Taking Stock: Fish Harvesters' Knowledge and Science Research and Practice for Newfoundland and Labrador and their Potential Role in Future Sustainable Fisheries

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Introduction

Documenting fish harvesters' knowledge (FHK) was routine in early NL fisheries science accounts of researchers like Templeman, but this changed over time with the development of stock assessment resources after the extension of the 200 mile exclusive economic zone.[1,2] With the collapse of Atlantic Canadian cod and other groundfish stocks in the early 1990s interest in systematic documenting of FHK, comparing it with available science, and examining the relationship between FHK and science in management re-emerged leading to the development of an extensive body of research in the broad field both within Atlantic Canada and globally.

FHK can be accessed using diverse methods and approaches and can provide insights into fish and fishing behaviour, and dynamics of different segments of regional fishing industries. It can also be used, along with scientific data to reconstruct environmental histories at multiple spatial and temporal scales and to explore both seasonal and longer-term dynamics of marine and freshwater social-ecological systems. The results can help inform stock assessment processes and management.[3–6]

This *Taking Stock* background paper reviews post-1980s Atlantic Canadian FHK research, with especial focus on Newfoundland and Labrador, and locates it within the international literature on FHK and science. It also discusses policies and practices in the region with the potential to marginalize and/or increase effective access to and use of FHK in stock assessments and management. The review of this literature is used to inform a discussion of strengths, weaknesses, and gaps in existing Atlantic Canadian FHK and science research, policy and practice. The paper also draws attention to FHK datasets on the historical presence, composition, and distribution of fish assemblages in coastal areas of NL that could be useful to OFI Module I and other Modules focused on sustainable fisheries.

Methods

We have accessed relevant Atlantic Canadian literature and resources using three strategies: a) by sharing articles, reports and available datasets known to the co-authors of this paper; b) by reviewing the bibliographies of these shared resources; and c) by carrying out an environmental scan of the international literature applying a set of inclusion/exclusion criteria to limit the scan and to extract relevant sources from Atlantic Canada. The strategy for the environmental scan of the international literature on FHK and Science followed three steps: (1) literature search; (2) scan of selected abstracts; and (3) scan of selected full-documents from Atlantic Canada.

For the initial international scan, a list of search terms identified by the team was used in searches of three online databases: Scopus, Web of Science, and Google Scholar. All search terms were combined into search strings to increase the capture of relevant documents. Search strings were a combination of two or more search terms, for example, "fishermen's knowledge" OR "traditional ecological knowledge" AND "fisheries" (see detailed methods statement for more information on this). This first search produced 701 sources. Lorenzi scanned the abstracts for these 701 sources and used a set of exclusion criteria to narrow the focus of the scan. All documents that met one or more of the following criteria were excluded: (1) not written in English; (2) published before 1980; (3) not peer-reviewed articles, books or book chapters; (4) documents that did not use data provided by fish harvesters; (5) documents not focused on marine environment/fisheries; (6) documents not concerned with fisheries management and/or stock assessment topics; (7) documents focused on recreational or subsistence fisheries, and (8) duplicate publications. The use of these exclusion criteria reduced the number of sources included in the scan to 242.

In step 2, key information was extracted from the abstracts of these 242 documents and incorporated into a qualitative database. Only the abstracts of the documents were analyzed during this phase with information related to the year of publication, the location of the study, general discipline, publication type, the general subject of the document, research methods and the relationship between FHK and Science extracted into a database of sources.

The last step of the environmental scan involved a deeper analysis of literature from Atlantic Canada. The 242 documents selected from the international scan covered a large array of themes and locations, therefore a list of inclusion criteria was developed to guide the selection of documents relevant to Atlantic Canada fisheries. These were selected reviewed in full. The inclusion criteria included: (1) FHK research on temperate and/or arctic environments; (2) focused on commercial and marine (versus subsistence and freshwater fisheries); (3) species at risk; or (4) on environmental impacts (i.e. impacts of fisheries on coral, climate change, and FHK). In addition to the information retrieved from the abstract, full-document analysis focused on extracting information about the conceptual frameworks and approaches, types of fisheries, research questions, findings and insights, and the wider context in which FHK can contribute to stock assessment and fisheries science and management for that specific fishery or situation.

