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Lessons Learned from Reconstructing Interactions Between Local Ecological Knowledge, Fisheries Science, and Fisheries Management in the Commercial Fisheries of Newfoundland and Labrador, Canada

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Questions centered on the development of local and traditional ecological knowledge and the relationship of that knowledge to the development of conservation and management practices have recently attracted critical attention. We examine these questions with respect to the dynamic commercial fisheries of the Canadian province of Newfoundland and Labrador. The knowledge of fish harvesters coevolves with fishing practices and is embedded in a dynamic socioecological network that extends into and beyond the fisher, fishery households, and communities to include management, technologies, markets, and marine ecological conditions. Changes in these networks have moved knowledge and practices related to fishing in directions defined by policy, science, economic rationality, and new ecological realities. We characterize this movement as a shift along a continuum from local ecological knowledge (LEK) towards globalized harvesting knowledge (GHK) as harvesters become increasingly disconnected from socioecological relationships associated with traditional species and stocks. We conclude with a discussion of how LEK/GHK have interacted over time and space with other knowledge systems (particularly science) to influence management, and suggest that contingent, empirical evaluations of

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these interactions will provide a fruitful avenue for future interdisciplinary research.

KEY WORDS: local ecological knowledge; fisheries management; Newfoundland and Labrador.

INTRODUCTION

In the context of a growing lack of confidence in centralized, scientific fisheries management some researchers and policymakers have called for an increased role for fishers in the production of knowledge used in management decisions, and for a movement toward collaborative management arrangements that involve mixtures of collective, state, and for some advocates, private control over marine resources (Apostle *et al.*, 2002; Felt *et al.*, 1997; Grafton, 1993; Mansfield, 2004; Neis and Felt, 2000; Neis *et al.*, 1999; Pinkerton, 1990, 1994). In the period following the collapse of the Northern cod stocks off the Canadian province of Newfoundland and Labrador, for example, the Canadian Department of Fisheries and Oceans (DFO) wants to increase the participation of fishers in management and to include their knowledge in assessing cod stocks and designing management regimes. Related to these initiatives, an important emerging research focus is the ways that fishers' (and other natural resource users) knowledge is created and how it develops in a society. Another emerging area of interest involves questions that center on how conservation and management practices develop in a society (see the other contributions to this issue).

This paper addresses these issues in the context of the commercial fisheries of the Canadian province of Newfoundland and Labrador. These fisheries, with dynamic, international, commercial histories stretching back over 500 years, are significantly different from many of the fisheries that have been the focus of research concerning resource users' local or traditional ecological knowledge (LEK, TEK). Studying knowledge production and change in these fisheries provides an opportunity to explore local knowledge creation and development and their relationship to conservation and management where fishing as a livelihood is tightly woven into the social, cultural, and economic fabric of the community, yet where heterogeneous fisheries have become increasingly market-driven, technologically intense, 'scientifically managed,' capital intensive, and are operating in the context of dramatic and rapid ecological change.[4]

[4]While there is evidence of overfishing that extends back into at least the nineteenth century in Newfoundland (Cadigan, 1999), the rate and degree of ecological change induced by

We start from the premise that fisheries are best approached as socioecological networks within which such different knowledge systems as local knowledge, natural science, governance and social science, and many different groups of human and natural actors have interacted at different spatial, temporal, and organizational scales to shape the history of fish and fisheries(Murray *et al*., in review; Perry and Ommer, 2003). A focus of our research is therefore on knowledge production (including our own) and knowledge systems, or how different social groups produce knowledge about what we perceive as the social and natural world in different times and places (Murray *et al.*, in review; Neis *et al.*, 1999). A related focus is how different forms of knowledge, including 'local' knowledge, have interacted with each other in different ways and in different areas to influence environments, human relationships with those environments, as well as with each other (including relations among resources users, managers, and policy makers).

We begin with a brief discussion of what we consider local ecological knowledge to mean in the context of the complex, dynamic, non-bounded socioecological network of our study area. After explaining our approach and methodology, a case example developed from an interview conducted in our study area is used to illustrate and elaborate on how the production of this knowledge has changed in the context of radical technological change, market shifts, elaborated management, and ecological change. In the final section we look at how conservation and management practices have also evolved in this spatial, temporal and social-organizational context. We return to the image of different knowledge systems interacting in a socioecological network and explore how LEK and other ways of understanding the world (particularly science) have coexisted and interacted over time and space to shape management and/or conservation practices and their outcomes, and discuss some implications for future interactions among these knowledge systems in light of our findings.

COMMERCIAL FISH HARVESTERS' LOCAL ECOLOGICAL KNOWLEDGE IN NEWFOUNDLAND AND LABRADOR

The detailed knowledge about fishery resources and their environments developed by fish harvesters and members of their families is often referred to as local or traditional ecological knowledge (LEK, TEK) (Berkes, 1993, 1999; Freeman and Carbyn, 1988; Johannes, 1981; Neis and Felt, 2000). Knowledge is embodied in a variety of material forms, as talk,

(over)fishing has been particularly high in the post WWII period, and it is important to consider how local knowledge responds to this context.

action, performance or as texts or artifacts (Law, 1992). Like all knowledge, the knowledge of fish harvesters in Newfoundland and Labrador is 'situated knowledge' (Haraway, 1991). As such it is shaped and influenced by local context and conditions, including the local mix of class, gender, organization, and so on. Vernacular or experiential knowledge related to fishing can be characterized as local in the sense that it is primarily a product of interactions with particular social, technological, and natural environments (Kloppenberg, 1991). To some degree, harvesters' knowledge is built up over a lifetime. It is subject to revision due to fluctuations in any of the above, as well as the effects of memory and other processes.

