

A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science¹

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Abstract

Fishers' knowledge research is an approach to fisheries research that has a relatively long history, yet has generally failed to become integrated into the fisheries science mainstream alongside approaches that rely primarily on the knowledge of professional scientists. Its continued position on the margins of fisheries science has not however stopped fishers' knowledge researchers from publishing an expanding literature, which they often use to advocate for the greater consideration of fishers' knowledge by fisheries scientists and managers. They believe that the unique and often highly qualitative knowledge of fishers could inform better decision-making, resulting in improved socio-ecological outcomes for fisheries. This review first outlines the scope of the fishers' knowledge literature, before outlining five waves of fishers' knowledge research that have developed over the last century. For each wave, the nature of the fishers' knowledge documented during it is noted, as is the research and dissemination approach taken by its practitioners. The impact of that wave on mainstream fisheries science is then assessed. Overall, it is found that only one wave of fishers' knowledge research is beginning to have consistent success integrating with mainstream fisheries science, a wave that omits the research of many of the unique elements of fishers' knowledge. Other waves have died out, or are in danger of dying out, either because they have failed to be noticed by mainstream fisheries scientists or because mainstream fisheries scientists have not welcomed their outputs. It is summarized that fishers' knowledge research will only continue as a productive activity if mainstream fisheries scientists begin to open their discipline to other knowledge cultures and if fishers' knowledge researchers facilitate this action by disseminating their research so that it is more accessible to these scientists.

Introduction

Documented to be approaching at least a century old (Johannes 1981; Hutchings et al. 2002; Murray et al. 2008b), fishers' knowledge research is an approach to fisheries science that to date has struggled to take a place at the top table of fisheries science (Soto 2006; Hind 2012). Its focus is the study of the experiential knowledge of marine and freshwater environments that fish harvesters accumulate while operating in their respective fisheries. Those who seek in different guises to achieve greater consideration for this experiential knowledge in mainstream fisheries science and management can be considered fishers' knowledge researchers.

The profile of fishers' knowledge research compared with established approaches towards conducting fisheries science can currently be described as marginal. The content of this very journal can be considered an effective reflection of the paradigm defining approach to fisheries science taken by The International Council for Exploration of the Sea (ICES) (Rozwadowski 2002), yet, up until 2005,

it had only published three papers which in their abstracts even referred to what might be understood as fishers' knowledge (Alcala and Russ 1990; Dorn 2001; Maynou and Sardà 2001). Figure 1 illustrates how this trend has barely changed since.

Fishers' knowledge has been neglected by not just the scientists at the forefront of fisheries research but also by eminent policy-makers and governance institutions. Major international fisheries management instruments have tended to either barely consider such knowledge or omit it totally. For instance, the 2001 Reykjavík Declaration of the United Nation's Food and Agriculture Organization (FAO) does not mention fishers' knowledge as a possible source of information (Turrell 2004) despite a stated aim "to gather and review the best available knowledge on the marine ecosystem issues" (FAO 2001). Even where policies have included directives to introduce fishers' knowledge into fisheries science and management, they have often been deemed to be only paying "lip service" to the idea (Johannes 2003, p. 119). The 2002 reform of the European Union's (EU) flagship Common Fisheries

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Policy (CFP) promised greater inclusion for fishers' knowledge, but feelings nearly a decade later were that fishers had simply been asked to comment on the knowledge of scientists rather than to actually contribute their own knowledge (Griffin 2007, 2009; Stöhr and Chabay 2010).

Even within anthropocentric fisheries research fields, where it would be anticipated that interdisciplinary researchers and social or political scientists might be more open to stakeholder-centric approaches, fishers' knowledge research has predominantly taken a back seat. By the turn of the millennium, when other social and political science approaches to fisheries research were becoming increasingly established, one of the most high profile and respected fishers' knowledge researchers (Ruddle 2008) stated:

Over the past two decades the study of community-based management of marine fisheries has expanded rapidly. [...] But efforts by researchers to seek out systematically and help put to use fishers' knowledge concerning their marine resources have not kept pace, as indicated by the contrastingly sparse literature on this subject. (Johannes et al. 2000, pp. 257–258)

However, while it is tempting to question whether a research approach that has failed to establish itself after nearly 100 years is ever going to provide fisheries scientists with methods or outputs that they should consider part of their day-to-day toolbox, fishers' knowledge research still has the potential to become mainstream, in the process considerably changing the landscape of fisheries science and management in the coming decades. Although its profile continues to be a low one, it

is one that nevertheless continues, which suggests that some individuals or institutions are prepared to dedicate their current and perhaps future efforts towards putting fishers' knowledge on research agendas. The repeated and strongly emphasized consideration of "the knowledge and experience of all stakeholders" in the most recent reform of the CFP (EU 2013); the sustained low-level presence of fishers' knowledge research in this journal; and the recent funding of new fishers' knowledge research by governments and mainstream fisheries science institutions in several fishing nations (Bangor University 2012; NOAA Fisheries 2012; Bjørkan 2013; Léopold et al. 2014; SCU 2014) provides evidence that fishers' knowledge research could well still have a substantial future. This paper reviews literature produced by a broad range of fishers' knowledge researchers to determine how that future might play out, and to ascertain whether it actually will mean that the fisheries scientists of institutions like ICES will indeed change their working practices to integrate fishers' knowledge.