Findings

Defining FHK

There was no consensus on the definition of FHK in the scanned literature. However, most of the studies captured in our environmental scan defined FHK as the Local Ecological Knowledge (LEK) of fish harvesters. LEK, as summarized by St. Martin[7], is based on complex processes of knowledge formation deriving from personal, shared, and inherited experiences. FHK is knowledge connected specifically to fishing groups and includes information not only on fishing practices and fish species, but also on annual cycles, winds, tides, fish species abundance and distributions ad different spatial and temporal scales[8]. Because of these connections, many authors see LEK, and therefore FHK, as a product of social, economic, ecological, and governance conditions[7–11]. In this way FHK, is linked in the literature to LEK, Traditional Ecological Knowledge (TEK), and Indigenous Ecological Knowledge (IEK) as LEK/TEK/IEK are also considered to comprise knowledge produced, accumulated, and organized by those interacting and using marine wildlife resources[12].

FHK and science research and practice globally

After applying the exclusion criteria (step 2), the environmental scan of international literature on FHK and Science returned 242 documents. Results of the abstract review of these documents indicate that in recent years, the number of publications on FHK and Science has been increasing (Figure 01). In fact, 75% of these sources were published between 2008 and 2018. Although the publication of Atlantic Canadian FHK and science research has been more evenly distributed over the years, 53% of the Atlantic Canadian sources were published in the last decade. Globally, most FHK and Science research has been published in multidisciplinary sources. Multidisciplinary sources are those drawing from several fields like, for example, sociology, economics, biology, and conservation. According to our environmental scan 63% of all documents came from multidisciplinary publications, while 25% were published in social science sources, and 11% in natural science. The main sources for peer-reviewed papers are the journals *Marine Policy* (14% of all publications), *Ocean & Coastal Management* (7%), *Ecology and Society* (4%), *Journal of Ethnobiology and Ethnomedicine* (4%), and *Fisheries Research* (4%). The ICES *Journal of Marine Science*, *Plos One*, and *Fish and Fisheries* combined account for 8% of all publications.

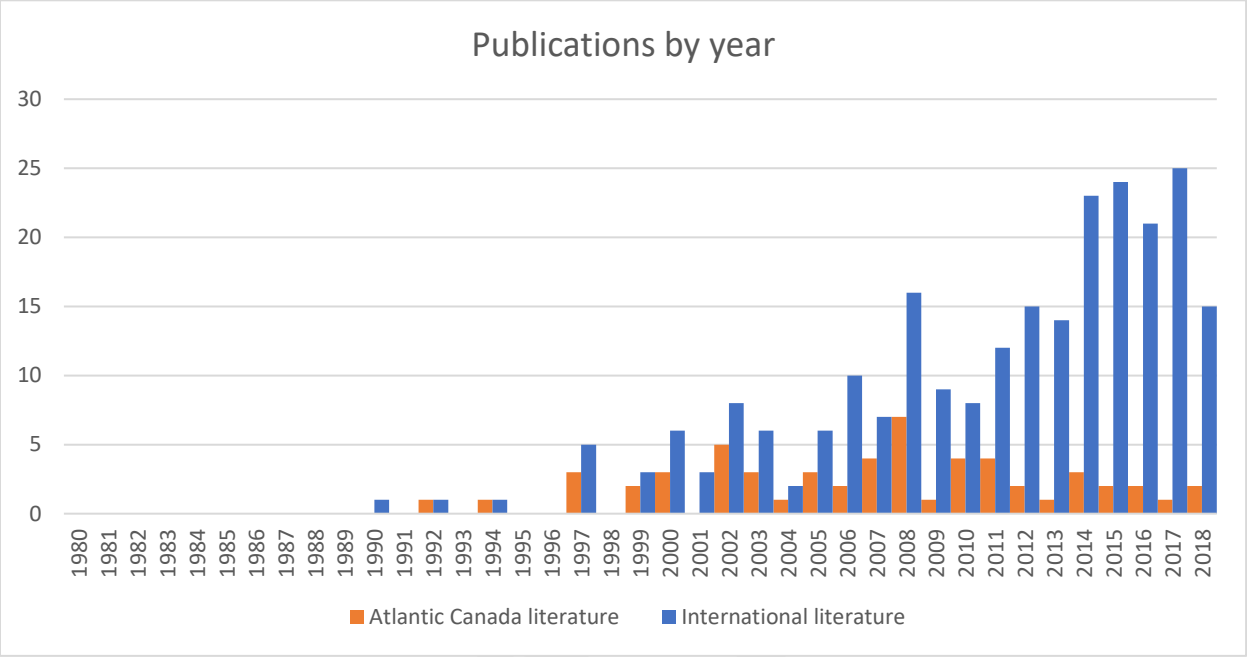

Figure 1. Number of documents meeting the exclusion criteria published – including grey literature – by year since 1980.