A particular fisher's LEK is shaped by varying combinations of observations acquired during fishing, knowledge transmitted from previous generations, and information from other sources such as harvesters from other areas, the media, managers, fisheries scientists, and so on. It is also to some extent unevenly held, and not every individual has equal knowledge. For example, in our earlier research we interviewed crew members and skippers and found that (particularly on larger vessels) they tend to have somewhat different kinds of knowledge (see also Pálsson, 2000). Likewise, when we included in LEK research the succession of fishing vessels and gear worked over the course of a harvester's career, we sometimes found that spouses may have some of the information needed to reconstruct when major career shifts occurred (these can sometimes be linked to major life history events such as the birth of a child or the decision of a family member to join the crew). In these senses LEK is both individual and collective.

Because of its experiential basis, knowledge and practice are closely connected in fisheries LEK and evolve together (Neis *et al.*, 1999; Pálsson, 2000). This coevolution can best be seen as the result of relationships or networks involving actors operating within their natural, technological, and social environments.[5] It is critical to understand that by using the term LEK we do not mean to suggest a sole focus on ecology or to the biophysical environment from which humans are much too frequently considered separate. As we outline below, we are concerned about knowledge and experience with respect to physical and biological components of ecosystems (the fish, the tides, water conditions, etc.) as well as fishing practices and issues related to the larger social and economic context of fishing.

In this view, fishing enterprises are part of complex webs of relations—or socioecological networks—that extend beyond the boundaries of the vessels and the fishers to local institutions such as households and communities (with all of their stratifications and dynamics), and to regional, national, and international organizations and institutions like management

[5]The social environment includes political, administrative, and institutional elements.

bodies and markets, as well as to dynamic marine ecosystems (Fischer, 2000; Johnsen, in press; Neis and Kean, 2003). In this sense, LEK is neither given nor clearly bounded or defined. It is also fundamentally dynamic. When relations, networks, institutions, ecological conditions, and practices change, associated knowledge will also change.[6] That is the focus of the following sections.

METHODS AND APPROACH

In order to illustrate the coevolution of knowledge and practice within the socioecological system of our study area, we have chosen to describe the experiences of one fisher (whom we call 'Jack') to visualize the complex web of forces that have influenced his fishing practices, and how that has related to his knowledge. In so doing, we do not claim that Jack's experiences or knowledge are representative for the complete range of experiences in the broader population, or thoroughly represent the full breadth and depth of LEK in our study area. Individually, fishers have responded and adapted to changes in many ways.[7] The inshore fishery in Newfoundland has always been diverse, involving more and less mobile elements, a variety of technologies and relationships with market forces and management, rising and falling fish stocks, and sociocultural contexts that can vary widely on a local scale.

Our principal goal here, however, is to highlight the complexity and dynamism of the socioecological network in which the fishers of Newfoundland and Labrador today are embedded (and the implications thereof for their knowledge) by focusing on the rich detail that can emerge from a focus on one individual. We chose Jack because he exhibited a certain pattern we wished to explore further. In general, fishery policies in Newfoundland were directed until recently towards industrialization, 'professionalization,' and an increasingly 'scientific' approach to management (Sinclair, 1987; Wright, 2001). To some extent, Jack is one of those who most adapted to this hegemonic ideology, and is therefore an interesting case. Furthermore, as noted, he and others like him have been operating in a context of rapid and profound ecological change. The pattern of change over Jack's career, in our view, has implications not only for our understanding of the development of LEK, but also for the relationship between LEK and science and management, and for the development of conservation and management measures.

[6] Indeed, research that attempts to document and assemble LEK in order to answer research questions is another source of dynamism and change (Murray *et al.*, forthcoming).

[7] In fact, this individual variability in response to contextual change constitutes another major focus of our current research.

It is important to 'locate' our chosen respondent with respect to the broader community of fishers in Newfoundland and Labrador. In doing so we draw on findings from interviews with a total of over 150 fishers in Newfoundland and Labrador conducted in three separate series carried out over two separate projects (Murray *et al.*, in review; Neis *et al.*, 1999). We also draw on information from a series of feedback sessions/community workshops, where we used the data we collected as a springboard for discussion with harvester communities. We rely particularly on a series that included interviews with 56 individuals (interviews were from 2–5 h each) conducted on the west coast of Newfoundland, the Strait of Belle Isle, and Southeastern Labrador.[8] We paid particular attention to identifying this latter group of 'fishing experts' (Davis and Wagner, 2003), as we did with many aspects of our methodology (see Murray *et al.*, in review). By labelling these respondents 'expert' we do not mean to imply that fish harvesters we did not interview in these communities are 'inexpert.' By definition, every fisher has some experience and some knowledge and most have a great deal. Our label expert is used to highlight the many years of experiential knowledge of each, not to imply that they have, in some fundamental sense, a level of expertise that is qualitatively different from that of their colleagues. That said, we acknowledge that fishers differ in experience and observational tendencies and some are more comfortable with researchers and with verbal discussion. A referral process was therefore used to identify our study participants. Potential respondents were selected from lists composed on our request by field representatives of the provincial Department of Fisheries and Aquaculture and the chairs of local fisheries committees (who are also fishers themselves). Each of our referees is experienced and knowledgeable about members of local communities and local fisheries, and is well situated to identify these individuals.[9] Each was asked to identify individuals in their area they felt were particularly knowledgeable and who had been engaged in the fishery for a long time (specifically, we asked for long time, but still active fishers in their 50s and 60s). Fishers identified on both lists were contacted preferentially. Additional respondents were sometimes identified using snowball sampling by asking interviewees to recommend other fishers in their area. Reflecting our assumption that LEK is socioecological knowledge and because we were seeking to reconstruct changes in fish and fisheries for the Northern Gulf and Southern Labrador and to gather detailed information on cod migration patterns, spawning areas, and juvenile habitat areas, we tried to distribute interviews along the full length