Analysing an unsettled literature

Preceding literature reviews and summary papers have analysed the progression of the concept of fishers' knowledge and its research. These have taken various approaches. Huntington (2000) documented the development of the social science methods used to actually conduct fishers' knowledge research. His introductory paper, as well as further reviews (Berkes et al. 2000; Johannes et al. 2000; Drew 2005; Johannes and Neis 2007), then described real-world case studies to show how fishers' knowledge could be used to support and supplement existing fisheries management activities (e.g. stock assessment, ecosystem-based management, and fish larval biology). More recent reviews have focused on what seems like an obvious next

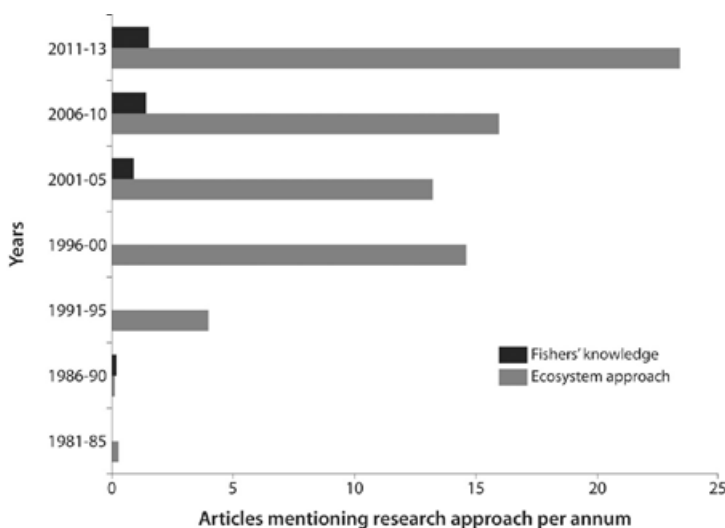


Figure 1. Change in publication rate of fishers' knowledge research and the ecosystem approach in the journals *Fish and Fisheries*, *Fisheries Oceanography*, and *The ICES Journal of Marine Science*. These are three of the top five (by impact factor) "fisheries" journals in the 2013 ISI Journal Citation Reports that support searching by "title" and "abstract". Papers were considered to be fishers' knowledge research if the title or abstract included the terms "fishers' knowledge", "fisher knowledge", or "fishermen's knowledge", or if they included "fisheries" and either "local ecological knowledge", "local knowledge", or "traditional knowledge". Papers were considered to detail the ecosystem approach if they included the term "ecosystem".

step for the research approach; the integration of fishers' knowledge alongside other knowledge cultures. Soto's (2006) thesis outlined the barriers to the integration of fishers' knowledge in mainstream fisheries science, before Thornton and Scheer (2012) then Bohensky et al. (2013) summarized attempts to break down those barriers. Yet, while the review papers and book chapters mentioned in this paragraph have covered new ground, they have not expended much attention on two important factors that are strongly dictating the direction of fishers' knowledge research.

First, except Bohensky et al. (2013), they have primarily been written without describing the aims and structure of the research approach. In two further reviews (Davis and Ruddle 2010; Ruddle and Davis 2013b), Anthony Davis and Kenneth Ruddle have criticized this trend, stating in the former that fishers' knowledge researchers need to get their "house in order". They noted that much of the literature produced by this community has failed to consider the needs of transparency, critical analysis, and reliability required of research approaches that want to become integrated within mainstream fisheries science. This lack of organization is deemed to have created confusion over what fishers' knowledge research actually is, not just for those who are not fishers' knowledge researchers but also for those who are (Davis and Ruddle 2010; Bohensky et al. 2013). The blame for what is assessed to be a low profile for fishers' knowledge (Brook and McLachlan 2008), and a lack of progress integrating it into mainstream science (Bohensky et al. 2013) is at least partially attributed to this situation. A future for fishers' knowledge research cannot be effectively planned or predicted until the approach is itself better defined.

Second, apart from Soto (2006), the existing reviews also lack coherence in identifying their target audience. By not always adequately addressing the historical split between fisheries science and marine ecology, they have introduced a further confusion, around who should be using fishers' knowledge as an information source and how they should be using it. Although the gap between fisheries science and marine ecology is beginning to close (Hughes et al. 2005; Degnbol et al. 2006), it cannot be currently assumed that communicating with one of these audiences means you are simultaneously communicating with the other (Hind 2012, pp. 202–262). For instance, Thornton and Scheer (2012) review the relationship between fishers' knowledge and mainstream fisheries institutions, but the keywords they select to represent the content of their paper do not include "fisheries science", "fisheries management", or "population ecology". Instead, they opt for the vaguer and less fisheries-specific "resource management" alongside terms more associated with marine ecology (e.g. "ecological monitoring",

"environmental change", and "marine conservation"). By rarely directly addressing the fisheries scientists of national fisheries departments and institutions like ICES, they and others like them are not alerting fisheries scientists to the fact that they believe fishers' knowledge research should be part of wider fisheries science practice. Targeting an audience of marine ecologists is seen as a way to increase outlets for fishers' knowledge research (Wilson 2009; Brattland 2013), but it is also stated that such a constrained focus may reduce its chance of integration with more established approaches to fisheries science (Hind 2012).

This review, then, attempts to take a different track to those that precede it to clarify for those outside the fishers' knowledge research approach what its development may mean for them. It specifically talks to fisheries scientists who ultimately are the primary audience for any fisheries data. It is also hoped the review will help highlight a path for fishers' knowledge researchers towards making their research more impactful, helping them perhaps to get their "house in order" as Davis and Ruddle (2010) suggested. A chronological approach is taken so that the evolution in fishers' knowledge research can be logically charted. Through describing the aims, structure, and target audience of fishers' knowledge research at each stage of its evolution, it is possible to determine in which guise it may become part of the future of fisheries science, if at all.