Overall, international research has mainly focused on temperate[13] (49%) and tropical[14] (40%) environments, while commercial fisheries in polar[9] regions (3%) have received less attention. Brazil (14%), Canada (26%) and the United States (11%) are the countries with the most FHK and science research. Research focused on these three countries contributed 51% of all 242 documents. Globally focused documents, including those on larger marine areas such as the Atlantic and Indian Ocean[15], and the Mediterranean[16] and Adriatic Sea[17], comprise 9% of the publications.

A diverse array of methods and approaches can be used to gather and assess potentially valuable information from fish harvesters. In our environmental scan, most of the researchers (48%) used interviews to collect data. Another 32% used mixed methods, combining harvester interviews or surveys with environmental sampling. Conceptual papers, i.e. publications that were not based on new data collected either by interview/survey or environmental sampling accounted for 10% of the scanned documents.

In international research on FHK and Science, 40% of all publications have focused on understanding or assessing FHK.[10] However, this literature has contributed to a variety of other subject areas including those related to ecology, abundance and diversity of fish species[18] (20%), changes in fishing efficiency through technological and other changes in fish harvesting practices[4] (14%), fisheries management and policies[19] (13%), the ecology of marine environments[20] (8%), participatory mapping[21] (4%), and gender and FHK[22] (1%).

In 36% of the studies, FHK was used to inform management decisions, attempting to contribute to fisheries governance[6]. In 29%, FHK was used to generate of new knowledge or information in fisheries where data were poor or limited[23], and in 25% to assess the kind of information or knowledge that was

available[24] (25%). The remaining 10% of publications compared the availability and quality of FHK knowledge with results from direct scientific sampling [25].

FHK research and practice in Atlantic Canada

A total of 51 Atlantic Canadian FHK publications identified through the international scan were populated into a qualitative database for in-depth analysis of the full articles. Suggestions from the supervisory committee generated an additional 11 sources – 9 theses, 1 technical report, and 1 conference paper resulting in 61 publications. Overall, 43% of these documents were published as peer-reviewed papers, 25% as book chapters, 15% as books, and 15% as theses. The remaining 4% were technical reports and conference papers.

The post-1990s round of research in Atlantic Canada on FHK and science[26] was mostly inspired by the collapse of cod and other groundfish stocks[27]. Although related initiatives happened across the Atlantic Canada[28], it is noteworthy that the pioneering studies happened in Newfoundland and Labrador (NL) in response to deepening concerns about northern cod stock assessment science[29] including among some groups of fish harvesters. After the northern cod fisheries were closed in 1992, FHK and science research in NL was integrated into a larger program of study to understand the origins and dynamics of the stock collapse and its impacts[30]. This mid-1990s FHK research focused on the Bonavista and Trinity Bay region and encompassed inshore, midshore and offshore harvesters[27,31]. Similar research done after 2000 focused on Southern Labrador, the Northern Peninsula and the NL West coast[32,33], but some was also undertaken in other parts of Atlantic Canada[34] including in Nova Scotia.

Most of the early documents were published as books or book chapters, of which the book *Fishing for Truth: A sociological analysis of northern cod stock assessments from 1977-1990*[29] published in 1994 by Finlayson can be highlighted as the first book focusing on stock assessment science, *i.e.*, the stock assessment of the northern cod stocks, and speaking to some scientists' perceptions of FHK (particularly FHK of small scale harvesters). A companion piece was based on interviews with fish harvesters in Petty Harbour and was the first NL publication on FHK and one of the first globally on FHK in commercial fisheries. [26] The edited collection *Finding Our Sea Legs: Linking Fishery People and their Knowledge with Science and* Management[35] was based on presentations at the 1998 international workshop, "Bringing Fishers' Knowledge into Fisheries Science and Management", the first such workshop in Atlantic Canada involving fishers and social and natural scientists. *Finding our Sea Legs* addresses issues such as the need to understand the different types of knowledge, alternative methodologies for gathering FHK, the contribution can make to filling gaps in scientific knowledge, the potential use of FHK to generate new information on temporal and spatial changes in fisheries. It also explores issues, prospects, and problems around the integration of resource users and their knowledge into fisheries science and management.