[8]See Murray *et al.*, in review for a complete description of the methods used in these interviews.
[9]Given the geographic scale in Newfoundland, the wide spacing between communities, and the very small size of some communities (and the small number of fishers in each), we chose this method of referral over other methods (e.g., Davis and Wagner, 2003).

of the coast for the study area, with some concentration in areas where fisheries were particularly intensive and complex. Organized around the main boats owned or operated by the fisher over his career, these semistructured interviews also explored:

- Fishing areas (location and depth)
- Trends in landings
- Vessel characteristics (including size, engine size, range, materials, electronics usage, hauling equipment)
- Species targeted and gear utilized (type and amount)
- Crew size and composition (e.g., kinship ties)
- Training

We tried to both capture and account for some individual variability along several axes (including gear sector and mobility, experience, local physical and social contextual influences, as well as individual 'devotion to observation' and 'truthfulness') by interviewing as many individuals as time and resources would allow (Mailhot, 1993; Neis *et al.*, 1999a).[10]

'JACK': AN EXAMPLE OF CHANGING KNOWLEDGE[11]

'Jack' is a third-generation fisher with several decades of fishing experience (our respondents averaged 33 years of experience) of approximately the average age of our respondents (average = 53) who has navigated the radical changes in the inshore and nearshore fisheries associated with the Newfoundland and Labrador fisheries in the post World War II period. Like most harvesters, he began his career in a small, family-owned enterprise and fished immediately adjacent (within a couple of kilometers) to his community. Unlike some, he took some years off from the fishery, and has received more education (including training in fishing) than many of the respondents we interviewed. As Fig. 1 (which illustrates the wide variety of changes in vessel length over interviewees' careers) suggests, Jack has been more aggressive than others in pursuing larger vessels, and pursued these changes earlier than most others we talked to (though not as early as some). These changes have been concomitant with changes in other indicators of technological intensification, including the adoption of more powerful

[10]Though it is difficult to obtain precise measures (due to a number of inactive license holders) we would estimate that this sample represents somewhere between 5% and 10% of active fishers in our study area. Of course, it would represent a higher proportion of the older age category we targeted.

[11]'Jack's' name has been changed, and other details have been left intentionally vague in order to preserve anonymity.

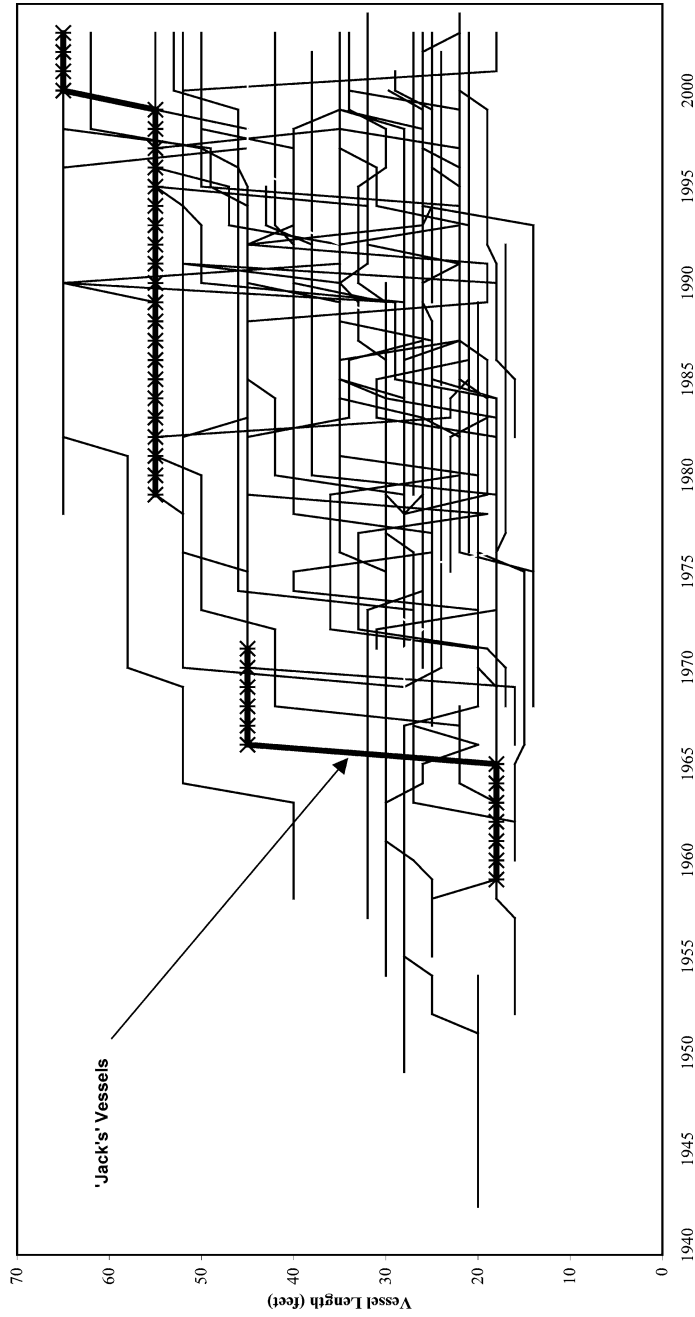

Fig. 1. Changes in vessel length for 51 respondents (including Jack) from 1940–2004.

engines, greater carrying capacity, large investments in electronic navigation and communication aids, and mechanical harvesting aids. As we will see, this technological intensification has enabled him to spatially expand and 'ecologically intensify' his fishery.[12]

Jack's interview began with some questions about his age, background, place of birth and about how he first learned how to fish. His response to the last question suggests that, like his contemporaries, he had limited formal education and learned fishing by doing it as a young boy. It also highlights the social importance of learning how to fish, and the cultural centrality of the work of fishing in his community: "Yeah that's right, when you get old enough and you could walk on your own well you had to go fishing and take part into it. To more or less, to help everybody to survive, certainly."