Methodology

Literature qualified for review was primarily sourced by using the Google Scholar search engine to perform sequential online searches for "fishers' knowledge" and similar pre-identified terms (see Hind 2012, p. 58). A systematic approach was used, where all papers, reports, and books were included that met a criteria of documenting information that authors believed could be attributed to fishers' experiences. Searches ceased when fewer than 5 of 10 publications on a results page met inclusion criteria. Many papers were returned in multiple searches, indicating good coverage of the relevant literature.

Exceptions to a systematic reviewing approach were made for very recent and pre-1950 literature. For very recent developments in fishers' knowledge research, such as the emergence of fishery dependent data, little was published in print and so conference presentations attended by the author were considered. The systematic approach was also excluding publications by amateur natural historians researching pre-1950, which were nevertheless being referenced in the more recent publications discovered systematically (e.g. in Johannes 1981; Murray et al. 2006). These were considered for review when referral to them was made. More than

500 research outputs ultimately fit the inclusion criteria and many are referenced here.

The history of fishers' knowledge research

The evolution of fishers' knowledge research is primarily a gradual one, but it is possible to chart the introduction of new practices, theories, and approaches when analysing the literature longitudinally. These can be broadly categorized into at least three fairly well defined waves, and potentially a fourth and fifth. Each of these waves can be coupled, in a general sense, to a certain approach to research (e.g. ethnography or applied social science). They are described here in turn.

The first wave: birth—natural history

There is clear evidence that fishers' knowledge predates the Twentieth Century, which given that all fishers are deemed to possess such knowledge (Pálsson 1998) should not be a surprise. The first deliberate recording of fishers' knowledge appears however to be that uncovered by contemporary fishers' knowledge researchers. The studies of Hutchings et al. (2002) and Murray et al. (2008b) on the stocks and migrations of cod in the Gulf of St. Lawrence, Newfoundland, referenced the work of W. A. Munn, a local merchant and amateur natural historian. Munn (1922) did not overtly identify his work as research, but his study used an intensive method of questioning local fishers that can certainly be considered a scholarly approach. When he amalgamated all the fishers' qualitative inputs, he found that he was able to identify traits in the life cycle of the local cod population, including migratory patterns.

In the South Pacific, another contemporary fishers' knowledge researcher identified a further early amateur study. Johannes (1981, p. ix) commended Nordhoff's (1930) ethnography of the Tahitian fisheries for the way in which it described, in great detail, the traditional offshore fishing techniques used by Society Islands' fishers, perfected based on their knowledge of fish and even bird behaviour. For example, he depicted how the fishers knew when albacore tuna (*Thunnus alalunga*) were catchable due to the swooping behaviour of a species of tern (*Leucanous albus pacificus*). Like Munn, Nordhoff was no professional scientist, but instead the co-author of the well-known novel *The Mutiny on the Bounty*. He went as far as to state that he had only conducted such a study "because no one better qualified was on the ground". He was one of the first to urge professional scientists to pay attention to fishers' knowledge (see Table 4).

Nordhoff's (1930) call for the greater recording of fishers' knowledge as scientific data was not to be soon answered however. Fishers' knowledge was

not studied in detail again for another 40 years in the South Pacific (Johannes 1981). In Canada, Munn's research continued to be the only cod fisheries data and was even used to form the basis of one of the first stock assessments for the species in the early 1940s (Thompson 1943), but this was a reliance on fishers' knowledge that would not last. By the second half of the twentieth century tagging studies performed by professional fisheries scientists began to replace the anecdotes of fishers (Murray et al. 2008b), and the first wave of fishers' knowledge research had come to an end. It was an era where in just a few locations, fisheries that were not quantitatively assessed by fisheries scientists were documented qualitatively by keen amateurs who simply enjoyed spending time with fishers. Yet, its practitioners were aware of fisheries scientists as a target audience, as can be seen by Munn's contribution to the first professional stock assessments and Nordhoff's direct addressing of trained fisheries specialists. Their permanent contributions to allying fishers' knowledge research with mainstream fisheries science were however limited to these relatively low-key events.

The second wave: rebirth and radicalism—ethnography

Those who were effectively the fishers' knowledge researchers of the first wave never identified as a community, but this changed as a group of scholars practising ethnography primarily in the subsistence fisheries of the developing world, and the indigenous fisheries of developed nations, rediscovered the research approach. The individual credited as being a pioneer (Haggan et al. 2007b; Ruddle 2008) in this re-emergence was a fisheries biologist, Robert Johannes, who latterly turned to more ethnographic work as a result of his experiences during fieldwork in Palau.

In many short articles published between 1978 and 1980, Johannes documented both how indigenous fishers' knowledge of spawning aggregations could be used to inform fisheries management (Johannes 1978a, 1980) and how traditional marine management systems could be implemented where typical western techniques for managing fisheries had failed (Johannes 1977, 1978b). He then published his full-length ethnography, *Words of the Lagoon*. In the preface to this book, he stated that he "gained more new (to marine science) information during sixteen months of fieldwork using [ethnography] than [he] had during the previous fifteen years using more conventional research techniques" (Johannes 1981, p. x). The appendices of this tome show, for instance, that he was able as just part of his study to comprehensively record reproductive rhythms, spawning locations, and seasonal migrations for 58 species of reef and lagoon fish across Palau and the wider Pacific. Like for most of the

literature that had emanated from the first wave, Johannes' descriptions of fishers' knowledge were highly qualitative. Rather than being formally recorded with techniques such as surveys and interviews scheduled by external researchers, fishers' knowledge was being transferred via semiformal interviews arranged by embedded researchers like Johannes who were living and working alongside fishers, as well as ethnographically via observation, conversation, and social interactions over extended timescales.