Coasts Under Stress: Restructuring and Social-ecological Health[36] from 2007, *Making and Moving Knowledge: Interdisciplinary and Community-based Research for a World on the Edge*[37] from 2008, and at the international level *Fishers' Knowledge in Fisheries Science and Management*[38] (2007) were other important books that explored the relationship between FHK and science. The book *Coasts Under Stress* presents an interdisciplinary analysis of changes in the environment and society, and the capacity of coastal communities of Canada's east and west coasts to deal with these changes. The book combines natural and social scientific data with an examination of the experience of coastal communities' people. It analyses the effects on coastal communities caused by economic decline and ecosystem damage. *Making and Moving Knowledge* focused on how knowledge is created and transferred; it compares the knowledge generated by universities and government with practical knowledge from coastal communities. *Fishers' Knowledge in Fisheries Science and Management* is compilation of international

case studies and focuses on how and where fisher's knowledge is being used in association with science. This book stresses the importance of creating a framework that effectively integrates FHK into fisheries science and management. It also calls for the establishment of international efforts to collect, preserve, disseminate and apply FHK.

In recent years, more Atlantic Canadian FHK studies have been published as peer-reviewed articles. In the last decade 33 documents addressing FHK and Science in Atlantic Canada have been published, more than half (55%) as peer-reviewed articles. These articles focus on notions of justice[39], the development of fisher's local knowledge[40], mapping local ecological knowledge[24], the key issues faced by inshore fishers[41], ways to combine different types of knowledge within fisheries management[10,42,43], and the information in FHK about biology, abundance, and the biogeography of fish species[3,4,44,45]. The species of interest in these studies include: northern cod[3], Iceland scallops[42], lobsters[45], wolfish[44,46], green crab[40], redfish[6], and herring[47]. One paper also specifically addressed the impact of aquaculture activities on capture fishing[48].

In the NL literature, researchers have gradually developed and refined FHK and Science methodologies that combine regionally-based career history interviews with a review of relevant stock assessment science[33]. Most of the NL studies have used a combination of taxonomic/toponymic interviews with retired harvesters to generate familiarity with species, fisheries and place names across a larger region followed by a series of career-history semi-structured interviews with older, often still active harvesters identified as experts in local areas. Career history interviews organized around mnemonic devices such as different boats owned over harvester careers were designed to use FHK to reconstruct the history of fisheries and fish distributions and to explore key issues like species distribution in coastal areas and to a lesser extent offshore, changes in efficiency and in spatial and temporal distributions of fishing effort, and migration and spawning patterns for different species. Over time, researchers changed the design make it easier to link transcripts with map data and began to undertake systematic analyses of transcript data across large datasets using qualitative software like N-Vivo. Interviews, in contrast to other methods such as participant observation[5,49], have the advantage of allowing for historical reconstructions and to gather data across relatively large spatial areas like the NL west coast.[27].

Targeted single-species studies on FHK and science on lumpfish[27], capelin[50], herring[47], snow crab[9] and corals[51] emerged from these larger studies. In recent years more publications have used a multi-method approach combining interviews or structured surveys with fish harvesters with fishery-independent data[33] such as research vessel (RV) survey data[44], fisheries observer data[52], or onboard observation[53]. In this region, fishery science is largely based on RV data collected by the Department of Fisheries and Oceans (DFO) research vessels that are, therefore, independent from information provided by fish harvesters or collected from fisheries (as with logbook or purchase slip data) but may not overlap temporally or spatially with FHK data.

According to Paterson et. al.[47], by bringing together different knowledge sources such as those from science, management, and FHK, it is possible to deepen our understanding of fisheries and fish stocks. Both FHK and scientific knowledge are arguably partial[54] in that they are a product of times, places, and socio-cultural and ecological contexts[33]. Interview data can be a vital addition to scientific data because they contain information that are often at temporal and spatial scales that are different from the data in trawl surveys. Insights from micro- and meso-scales can inform and complement macro-scale data [6,33,40,55,56].