Jack began fishing with family members in the 1950s and he helped to build an 18-foot wooden boat from local materials to fish for cod—a common story among our respondents. At this stage he fished with family members with no right to a formal share, also common among our respondents (see also Kennedy, 1996). Jack gives the impression of relative equality with respect to power, knowledge, and experience in this small-scale, household-based fishery. From the late 1950s to the mid-1960s, he relied primarily on handlines and trawl[13] (a local name for longlines), and never traveled more than a few miles from his home. Cod was all they caught, he says, and all they could sell.

In the late 1960s, Jack purchased a 45-foot 'longliner,' a local term for a larger vessel that was capable of traveling much greater distances and was better suited to fishing increasingly prevalent nylon and then monofilament gill net technology (i.e., longliners did not necessarily utilize longline fishing technology). His shift to a larger vessel was partly a response to the increasing scarcity of fish inshore, but was also supported by the active modernization agenda and related policies of the Newfoundland and Canadian governments (Sinclair, 1987; Wright, 2001) and he took advantage of a loan from the Fisheries Loan Board, one of several federal and provincial programs designed to enhance Canadian fishing capacity and efficiency, to buy his longliner. He also sought to reduce uncertainties in landings and to make work easier. Jack followed the lead of mobile harvesters

[12] Intensification and expansion have spatial, temporal, and ecological dimensions. In the case of intensification, traditional grounds and species are harvested more intensively though such things as smaller or larger mesh sizes (harvesting smaller or larger fish), fishing a growing proportion of the bottom or water column in a particular area, and the extension of fishing seasons and days. Expansion refers to fishing in new areas, targeting new populations as others get depleted, and shifting effort across species, often from higher to lower trophic levels (Neis and Kean, 2003).

[13] This stands in contrast to other areas in Newfoundland that relied more heavily on the cod trap at this time.

with longliners from a nearby community: "... there was fellows that was on the Northern Peninsula that was fishing ... not only that we thought that the fish was starting to get a bit scarce inshore so we figures like you know we'd have to ... if we had to move off further, if you had to go into deeper water. And not only that you'd have to move along the coast and go different places, you got to be a bit mobile. So if you're going to be mobile you'd have to have something bigger then a 18-foot boat." Importantly, in his larger, more powerful boat Jack was able to travel much farther in pursuit of the cod increasing the length of the fishing season and possibly changing the populations of cod to which he had access.

Jack left the fishery for a period in the 1970s and when he returned in 1980 he bought a larger, 55-foot vessel. This time he found it more difficult to obtain financing and had to rely on a bank loan. He replaced gillnets with otter trawl technology when the government expanded licensing opportunities in this emerging gear sector. His new vessel featured multiple depth sounders, radar, VHF communications, and a much more powerful engine. The following quote describes the challenges Jack faced in learning the skills necessitated by the technological, temporal, and spatial shifts in his fishery precipitated by technological (available gear), political (the provision of additional mobile gear licenses), and ecological (the need to fish more intensively in the face of decline) changes. He also describes some of the actions they took to cope with the changes including resorting to formal training:

> When we started at the otter trawl like the entire crew we ... didn't know what to do. We got a little bit of help from a guy ... in Port au Choix that helped us put the gear on. And we went out fishing, we didn't really know if we were putting it overboard right or not ... And not one of us knew anything about twine ... The first tow we had, we went out we got 15,000 pounds the first tow ... We were shocked but ... we got to get it out of the net but ... There was a couple of fellows that was fishing the same area that time and we talked back and forth to them and got a bit of information from them what to do ... And basically we learned from that. That winter I sent two of the crew off to St. John's to go to school to learn twine.

When the government expanded licensing opportunities, Jack took advantage and by the early 1980s had begun to fish for shrimp as well as for cod. This switch into shrimp fishing was made relatively easy for him as a vessel outfitted for cod dragging is quickly adaptable for shrimp dragging. According to him, the process of learning to successfully fish new, more mobile technologies in new areas involved not only trial and error, but also an increased use of logbooks (which facilitated a return to specific places and specific times) and an increased dependence on communications technology which allowed the mobile fishing fleet to work together to quickly locate, pursue, and capture fish. At the same time, Jack's crew size had expanded to four and a more formal share system and division of

labor had been instituted (though in his case crew members were still family). Jack talks about how the fleet of 90–100 under 65-foot otter trawlers in Newfoundland's northern Gulf fleets (from a wide range of harbors) began to communicate with each other in a sometimes uneasy blend of competition and collaboration.

Jack also began going to school in St. John's in the off season to get his 'tickets,' professional fishing accreditation based on courses that trained him in the increasingly sophisticated technologies he was employing. This formal knowledge was integrated with the largely practical knowledge transferred through working collectively with family members in particular work and ecological situations, observing others and eventually interacting with other members of the longliner and otter trawl fleet.

When considering the socioecological network in which fishers like Jack are embedded over the course of their careers, it is important to realize that adopting and learning to operate these efficient new technologies also placed increased pressure on an already declining resource as fishers were able to more quickly pursue and capture dwindling populations of cod over a greater area, during a longer season and during periods (such as during pre-spawning and spawning periods) when dense aggregations increased the 'catchability' of the cod.[14] As indicated by the work of Palmer and Sinclair, the activities of this fleet of harvesters and their knowledge were also affected by the introduction of individual quota systems that encouraged highgrading and discarding by some fishers that went largely undetected by scientists and managers throughout the 1980s (Palmer and Sinclair, 1997).