Johannes had been influenced by the early reporters of fishers' knowledge in the South Pacific such as Nordhoff, as well as by the more recent but briefer endorsements of such knowledge that stopped short of being comprehensive fishers' knowledge research efforts (e.g. Gosline and Brock 1960; Ottino and Plessis 1972). Notably however, Johannes and his contemporaries appear not to have referenced fishers' knowledge from the commercial fisheries of the developed world. Munn's work for instance is not mentioned by second wave scholars. Johannes (1981) himself was the one to identify the true trigger for the relative upsurge in fishers' knowledge research that started in the 1980s; the terrestrial ethnographic research recording experiential knowledge of those making their livelihood from the land.

From the mid-1970s the "ethnographic turn" had been under way, a movement rebelling against hard quantitative sciences like fisheries science. Some social researchers, angry at poverty creation that they blamed on the modernist agenda, turned to more qualitative methods such as ethnography which they believed more accurately described phenomena like the widening gap between rich and poor (Purcell 1998; Culyba et al. 2004). This new academic counterculture then spilled over into the environmental sciences where it was perceived that ecosystems were being destroyed for global capital gain at the expense of local communities (Agrawal 1995). Environmental researchers working with indigenous communities outside of capitalist systems quickly realized that they could not ply their trade without understanding the experiential knowledge held in these communities, especially that used to sustainably manage ecosystems which had not changed for centuries. Because the ethnographic turn started within the development field, it is no surprise then that the terrestrial agricultural systems so important to human subsistence were the first focus of the ethnographic study of this type of knowledge.

The subsequent connection with ethnographic research of the marine environment is then observed in Johannes' (1989b) self-edited collection of essays on "traditional ecological knowledge".

Five of seven case studies in the book are terrestrial, and the one marine case not penned by the editor also refers to several land-based examples for inspiration. Studying New Caledonian traditional fisheries management, Dahl (1989) identifies parallels with traditional agricultural management in the same territory (Barrau 1956) and in Vanuatu (Spriggs 1981). With fishers' knowledge research again under way, the rate of publication within the research field began to increase. By the mid-1990s however, the published literature was seen to be "scattered and fragmented" (Ruddle 1994a).

The literature often appeared in quick flurries, such as with the publication of edited anthologies of traditional marine management studies, some of which were summaries of thematic journal issues or specialist conferences (Ruddle and Johannes 1985; Freeman et al. 1991; Dyer and McGoodwin 1994). The cases in these compendiums typically focused on qualitatively documenting examples of fishers' knowledge in certain locales, before describing how that knowledge was being used by the fishers possessing it to sustainably manage the fishery they operated in. As can be seen in Table 1, these fisheries were primarily the coastal or freshwater fisheries of the developing world, particularly the Pacific Basin, where little or no professional fisheries science was being undertaken.

While the initial fishers' knowledge research focused on these developing world fisheries, it was primarily being conducted by academics based in the higher education institutions of developed nations. Having rediscovered fishers' knowledge in the subsistence fisheries of Asia-Pacific, Africa, and Latin America, they began to look for similar examples closer to home. They found them in the First Nations fisheries of Canada, the Inuit fisheries of the Arctic region, and other indigenous fisheries in the United States and Russia (see Table 1). The Cree of James Bay in sub-Arctic Canada possessed, for example, the same kind of knowledge of fish behaviour that had been documented elsewhere. They were likewise using it to support traditional marine management, relocating their whitefish fisheries when they noticed local drops in catch per unit effort (cpue) (Berkes 1998).

At the same time, efforts were being made to consolidate the research approach's outputs beyond being just a list of isolated examples of fishers' knowledge. Comparing subsistence fishers' knowledge of managing coastal fisheries in several Indian communities (Bavinck 1996), of similar ecosystems in Indonesia and the Solomon Islands (Berkes et al. 1995), and of the marine environments of Venezuela, The Pacific Basin, and the Virgin Islands (Ruddle 1991), various researchers developed theories and frameworks that scaled up the information

source, finding linkages, and shared applications across different locales. Their summary findings were consistent with what seems to have been the main finding of second wave research; that subsistence fishers have a rich ecological knowledge, which when they are permitted, they often use to manage their fisheries sustainably without the need of intervention from professional fisheries scientists or managers.

There is no denying the re-establishment of fishers' knowledge research between the late 1970s and early 2000s, but Table 1 shows that the added structure was not resulting in a totally unified approach. Despite the widely shared use of ethnography and a similar focus on the subsistence fisheries of developing nations and indigenous ones of developed countries, the research field was effectively divided into two. On each side of the division were

individuals who had higher profiles due to their larger publishing footprints.

Among the higher profile researchers on one side of the divide were Fikret Berkes and Madhav Gadgil. They were certainly aware of the work contemporaries like Robert Johannes and Kenneth Ruddle, regularly citing their work (e.g. Gadgil 1998; Berkes et al. 2000), an occurrence reciprocated by Ruddle (1994b) if not Johannes. Yet, they and select others were perhaps more allied to the principles behind the ethnographic turn and wanted fishers' knowledge research to be in conflict with positivist fisheries science. Favouring a parametric style of fisheries management, based on a multispecies ecosystem approach and self-management (Acheson and Wilson 1996), they used their publications as vehicles with which to suggest the full replacement of quantitative fisheries science with a new model based on

Table 1. A sample of publications from the second wave of fishers' knowledge research.