More recent studies have focused on understanding the development of FHK[40] and its implications for the management of new environmental scenarios, such as the arrival of invasive species. The interactions between fishing behaviors and management practices and their socio-ecological implications[57] have also been explored, as well as notions of justice,[39] and the key issues faced by the fishery from the perspective of fisheres[41], as well as how FHK can provide advice for an ecosystem approach to inshore coastal

management[55]. Attention has also been paid to how FHK can contribute to our understanding of stock structure, stock fluctuations and fishing fleet dynamics[47]. The characteristics of stock assessments and their strengths and weaknesses from the point of view of harvesters are among the central issues addressed in the FHK and science literature. In the latest publication on the subject Duplisea[6], compared historical catch data from interviews with fish harvesters with reported data to reconstruct the total catch of two species of redfish fished in Atlantic Canada. The results not only showed that catch statistics may have underestimated catch by a factor of 2 and so stock assessment models should consider misreporting scenarios to decrease uncertainties, but also showed that fishers can provide reliable historical catch data and thus a useful context for current stock assessments. Murray and Ings[9] suggest that the interpretation of fisheries-dependent data (e.g. logbooks) sometimes used to assess stocks status can benefit from recognizing adaptations in fishing strategies in response to factors such as key management actions or environmental changes.

Fishers pay attention to the surrounding environment as local conditions have an impact on fishing activities[45] therefore, FHK is dynamic[10] and mutable[34]. It has the capacity to incorporate new understandings and needs. Within this dynamism, new knowledge may emerge. Assessing the local knowledge of Nova Scotian fishers on a recently arrived invasive green crab, Cosham et. al.[40] concluded that FHK may develop in a short period of time and thus have an advantage over older sources in that it may better reflect recent changes. This up-to-date information is valuable not only for management goals but can also help guide future research.

At present, little is known about the impact of finfish aquaculture operations on commercial wild fishery species and how these affect capture fishing practices[48]. As the Southwest New Brunswick (SWNB) case study by Wiber et. at. shows, FHK and related insights should be taken into account in designing future research on the environmental changes around aquaculture sites, including in nursery and spawning grounds, and on effects of salmon aquaculture on key habitats for commercial stocks. In their study, the input from local fishers was also vital to improve management systems. In SWNB, aquaculture was perceived by local stakeholders as part of a viable coastal community. This might be the case for other areas of Atlantic Canada where aquaculture activities are growing. However, the inclusion of FHK in the design of research, as well as in the management systems, is crucial, they argue, to ensure the sustainability and successful co-existence of aquaculture and capture fishery[48].

Another research gap identified in the Atlantic Canadian FHK research relates to species at risk. Dawe and Neis[46] stress the importance of creating a legitimate space in the Species At Risk Act (SARA) process for the inclusion of stakeholder participation and FHK. Future research aiming to contribute to the conservation of species should be based on systematic collection of FHK in conjunction with a review of scientific data and development of new research programs. For this to work, there has to be an allocation of resources to allow for the systematic collection of FHK. However, as Carruthers and Neis[4] pointed out research on topics that may impact fishing regulations, such as species at risk or by-catch, have practical and ethical issues. Fishers may be concerned about negative impacts generated by the research making the process of engaging fishers in the research crucial but laborious and time consuming[4,58]. Although FHK studies are recognized as being an economical way to gather information on fisheries and fish stocks, it is important to provide a pool of resources to appropriately gather and analyse FHK-related data and to allow FHK and science research to expand in new directions in the future.[5,59]

Bundy and Davis[55] draw from a case study with small-scale fish harvesters in Nova Scotia to emphasize the importance of including fish harvesters in decision-making processes related to the determination of what matters in terms of protecting marine habitats and ecosystems. Excluding fishers from this process could, they argue, disrupt harvesters' trust in science and government resource managers. On the same note, in their study of the perspectives of fishers on the key challenges facing the inshore fishery in NL, Smith et. al.[41] stress that even though fishers having an "insider's view" based on observations, reflection,

and adaptation, unfortunately, efforts to include FHK have been limited. However, fishers have prioritized the "use of all forms of knowledge" and expressed their willingness to bring their expertise and perspectives to create a more well-rounded perspective for the fisheries governance[60].