Earlier in his career, cod was Jack's primary species and he essentially waited for migrating populations of codfish to arrive in his area. As he became more mobile, he and others began to aggressively intercept aggregated bodies of migrating fish before they arrived in his area and after they had left, following a pattern that he quickly began to learn and that eventually took him far down the Northern Peninsula of Newfoundland and to the 'northern cod' (a stock of fish largely distinct from the Gulf fish he had been fishing) fishery off Black Tickle, Labrador. This pattern is shown as an arrow in Fig. 2, which is a stylized map developed from actual charts used during our interview. As noted, Jack's original fishing area was in a small, surrounding area no more than a few miles from his home, a fraction of the extent of the areas fished later in his career.

At the same time, over-harvesting added to the pressure on all harvesters to intensify their effort and their efficiency, with eventually tragic

[14]Several of the fishers we talked to, for example, talked about such an aggregation off of Port aux Basques (southwest Newfoundland) that could be fished in late winter before it spawned and began migrating north along the coast towards the Labrador Straits. See Fig. 2.

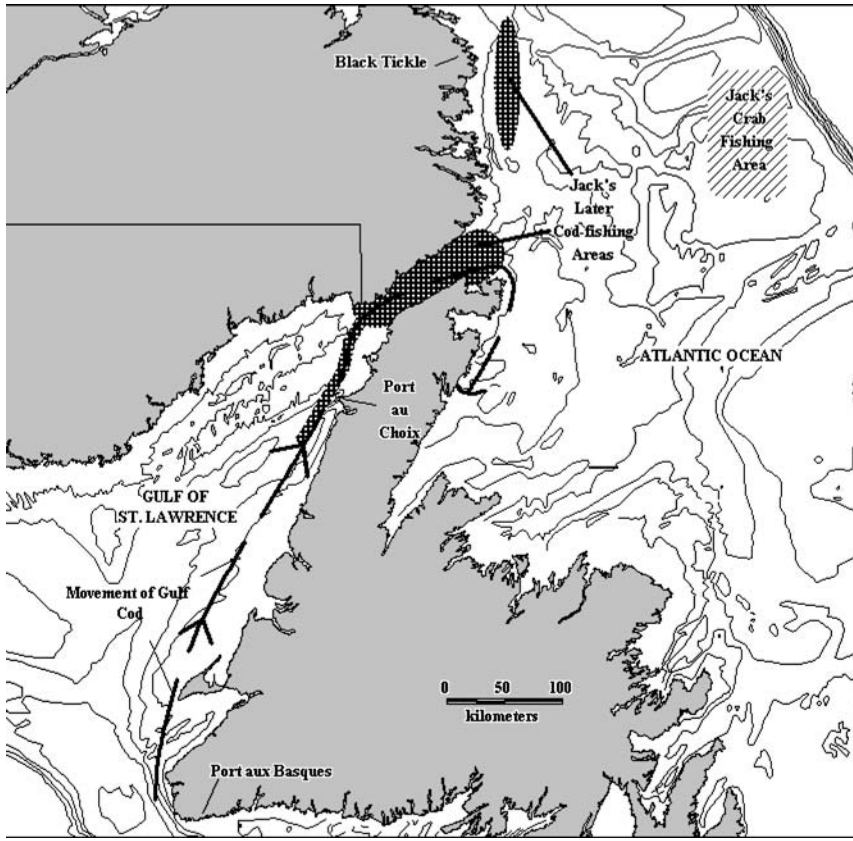

Fig. 2. Map of Newfoundland and Southeastern Labrador showing cod migration, and shifts in Jack's fishing patterns over his career. Adapted from nautical charts used during an interview with Jack.

results that are reflected in Jack's effort and related catch.[15] In the early 1960s, Jack recalled that around 2000–3000 lbs of cod per day was average—at this time he was fishing in an 18-foot vessel, using approximately 2000

[15]The recall of landings by harvesters tends to be weighted towards very good and very bad years. Harvesters also generally emphasize that interannual variations in landings were essentially normal and to be expected. However, many can provide a general sense of long-term trends in catch rates associated with particular technologies. Compared to some other harvesters we interviewed, Jack spent relatively short periods of time fishing from particular boats, with a particular type of gear, and in particular areas. The comparability of the information he was able to recall regarding catches associated with different types of vessels and volumes of gear over time is therefore limited.

baited hooks on line trawl. By the late 1960s he began using gill nets. He started with approximately 30 nets but after noting a decline in his landings in the late 1960s, Jack increased the number of nets he was using until, by the late 1970s, a good day would produce around 8000–10,000 lbs out of 120 nets. He also switched from nylon to more effective monofilament nets. By 1980, he had switched to otter trawl, and over a season, he was limited in total catch by his allocated quota (which changed from 700,000 pounds in the early 1980s to 300,000 just before the moratorium[16] in 1994) but recalls that over the 1980s in general terms his catch rates declined, and the average size of the fish got smaller. He also noted that the average time (number of days) taken to fill his quota increased from year to year (over years when his Individual Quota was not changed). He also paradoxically, and like some others in both the mobile fleet and small boat sectors, suggested that despite these declines, the last year before the moratorium was, for him, one of the best. The general trend towards moving towards more and/or more efficient gear was echoed by the large majority of our respondents, suggesting one reason for periodic reversals in catch rates and a need to fish more intensively in the face of declining abundance.