Publication	Study location(s)	Fishery type(s)	Research approach(es)	Audience(s)	Publication type(s)	Relationship with mainstream
Johannes (1977)	Micronesia	A	E	FS	J-O	Ch
Johannes (1978b)	Pacific Basin	A	E	FS	J-E	Ch
Johannes (1981)	Palau	A	E	FS	B	I
Berkes (1987)	Canada (I)	A	E	ME	BS	I
Dahl (1989)	Pacific Basin	A	E	Un	BS	I
Johannes (1989a)	Pacific Basin	A	E	FS	BS	Ch, I
Gadgil and Berkes (1991)	Canada (I), Fiji, Mali, Solomon Islands	A	E	ME	J-O	Ch
Ruddle (1991)	Pacific Basin	A	E	FS	J-O	I
Smith (1991)	Micronesia	A	ASS, E	FS	J-O	Co
Dyer and Leard (1994)	United States	C	E	FS	BS	Ch
Ruddle (1994b)	Pacific Basin, Venezuela, US Virgin Islands	A	E	FS	BS	Co, I
Stoffle et al. (1994)	Dominican Republic	A, C	ASS	FS	BS	Ch, Co
Berkes et al. (1995)	Indonesia, Solomon Islands	A	E	ME	BS	Ch, I
Bavinck (1996)	India	A	E	FS	J-MM	I
Berkes (1998)	Canada (I)	A	E	ME	BS	Ch, I
Gadgil et al. (2000)	India	A	E	Un	J-E	Ch
Johannes et al. (2000)	Canada (I), Kiribati, Solomon Islands, United States (I)	A	ASS, E	FS	J-F	Ch
Klubnikin et al. (2000)	Russia (I)	A	E	Un	J-E	Ch, Co
Pierotti and Wildcat (2000)	United States (I)	A	E, NS	Un	J-E	Ch
Hickey (2001/2007)*	Vanuatu	A	E	FS	BS, C-FK	Ch, I
Kalikoski and Vasconellos (2001/2007)*	Brazil	A	ASS, E	Un	BS, C-FK	Ch, Co
Menzies and Butler (2007)	Canada (I)	A	E	FS	J-O	Ch

Codes have been used to keep table compact: study location (I, indigenous); fishery type (A, artisanal; C, commercial; R, recreational); research approach (ASS, applied social science; E, ethnography; NS, natural science); audience (FS, fisheries scientists; ME, marine ecologists; Un, unspecified scientists); publication type (B, book; BS, book section; C-E, ecology conference; C-F, fisheries conference; C-FK, fishers' knowledge conference; J-E, ecology journal; J-F, fisheries journal; J-MM, marine management journal; J-O, other journal; R, report; T, thesis); relationship with mainstream (Ch, challenges; Co, complements; I, independent from). This table does not include all the second wave publications that were reviewed. The representative list of references displayed here was systematically selected from a database constructed in the software package endnote. All references were sorted by year then those at set intervals were chosen for inclusion. *First published in 2001 as part of conference proceedings.

the work of marine ecologists and the knowledge of fishers. As quoted in Table 4 they favoured this approach not just in the developing nation and indigenous fisheries that they had studied but in developed world fisheries too.

Johannes, Ruddle, and another group of contemporaries, again quoted in Table 4, also made a radical challenge towards positivist fisheries science. Likewise, they criticized its failures (Freeman et al. 1998; Johannes et al. 2000) and its inability to deliver the same kind of sustainable fisheries that fishers had been able to do using their own knowledge (Ruddle 1994b; Bavinck 1996), but they instead favoured the engagement of the same scientists that they were challenging.

Rather than attempting to unseat them, they delivered a wake-up call asking practitioners of the established fisheries science to take fishers' knowledge seriously (see Table 4). As Ruddle (2008) identified, Johannes in particular was notably forthright, often questioning the disdainful attitude of most fisheries scientists at the time towards fishers' knowledge. He and his more moderate contemporaries saw that there would always be an important place for quantitative fisheries science at the head of the marine management paradigm, but were left frustrated at scientists who ignored fishers' knowledge, even when it would have informed better management, simply because it was mainly constructed of qualitative anecdote which they saw as non-scientific (Johannes et al. 2000). He openly wondered why fisheries scientists would not at least use fishers' knowledge in data-poor fisheries management situations when there was no capacity for quantitative science (Johannes 1998).

In its fragmented state, fishers' knowledge research still struggled to have any impact on the structures and institutions of fisheries science. Fisheries scientists, mostly based in developed countries and researching commercial fisheries, were probably little aware of the books and conferences where most fishers' knowledge research was being discussed. Table 1 shows that second wave journal articles published about fishers' knowledge mostly appeared in ecological journals. At a time where marine ecology was not the day-to-day part of fisheries science it is now becoming (Hughes et al. 2005) fisheries scientists would have read relatively few such publications. Finally, the ethnographic style of almost all the second wave research would have been off the radar of fisheries institutions that did not then typically employ researchers who practiced ethnography. The later publications of this wave did however pave the way for a third wave of fishers' knowledge research. A few years before his untimely passing, Johannes with colleagues highlighted the first in-depth cases of fishers' knowledge research in

commercial fisheries. Primarily Canadian examples Johannes et al. (2000), these were published by the early members of the third wave.