Existing Fisher's Knowledge datasets

- Coasts Under Stress database

The Coasts Under Stress Research Project was a seven-year interdisciplinary project focused on social-ecological restructuring and its impacts on the health of people, their communities and the environment on the Atlantic and Pacific coasts of Canada [36]. On the Atlantic side of the Coasts Under Stress project, FHK research was conducted by an interdisciplinary team with four core researchers experienced in collecting FHK from fishers that included both social and natural scientists. The overarching goal of the project was historical reconstruction using FHK coupled with other sources of information (landings records and trawl survey data) to illuminate the social-ecological dynamics from ~1950 to the time of the study in 2002-2005. The study area included the west coast of the Island of Newfoundland from port aux Basques to St. Anthony (corresponding to NAFO division 4R), as well as Southern Labrador, from the Quebec border to Cartwright (corresponding to NAFO division 2J). This dataset is managed by Grant Murray of Duke University who can be reached at grant.murray@duke.edu. Transcripts and maps from the 1990s FHK study of the Bonavista and Trinity Bay Peninsula region are stored in the folklore archive at Memorial University.

Given OFI interest in halibut and flatfish stock assessments and management, we have quickly extracted from the transcripts information on these species that has not yet been published. These data can be accessed through Grant Murray.

The target population of fishers was distributed throughout the study area, with some concentration in areas where fisheries were particularly intensive. Consistent with the idea of social-ecological systems, FHK interviews were built around the idea that fishers are part of interactive systems that include their biophysical environment, as well as 'human' dimensions' such as management frameworks, diverse and changing technologies, communities and markets. Interviewees were identified by cross-referencing two lists (created at our request): one by field representatives of the provincial Department of Fisheries and Aquaculture (DFA) and the second by chairs of local fisheries committees (who were also fish harvesters). 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. Additional respondents were sometimes identified using snowball sampling by asking interviewees to recommend other fishers in their area.

Two types of semi-structured interviews were conducted, for a total of 88. The first series became known as the taxonym/toponym (tax/top) series and included 32 interviews with older fish harvesters. The second became known as the fishing expert (FE) series and included interviews with 56 individuals who were still active or recently retired (interviews were from 2–5 h each). The tax/top series was focused on the presence/absence (whether it was present in their fishing area) of a wide diversity of species, observations about trends in abundance of those species, local names for those species and some information about changes in fishing effort and vessel type over time. The FE interviews were detailed career history interviews and included questions about vessels and engines, gear, species fished, seasons, catch rates and fishing locations, and specific bio-physical conditions. The FE interviews covered a wide range of species in limited detail, but emphasized certain key species in particular, including cod, snowcrab, shrimp, capelin, and others. Both sets of interviews involved the use of nautical charts during the interview to help structure the conversation, and tie observations to particular places as appropriate.

Nearly all interviews were recorded and fully transcribed, then coded and organized using NVivo. Quantitative information on vessels, equipment, fishing gear and catch were organized using Excel. Chart-based information was digitized into MapInfo GIS software. Methodological details for the related studies are available in two related publications[29,30].

- Community-Based Coastal Resource Inventories in Newfoundland and Labrador

The interviews with fish harvesters carried out as part of the Community-based Coastal Resource Inventories have been assembled into a database of maps related to presence/absence of diverse species in the coastal zone of Newfoundland and Labrador. This information was collected by interviewing people living in the study area and knowledgeable about various aspects of the marine environment as well as by visual surveys. Across the province, communities prepared inventories of marine resources, traditional fishing areas, and marine-related uses such as fish processing plants and wharves. The inventories generally include information about groundfish, pelagic, shellfish, marine mammals, aquatic plants, birds, aquaculture, infrastructure, culture, tourism and recreation, and shoreline classification. The coastal zone inventory also contains information on tourism and recreation resources and can be access through the link: https://goo.gl/5ixPkV

Conclusions and implications for future work

The existing substantial body of research on FHK and science in Atlantic Canada reviewed here can provide some insights around knowledge and governance options for sustainable fisheries in the future. Since the 1990s, here and elsewhere, attention has been paid to the development and refinement of methods and employment of systematic approaches to critically assess FHK[34] and to find ways to draw productively on FHK and science in stock assessments and management. A noteworthy point is that this review has focused on self-reported FHK/LEK done from the perspective of harvesters, thus looking at science through FHK lenses[61]. Additional research on studies and reports that look at FHK including LEK through the lens of science and management is needed to assess how these are being brought together in these processes in Atlantic Canada and globally including from a governance perspective.

FHK and science research has come a long way since the early 1990s. The initial goal of creating awareness of potential uses for, and of the need to include FHK in management and fisheries science, including stock assessment[26] has been achieved. Research is expanding with FHK being collected and applied in different ways, as this Taking Stock exercise has shown. The growing number of scientific publications showing the potential benefits of bringing together FHK and science demonstrate this. However, it is no longer enough to argue for the inclusion of fish harvesters and FHK in science and management.