By 1994, as Gulf and northern cod stocks dwindled over the 1980s and moratoria were imposed on Newfoundland groundfish fisheries in the early 1990s, Jack switched effort to the snow crab (*Chionoecetes opilio*) fishery. He also purchased an additional shrimp (*Pandalus* spp.) quota in 1996. By the late 1990s Jack suggested that crab catch rates in his original areas had begun to decline, and he was forced to move farther offshore to keep them high. By the year 2000, to cope with these distant, offshore fisheries he lengthened his vessel to 65-feet (the legal maximum) and widened and deepened it. He also began to employ more sophisticated hauling, communications, navigation, and fish finding equipment.

Once again, these changes required learning how to operate new equipment and gear, and also involved monitoring the activities of other vessels engaged in these fisheries, as well as identifying new fishing areas and studying the behavior of this new species.

Jack has also had to learn to 'navigate' new management regulations. Like other crab fishers in Newfoundland and Labrador today, Jack is limited to certain areas where he can fish crab, has a set trap limit, and has a yearly individual quota. He was also obligated to keep records in a logbook. One of the major ways managers have monitored the status of crab stocks has been to collect catch per unit effort (CPUE) data from commercial

[16]In response to declines in abundance, by 1994 the DFO had declared a moratorium on cod fishing on the 'northern Gulf' cod stock of the Gulf of St. Lawrence. This followed a similar moratorium on the stock of 'northern cod' (off the northeast coast of Newfoundland and Southeastern Labrador) in 1992.

fishers. They rely on logbooks completed by harvesters to do so. Interestingly, Jack talked about how these requirements of science and management had begun to affect the way that he fished. After some initial reluctance, Jack and other fishers began to see how a more 'scientific' approach to record keeping could improve his own fishing performance:

> "If I put the wrong information in my logbook, if I want to go back and look at it next year when I go back I'm going to get the wrong picture."

FROM LOCAL ECOLOGICAL KNOWLEDGE TOWARDS GLOBALIZED HARVESTING KNOWLEDGE

As Jack shifted to larger vessels fishing different gear in different places, the spatial, temporal, and to some degree ecological bases for his knowledge began to change. Some of the changes in Jack's fishing practices are suggested in Fig. 1. Jack began his career in the late 1950s fishing in an 18-foot hand-built wooden vessel, primarily for cod in local areas, using no more than a compass, local landmarks, and accumulated knowledge of the sea. By the time of our conversation (2003), he was fishing up to 250 kilometers offshore in a fiberglass vessel with sophisticated communications and navigation technologies for two species, crab and shrimp, that were not targeted at all when he began his career.

During his career Jack has been part of a shifting socioecological network, in which the practices, the social organization related to harvesting fish, and the fish resources themselves have shifted radically. There have been changes in markets, management and/or fisheries science, the target species for fisheries, intergenerational and skipper-crew relations, vessels and gear technology, and changes in the biological and to some degree the physical-chemical environments within which Jack has fished. Indeed, ecological change (particularly declining abundance in target species) has been one of the primary drivers affecting Jack's fishing practices and the management frameworks within which he operates. At the same time, of course, the changing fishing practices of fishers as a whole have created ecological change. Likewise, as Jack shifted towards mobile technology, he learned about the migration of fish in areas beyond his original fishing area. The importance of ecological change as an 'actor' comes into sharp relief from our interviews, and stands in contrast to causal explanations of fishers' behavior that focus purely on economics.

Jack describes learning to fish as a part of growing up on the water, by being immersed within a fishing culture and learning from family members, and through fishing local areas that had been fished by his family for generations. Where harvesters once knew local grounds intimately through remembered experiential knowledge and accumulated wisdom collected

over decades (or centuries), making them often reluctant to travel elsewhere to fish, they now rely on mobility and come to more superficially 'know' much larger (and deeper) areas through practices that are mediated more directly by sophisticated technologies in a fishery that moves quickly from place to place and species to species, but in which they record in written or electronic form (rather than orally and by memory) catches, depths, water conditions, and other information for future consultation. More recently Jack, and many successful fishers like him, also began taking formal training to help them work with increasingly sophisticated technologies. This has helped to direct the development of more 'rational and efficient' fishing practices, ideas and values that also were shared by many of the other participants (managers, fish buyers, etc.) in the expanding networks that produce knowledge. He has also begun communicating (even during fishing) with others outside of his immediate family and community, including competitors and the scientists, managers, politicians, insurance agents, fishing gear manufacturers, and fish buyers with influence over his enterprise.

In the past, fishers' knowledge and practices more closely reflected local ecology and customs, were shaped by relatively egalitarian (although gendered and generational) social relations among harvesters, and were primarily based on oral and practical transmission of knowledge and skills. At the beginning of Jack's career, networks were more local, with weaker relations outside the communities, and chains of relations were short. There was no management framework to speak of for fishing or fishing vessels and scientists were people you heard on the radio. More recently, knowledge and practices have changed as formalized institutions, laws, procedures, and new equipment-organized practices are moving them in new directions within which intimacy with the behavior of particular fish in particular times and places is much less important to the success of an enterprise than familiarity with an elaborate web of policies, industry practices, and rapidly changing technologies. Jack's contemporary socioecological network and, relatedly, his LEK are very different from that with which he began. Furthermore, Jack's story suggests that rapid change is continuing as he prepares to deal with the possibility that the snow crab stocks to which he has access may be in decline. As species, snow crab and shrimp represent a very different challenge for a harvester than cod, particularly in the days before the otter trawl. When you find the holes, the crab will be there, if there are any to be had. Shrimp involve long, boring tows. Some older harvesters find the fishery of today for these species much less interesting and challenging than pitting their wits against the cod.