Third wave: growth and reform—applied social science

Citing the work of Johannes (1981), Barbara Neis was among the first to research fishers' knowledge in the commercial fisheries of the developed world. In a paper in a regional journal (Neis 1992), she brought together the ethnography of others (e.g. McCay 1976) with fishers' knowledge from formally arranged interviews she had conducted. In doing this, she provided a new narrative for collapse of the northern cod (*Gadus morhua*) of Newfoundland. This narrative showed that if Canadian fisheries scientists had listened more effectively to the concerns of some fishers about the deteriorating health of inshore cod stocks then they may have been able to act sooner to prevent the collapse (Neis 1992), one that there has been no real recovery from (Hutchings and Rangeley 2011). Over the next 10–15 years, Neis became part of a research cluster of Canadian scholars who began to broaden the documentation of fishers' knowledge of various stocks of cod (Hutchings and Ferguson 2000a; Murray et al. 2008b), salmon (Felt 1994), and lobster (Davis et al. 2006). Their publications referenced the first wave research of W.A. Munn (e.g. Hutchings et al. 2002; Murray et al. 2008b), as well as the work of second wave researchers of both the lesser and more radical approaches, such as Johannes and Berkes (see Neis et al. 1999; Murray et al. 2006). Yet, they were neither amateur historians nor using ethnography. They favoured applied social science techniques, selecting formally arranged interviews as their primary tool for recording fishers' knowledge. Among them were self-identifying natural scientists such as Jeffrey Hutchings and David Schneider, who were willing collaborators on research teams led by social scientists (e.g. on Neis et al. 1999), as well as leaders themselves of studies in fisheries science that employed interviewing ahead of mainstream fisheries science methods (e.g. Hutchings and Ferguson 2000b).

While third wave scholars have been influenced by the work of second wave researchers like Johannes, their approach has been less ethnographic and not always qualitative. Most fields of research moved towards more interdisciplinary approaches in the late Twentieth Century, with many scholars noting the benefits of broader approaches (Klein 1996). Fishers' knowledge research seems to be no exception. With the use of applied social science techniques, a commitment to recording the qualitative data typical of ethnographic approaches has been retained, but also permitted has been the introduction of structure that facilitates the quantification of

certain aspects of fishers' knowledge. Using semi-structured interviews, for example, Neis et al. (1999) were able to record both fishers' qualitative reasoning for the decline in northern cod stocks, as well as to quantify "poor", "average", and "good" catches of the same species back as far as the 1920s. Additionally, many third wave scholars have added further structure to the results they have published through using participative mapping as a technique during interviews. This approach asks fishers to in effect draw their knowledge onto nautical charts placed in front of them during interviews. The Canadian research cluster, for instance, aided by geographical information systems (GIS) were able to precisely record fishing grounds (Neis et al. 1999; Macnab 2000), spawning sites (Neis et al. 1999), and species migrations (Murray et al. 2008a) known by fishers.

Following the early Canadian efforts, a subsequent geographical expansion of the third wave of fishers' knowledge research occurred (see Table 2), with gradual spreading to Northern Europe and Central America in the 1990s, before a global expansion through the 2000s. As with the second wave, growth has included the replication of pioneer case studies in other geographic locations. Various fishers' knowledge researchers have confirmed that Norwegian and US fishers also have detailed knowledge of cod spawning grounds and migrations (Maurstad and Sundet 1998; Ames et al. 2000), that fishers in Belize are similarly capable of detecting changes in the health of fish stocks (King 1997), and that Icelandic fishers and scientists too can have different perceptions of fisheries status (Pálsson 1995). Unlike the second wave however, which had primarily been concerned with the small-scale fisheries of the developing world, the third wave has been more focused on researching the commercial fisheries of the developed world.

Additionally, quotes in Table 4 show that the researchers of the third wave have not followed their second wave colleagues in avoiding positivist approaches to fisheries science. Still readily critical of established science and management approaches that do not consider fishers' knowledge, third wave researchers have nevertheless refrained from advancing fishers' knowledge as an independent source of information on which fisheries management should be solely based. While they have concluded like their second wave predecessors that bottom-up management systems based on fishers' knowledge should be introduced, they have changed tact by emphasizing that fishers' knowledge should be a complement to existing scientific enquiry and biological datasets instead of a replacement (e.g. King 1997; Rowe and Feltham 2000; Baelde 2007). Resultantly, they have sought collaboration with quantitative biologists already operating in the commercial fisheries of their own.

The nature of this reform has become clearer following two events, evident in Table 2, which catalysed the more rapid growth of fishers' knowledge research in the 2000s. Leading these was the publication by Neis and Felt (2000a) of the first anthology to deal solely with the analysis of the experiential knowledge of fishers. It comprised mostly case studies that employed the applied social science methods of systematic interviewing and participatory mapping. The second event was the holding of the first major international conference focusing on fishers' knowledge at the University of British Columbia in Canada, attended by over 200 people from 24 countries. More than 40 presentations from the conference, titled *Putting Fishers Knowledge to Work*, were documented in the conference proceedings (Haggan et al. 2003) and a later peer-reviewed book (Haggan et al. 2007a). Following these substantial contributions, the publication rate of peer reviewed journal articles detailing fishers' knowledge has risen. This expansion has brought a similar expansion in the actual concept of fishers' knowledge. In addition to attempts to scale up research efforts to identify relationships between findings across case studies and regions (e.g. Degnbol 2005; Daw 2008; Gerhardinger et al. 2009), there has been a concerted move to recognize that fishers' knowledge is not solely ecological in character but also socio-economic.

