Spring): 32-37.

Willis, K. J., Gillibrand, P. A., Cromey, C. J., and Black, K. D. (2005). Sea lice Treatments on Salmon farms have no Adverse Effects on Zooplankton Communities: A Case Study. Marine Pollution Bulletin 50: 806–816.

Wu, R. S. S. (1995). The Environmental Impact of Marine Fish Culture: Towards a Sustainable Future. Marine Pollution Bulletin 31(4–12): 159–166.

Zarnikow, D. (2010). ISA Virus Outbreak Detected on Salmon Farm in southern Chile. Santiago Times, November 11, 2010. See http://en.mercopress.com/2010/11/11/isa-virus-outbreak-detected-on-salmon-farm-in-southern-chile, downloaded January 27, 2010.