Today's harvesters are embedded in networks that differ from sector to sector but are generally larger and more heterogeneous from a social,

political, technological and ecological perspective than those of coastal fishers in Newfoundland and Labrador's post World War II fisheries. Jack's story illustrates how a fishery and with it LEK, can evolve. Over his career, Jack supplemented and to some degree perhaps replaced his LEK based on in-depth, community-based, intergenerationally transmitted knowledge of a particular local setting with a combination of experiential, intra-fleet and formal extra-fleet knowledge about a broader range of ecologies and practices. If we think of Jack not as typical but as a "survivor" supported and encouraged by the interactive effects of modernization policies and persistent resource degradation, we can think of his LEK as moving along a continuum from small-scale, locally situated, long-term, harvest-oriented LEK towards what might be termed globalized harvesting knowledge (GHK). Other harvesters are in different places on this continuum which can help explain similarities and differences in their LEK.

DISCUSSION: EVOLVING CONSERVATION AND MANAGEMENT PRACTICES AND THEIR RELATIONSHIP TO LEK AND GHK

As we suggested earlier, fishers, like scientists and managers have always been part of dynamic socioecological networks that have mediated the development of their knowledge. Because all knowledge is to some degree situated at any one point in time variability in those networks and their related experiences have contributed to variability in their knowledge. The point we wish to make here is that, as the socioecological network in which these fishers are embedded has changed, so too has the very process of knowledge production and learning, as well as the orientation of these fishers to each other, the fish, their work, their communities, to scientists and to managers—and this has implications for the content of their LEK and ways it might interact with other knowledge systems in the development of more effective conservation and management practices in the future. This is a particularly salient issue given recent signals from the DFO.

As noted, another related question centers on how conservation and management practices develop, and how their development relates to the creation and development of LEK (in our case, the development of that LEK in Newfoundland and Labrador society). Several issues complicate that discussion here. The first is that the very concept of local knowledge becomes problematic in the context of dynamic, increasingly mobile commercial fisheries in Newfoundland and Labrador and the potential disappearance of inshore fisheries. The second is, as we also have learned from Jack's story, there is more than one knowledge system that has

interacted over our study period to shape interactions with the environment.[17] When local resource users make decisions about their individual and collective practices, LEK (along with other concerns/issues like spiritual beliefs, life cycle, kinship, etc.) necessarily mediates those skills and practices. Fishing practices in the early stages of Jack's career were by no means always conservationist, as evidenced by such things as a history of overly fine mesh in cod traps, a failure to retrieve gillnets encouraged by gear replacement programs at certain points in history, and by comments indicating that as markets for other species emerged, formerly discarded bycatch species (which were often dead) started to be landed.

As the locus of decision-making authority has shifted over time, different bodies of knowledge have come to play a more dominant role in influencing management. In the Canadian context, one new knowledge system that has come to interact with management in the post WWII period has been western stock assessment science. For example, the Department of Fisheries and Oceans, created to manage the newly 'nationalized' groundfish populations in the Canadian Exclusive Economic Zone (EEZ, declared in 1977), utilized data from randomized annual survey trawls and from the offshore dragger fleet as the basis for stock assessments. Data from the inshore fishery and the knowledge of its participants, when they were collected, were not used in fisheries management modeling or in the setting of the Total Allowable Catch (TAC) after the extension of the EEZ (Finlayson, 1994).

In the wake of cod stock collapses, many have begun to question the legitimacy of stock assessment science and the quota management approaches it is intended to support. In part to retain their legitimacy, the Canadian government has begun to signal a shift towards (re)including fishers and their knowledge in management, though it is essentially unclear how this will play out in practice (Murray *et al.*, forthcoming). We agree that fish harvesters and their LEK can and should play a more prominent role in scientific research and in 'managing' the human/environment interface, but suggest that this relationship should be treated cautiously. Our own research, for example, is based on the idea that traditional boundaries between vernacular and scientific knowledge (and related boundaries between natural and social science) can serve to mask interactions between fish and fishers, and within the larger socioecological network in which both are embedded, with serious consequences for the accuracy and

[17] It is important to recognize that these systems of knowledge are not entirely separate: indeed, as we suggest above, the generation of local knowledge is increasingly influenced by the generation and assimilation of 'scientific' knowledge. Conversely, stock assessments rely on information from and assumptions about the dynamics of commercial fisheries (Neis *et al.*, 1999).

effectiveness of fisheries science and management (Murray *et al.*, 2004; Neis and Kean, 2003). Observing fishing practices (or 'knowledge in action') provides critical insight into the interactions between fish, fishers, and larger systems. Observations of where a fisher sets his/her crab pots, for example, provide insight into, among other things, managerial (fishers are limited to certain management areas), ecological (crab are only found in certain habitats), and technological (vessel size/capability can determine where a fisher can fish) aspects of this network.[18] Furthermore, failure to take into account potential relationships between local and other forms of management, technology, and behavior can contribute to the misinterpretation by scientists of the results of LEK/GHK interviews and logbook programs.

It is also important to consider what LEK and science we might need if we are to plan recovery and what will be available in the future. Jack, for example, is a survivor. He estimates that when he started fishing as a young boy there were 120 fishers from his part of the coast. When we interviewed him in 2003, he said there were less than 20 left after the moratoria of the early 1990s. Although Jack suggested that he was encouraging his son to be a fisher, this stands in stark contrast to the large majority of interviewees (88%, $n = 34$) who stated they would not, or have not, encouraged their children to fish. It is important to note that the pattern of intensification coupled with expansion that Jack has followed is consistent across some of the fishers interviewed but by no means all of them (again, see Fig. 2). If all those harvesters who still wait for the cod to migrate to the limit of their range, or who rely on populations of cod that inhabit particular bays and inlets, disappear the composite LEK available for use in stock recovery and to calibrate our science will be less rich and less effective. In our project Coasts Under Stress, we have been combining the results of our career history interviews with landings data, archival data, research vessel survey data, and tagging data to try to reconstruct interactions between fish and fishers over multiple decades. In the feedback meetings we have conducted with fish harvesters we are trying both to validate some of the very detailed information that we have learned from them about critical juvenile cod habitat, local cod stocks, spawning areas and other processes, and using our reconstruction of changes in their marine ecosystems, to begin a conversation with them about ways to achieve recovery of their fisheries. In those meetings, a clear division is evident between those in the larger vessel, mobile gear sector of the nominally 'inshore fleet,'[19] and those that fish

[18] We recognize that direct observation is not always possible, nor is non-interpreted observation sufficient. We therefore have relied on interviews with the fishers themselves.