The interviews employed by third wave scholars have been of a more interdisciplinary nature, often being conducted by teams of researchers in which different individuals have brought socioeconomic then biological expertise (Neis 1992). In Murray et al.'s (2006) profile of a Canadian fisher, multidisciplinary researchers using an interview were able to describe how he, in addition to relying on a detailed ecological knowledge of cod, shrimp and crab stocks, was also able to reference a comprehensive operational and economic knowledge to maximize the day-to-day efficiency of his fishing activities. For instance, the fisher told how he had changed his fishing gears and licenses to reduce economic risk through gaining access to a wider range of marketable species. Other studies have investigated these "new" dimensions of fishers' experience across whole samples, collectively concluding that fishers' knowledge is indeed a socio-ecological construct. They have stated that the construct includes information about fishery logistics and culture, vessel and gear setup, perspectives on management and policy, and onshore marketing of seafood, as well as the ecological knowledge already discovered by the earlier fishers' knowledge researchers (Pálsson 1995; Neis and Felt 2000b; Crona 2006; Daw 2008). In fact, for many third wave researchers, it is these non-ecological dimensions of fishers' knowledge that they identify as likely the most useful complement to mainstream fisheries science. Studies, like

Table 2. A sample of publications from the third wave of fishers' knowledge research.

Publication	Study location(s)	Fishery type(s)	Research approach(es)	Audience(s)	Publication type(s)	Relationship with mainstream
Neis (1992)	Canada	C	ASS, E	FS	J-O	Ch, Co
Felt (1994)	Canada	C	ASS	FS	BS	Co
Pálsson (1995)	Iceland	C	ASS, E	FS	BS	Ch, Co
King (1997)	Belize	A, C	ASS, E	FS	J-MM	Co
Hanna (1998)	USA	C	ASS, NS	FS	BS	Co
Mackinson and Nottestad (1998)	Canada, Norway	C	ASS	FS	J-F	Ch, Co
Neis et al. (1999)	Canada	C	ASS	FS	J-F	Ch, Co
Ames et al. (2000)	USA	C	ASS	FS	BS	Ch, Co
Fischer (2000)	Nicaragua	C	ASS, E, NS	FS	BS	Ch, Co
Huntington (2000)	Russia, USA, USA (I)	A	ASS	ME	J-E	Ch, Co
Maurstad (2000)	Norway	C	ASS	FS	BS	Ch, Co
García-Allut et al. (2001/03)*	Spain	A	ASS	FS	C-FK	Ch, Co
Baelde (2001/07)*	Australia	C	ASS	FS, ME	BS, C-FK	Ch, Co
Nsiku (2001/07)*	Malawi	A, C	E	FS	BS, C-FK	Ch, Co
Küyük et al. (2001/07)*	Mexico	A	ASS, NS	ME	BS, C-FK	Ch, Co
Stanley and Rice (2001/07)*	Canada	C	ASS	FS	BS, C-FK	Ch, Co
Maurstad (2002)	Norway	C	ASS	FS	J-MM	Co
Moore (2003)	Scotland	C	ASS	FS	J-F	Ch, Co
Davis et al. (2004)	Canada	C	ASS, NS	FS	J-F	Co
Huntington et al. (2004)	USA (I)	A	ASS, NS	Un	J-E	Co
Hamilton et al. (2005)	Solomon Islands	A	ASS, E, NS	FS	J-F	Ch, Co
Murray et al. (2005)	Canada	C	ASS	FS	BS	Ch, Co
Crona (2006)	Kenya	A	ASS	FS	J-E	Ch, Co
Davis et al. (2006)	Canada	C	ASS	FS	J-E	Co
McCay et al. (2006)	USA	C	ASS, NS	FS	BS, C-F	Ch, Co
Stead et al. (2006)	NW Europe	C	ASS	FS	J-O	Co
Wilson et al. (2006)	Laos, Vietnam, Zambia	A	ASS, NS	FS, ME	J-MM	Ch, Co
Grant and Berkes (2007)	Grenada	A	ASS, E	Un	J-F	I
Hall and Close (2007)	Turks and Caicos Islands	A, C	ASS	FS	J-F	Co
Shephard et al. (2007)	Ireland	C	ASS, NS	FS	J-F	Co
Murray et al. (2008b)	Canada	C	ASS	FS	J-E	Ch, Co
Daw (2008)	NW Europe, Seychelles	A, C	ASS	FS	T	Ch, Co
des Clers et al. (2008)	England	C	ASS	ME	R	Co
McKenna et al. (2008)	Northern Ireland	C	ASS	Un	J-E	Co
Schneider et al. (2008)	Canada	C	ASS, NS	FS	BS	Ch, Co
Charles and Wilson (2009)	Canada	C	ASS	FS, ME	J-F	Co
Gerhardinger et al. (2009)	Brazil	A	ASS	ME	J-MM	Ch, Co
Hall et al. (2009)	New Zealand	C	ASS, E	FS	J-E	Ch, Co
Lavides et al. (2009)	Philippines	A, C	ASS	Un	J-E	Ch, Co
Valdés-Pizzini and García-Quijano (2009)	Puerto Rico	A, C	ASS	FS, ME	J-O	Ch, Co
Foster and Vincent (2010)	Mexico	C	ASS	FS	J-MM	Ch, Co
Stöhr and Chabay (2010)	Baltic states	C	ASS	FS	J-E	Ch, Co
Wise et al. (2010)	Portugal	C	ASS	FS	C-F	Co
Carruthers and Neis (2011)	Canada	C	ASS	FS	J-E	Co
Daw et al. (2011)	Seychelles	A	ASS, NS	FS	J-E	Ch, Co
Ruddle and Davis (2011)	Canada, Vietnam	C	ASS, NS	FS, ME	J-E	Ch, Co
Zukowski et al. (2011)	Australia	R	ASS, NS	FS	J-F	Co
Hamilton et al. (2012)	Solomon Islands	A	ASS, NS	FS, ME	J-E	Co
Heyman and Granados-Dieseldorff (2012)	Belize, Guatemala, Honduras	A	ASS, E	FS, ME	J-F	Ch, Co
Nenadovic et al. (2012)	USA	C	ASS	FS	J-E	Ch, Co
Blythe et al. (2013)	Mozambique	A	ASS, NS	FS	J-E	Ch, Co
Hallwass et al. (2013)	Brazil	C	ASS, NS	FS	J-E	Ch, Co
Golden et al. (2014)	Fiji	A, C	ASS, NS	FS, ME	J-E	Ch, Co