While disagreements still exist, scientists and fisheries managers are more welcoming of the knowledge and expertise fishers can bring to the table. One example of this is the lobster conservation initiatives that have been undertaken on the Newfoundland Eastport Peninsula, where the Eastport Peninsula Lobster Protection Committee successfully promoted an approach protecting lobster stocks based on a partnership among fish harvesters, scientists and government managers[62]. The growing number of initiatives bringing stakeholders and fisheries managers together points to the need for good research practice in studies of FHK and science. Several publications worldwide have stressed the importance of scientific rigor in FHK research in order to build trust and reliability in the information provided by fishers. Atlantic Canadian research has been addressing this issue and seeking to increase the validity of data and results derived from fishers' knowledge [3,4,34,45,63]. Neis and Felt[35] argued that fish harvesters' LEK can be systematically documented and can be aggregated to construct a picture of regional fisheries while giving

importance to local scale information. Furthermore, FHK, when combined with archival data, can be used to reconstruct and interpret the historical changes in fisheries[6].

However, FHK, experience and insights still face barriers around incorporation into fisheries science and management. Although FHK can be systematically documented and assembled, it does not fit easily into a quantitative scientific setting. St. Martin et. al.'s[7] research points out that institutional barriers to the incorporation of FHK into fisheries management can be substantial due to rigid standards and the assessment requirements of existing management systems. Stock assessment scientists interviewed in their study welcomed FHK but struggled to integrate it into a stock assessment. The complexity and non-traditional source of data generated by FHK research makes technical and peer review challenging affecting the likelihood it will be incorporated into management decisions. To overcome these challenges, some social scientists are calling for more flexible frameworks[7], an increase in funding for FHK research and a systematic integration of fisher's knowledge into traditional science[59]. The inclusion of stakeholder knowledge into management systems is not a straightforward task. Stephenson et al.[59] stressed the fact that the development of research capable to sample, analyse, and synthesise fishers' information is a substantial undertaking which requires considerable time, financial, and expertise resources. Sound research is necessary to add FHK to traditional assessment, and to facilitate the use of fisher's knowledge in participatory fisheries management.

It has been suggested that rather than including just their knowledge in fisheries science and management, including the direct collaboration of fishers during the design, data collection, and analysis of marine resources research could benefit science and management greatly[5]. Bringing together scientists, managers, and fishers and other stakeholders to develop a collaborative research project can result in shared trust in the data used in the fishery management process[64]. Dawe and Schneider[44] suggested a consilient approach to the conjoint use of FHK and Science. FHK and Science differ in spatial and temporal scales, but both can be used conjointly to assess the consistency of these two forms of knowledge. National legislation, Dawe and Schneider argue, is necessarily based on a large scale and therefore might not match local observations. Including the small-scale information from FHK into a larger scale science assessment would help fisheries governance by eliminating discrepancies between science and fish harvesters' knowledge. Such an approach could help to resolve distrust between stakeholders as the data derived from the joint effort would have the scientific robustness seek by scientists and the credibility asked for by fishers due to the involvement of their peers.

Only one paper in our scan addressed the connection between aquaculture activities and capture fisheries and ways FHK can contribute to our knowledge of this. Although aquaculture is not in the scope of this paper, with the increasing number of aquaculture sites in Atlantic Canada, especially with the expansion of aquaculture in Newfoundland, the gap in FHK research targeting the aquaculture-capture fisheries interface is important. Future FHK research addressing the external factors, such as aquaculture, impacting commercial stocks will be of great value towards a sustainable co-existence of commercial fisheries with other marine resource users.

Our environmental scan of international FHK and science literature and synthesis of research on FHK and science in Atlantic Canada makes a clear case for incorporating FHK into stock assessment and management decision-making in future sustainable fisheries. The review of the FHK and science literature suggests not only that existing fisheries science data are often insufficient to support sustainable fisheries but also that in some cases, reliance on traditional stock assessment science alone has led to negative social and ecological impacts[37,65]. Scientific research on FHK has shown that it can help to identify and fill gaps in scientific data and contribute to the fuller integration of ecological, economic, social, and institutional considerations into fisheries management. The different but often complementary strengths and weaknesses of FHK and Science make the two crucial for effective fisheries governance[33,44,66] by

helping to ensure scientists, managers and harvester representatives have the “best available information”[47] to achieve social-ecological goals.

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