[19] The range and mobility of the larger vessels of the nominal inshore fleet (defined by the DFO as vessels under 65 feet) has blurred geographic distinctions between the fishing grounds of the 'inshore' and 'offshore' (>65 feet) sectors.

from fixed gears in smaller vessels (see Sinclair, 1987, for an exploration of the early roots of this schism). There is a deep-seated concern about who will be able to survive in the fisheries of the future.

We have argued that accurate information about past ecosystems is of critical importance to managers and their harvester partners who seek to restore degraded ecosystems. To an astonishing degree, LEK is often the only information available about many aspects of our those past ecosystems in marine fisheries as in agriculture and forestry. If we are to make effective use of LEK in recovery, it is necessary to collect, along with the ecological information harvesters can provide, information on the process of coevolution from the LEK/GHK of active harvesters *and* those who have fallen by the wayside. This information is essential if we are to fully comprehend the extent to which we have transformed marine ecosystems, how this has happened, and the full range of potential options for recovery. It is also critical if we are to understand the changing politics of conservation. Part of the value of historical reconstruction work that draws on LEK is that it puts us in touch with the growing numbers of harvesters who have been forced out of the industry or who have retired as the industry has downsized. They will often have longer term LEK that differs from that of survivors in its intimacy with particular places and fish populations and assemblages. Historical depth matters in a rapidly restructuring fishery associated with resource degradation and fishing-down sequences, where both harvester and scientific knowledge can be associated with the "shifting baseline syndrome" (Neis and Kean, 2003; Pauly, 1995). Of course, this information must also be seen against a backdrop of technological change, changing markets, shifting management priorities and regulations, and dynamic ecological conditions.

Canadian fisheries appear to be at a point where the locus of management authority and responsibility remains with the DFO, where the goals of management appear to have shifted more heavily towards conservation, and where the DFO has signaled a desire to (re)include LEK in management decisions (Murray and Neis, 2004). Current (and future) relationship(s) among science, management and LEK are contingent on several things, including the species under consideration, as well as historical, political, and geographic variables. There is also concern that sometimes the mode of collection of LEK can relegate it to playing a supplementary and subordinate role to science, as in the case of the 'Sentinel' fisheries (Murray *et al.*, forthcoming).

Earlier, we noted that the production and usage of spatially (including depth) and temporally oriented information in fishing practices for harvesters like Jack has changed along with technological sophistication. Utilizing depth sounders, GPS technology, and position plotters, fishers like Jack now often have real-time mapping capabilities that allow them to

locate suitable bottom over a huge spatial range, track catch rates in specific areas, and return to those areas until catch rates decline. As with the offshore trawler data of the 1980s, this type of 'rational, efficient, and scientifically oriented' information is perhaps more 'legible' for managers (and fisheries scientists) than that which dates from earlier years and exists only in oral form or indeed only in local memory. Contributing to this congruence, the reliance of DFO managers on some of those same technologies has increased. For example, the DFO now requires vessels carry a 'black box,' which relies on GPS technology to accurately and continuously monitor the position of vessels in the crab fleet, thus making it more difficult for fishers to misreport fishing areas (which some harvesters we have interviewed suggest has occurred) or perhaps to surreptitiously offload catches and thus overfish their quota. But its introduction also suggests that the issue of control of this type of information will be an increasingly salient aspect of the relationship between local harvester, their LEK, GHK, and managers.

We can not assume that the uncritical inclusion of LEK (and perhaps particularly GHK) in management decisions will automatically lead to improved conditions for the fish, for the fishers, or for fishing communities in general. We argue that both LEK and GHK are concepts that combine elements from different knowledge systems, and result in fishing practices that mediate between a wide range of material and symbolic practices and techniques. At its most extreme, however, GHK is mainly concerned with the efficient capturing of economically valuable fish species, wherever they might be, and marketing those fish and shellfish species to the highest paying processor rather than, as was more characteristic of the past, to local processors who also provided employment to family members and other members of local communities. GHK characterizes large-scale, migratory, and industrialized fisheries all around the world. These fisheries are not necessarily new but were, historically, constrained by seasonality and other factors and starting in the 1970s, by the introduction of 200 mile EEZs and policies favoring local harvesters (Neis, 1991). The effectiveness of these policies, however, has been eroded significantly by continued environmental degradation and by the increasing dominance of neoliberal policies associated with globalization (Neis and Williams, 1997).

In recent years, harvesters in Newfoundland and Labrador have had to make radical changes to their fisheries. Many initially switched to larger vessels like longliners and otter trawl and, since the moratoria on the groundfish fisheries, to snow crab and/or shrimp. Many former coastal harvesters are now going far offshore in order to survive. As the relatively few who do survive adjust and adapt to the interactive effects of environmental degradation and sociopolitical change, their LEK will tend to move along

a continuum towards GHK. This does not mean the potential for conservation conversations and practices among harvesters disappears but it does change. We suggest that empirical evaluations of the contingent relationship between these bodies of knowledge and the larger, changing socioecological networks with which they are coevolving will provide a fruitful avenue of research for social scientists who can point to the potential risks, as well as the potential benefits, in interactions between LEK, science and management.

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