Codes have been used to keep table compact: Study location (I ¼ indigenous); Fishery type (A ¼ artisanal, C ¼ commercial, R ¼ recreational); Research approach (ASS ¼ applied social science, E ¼ ethnography, NS ¼ natural science); Audience (FS ¼ fisheries scientists, ME ¼ marine ecologists, Un ¼ unspecified scientists); Publication type (B ¼ book, BS ¼ book section, C-E ¼ ecology conference, C-F ¼ fisheries conference, C-FK ¼ fishers' knowledge conference, J-E ¼ ecology journal, J-F ¼ fisheries journal, J-MM ¼ marine management journal, J-O ¼ other journal, R ¼ report, T ¼ thesis); Relationship to mainstream (Ch ¼ challenges, Co ¼ complements, I ¼ independent from). This table does not include all the third wave publications that were reviewed. The representative list of references displayed here was systematically selected from a database constructed in the software package Endnote. All references were sorted by year and then those at set intervals were chosen for inclusion. *First published in 2001 as part of conference proceedings.

McCay et al.'s (2006) which found that fishers had novel methods for excluding discards in a US squid fishery, have been among a number (e.g. Shephard et al. 2007; Stanley and Rice 2007) to call for fishers' knowledge to be included systematically in the design of fisheries science experiments.

The latest third wave literature has generally identified how fishers' knowledge specifically complements other approaches to fisheries science. Valdés-Pizzini and García-Quijano's (2009) assertion that Puerto Rican fishers think in the same ecological way as fisheries scientists and managers, Lavides et al.'s (2009) belief that Filipino fishers' knowledge could immediately underpin local marine legislation and the assessment work of the International Union for Conservation of Nature (IUCN), and Carruthers and Neis' (2011) finding that even where there are few shortcomings in professional fisheries assessment the experience of Canadian fishers could still be valuable to fisheries managers are just a few examples. What is more, integration of fishers' knowledge has actually resulted following research conducted by third wave practitioners. The first case of fishers' knowledge being referenced in the management of a commercial fishery appears in the soft shell clam fishery of Maine, United States. Feedback of clam harvesters in regard to the predation of clams was used by scientists to make recommendations to fisheries managers on the appropriate rate of clam harvesting (Hanna 1998). Since, fishers' knowledge recorded during third wave research has been used to inform stock assessment of orange roughy (*Hoplostethus atlanticus*) in Ireland (Shephard et al. 2007), marine habitat management in Norway (Maurstad 2002), and regional marine protected area design in both Maine, United States (Nenadovic et al. 2012) and southwest England (des Clers et al. 2008).

Linkages between the second and third waves of fishers' knowledge research coincide with the integrations of fishers' knowledge into mainstream fisheries science and the broader adoption of applied social science techniques in its research. Cross-referencing Tables 1 and 2, and considering quotes in Table 4, it is seen that some of those considered part of the second wave can latterly be considered part of the third (i.e. Kenneth Ruddle and Richard Hamilton). Although these two researchers had been of the less radical persuasion within the second wave, their modified outlook is still representative of a period of consolidation in fishers' knowledge research post 2000. Additionally, one of the more radical second wave scholars, Fikret Berkes, has recently been involved in fishers' knowledge research that used the applied social science methods of scheduled interviews and focus groups (Grant and Berkes 2007). This is further evidence of the consolidation in fishers' knowledge research.

Second wave style publications that radically challenge the mainstream approach to fisheries science do still appear (e.g. Menzies and Butler 2007), but an overall slowing in the rate of second wave publications, evident in Table 1, shows that this wave has lost its energy. The collaboration of Robert Johannes in the final years of his career with Barbara Neis (Johannes and Neis 2007), and the former's contention that fisheries scientists and managers were already mutually sharing knowledge (Haggan et al. 2007b, p. 35) is emblematic of the broadening support for a reformist challenge to established fisheries science, rather than a radical one.

A more unified research approach should not however be mistaken for a settled one. The nascent integration of fishers' knowledge research into fisheries science and management has been slight (Soto 2006; Hind 2012). The case studies of integration detailed here have been the exception rather than the rule. This lack of full integration has overlapped a continued low profile for fishers' knowledge literature. Table 2 shows that much fishers' knowledge research has remained limited to the ecology journals, topic-specific books, and specialist conferences that mainstream fisheries scientists have neither ordinarily read nor attended. Little third wave fishers' knowledge research has been published in what can be considered pure fisheries journals, although Table 2 shows exceptions. Contrastingly, a potential new typology of fishers' knowledge researcher, one practising a very different approach to that consolidated by second and third wave scholars, is using this latter publication outlet above others.

The fourth wave: reinvention—quantitative biology

The concept of "fishery-dependent data" or "fishery-dependent information" can be traced back to the late 2000s in the ICES Journal of Marine Science and is only addressed in eight papers in the journal as of 10 February 2014. Until recently, fishery-dependent research had been independent of fishers' knowledge research, operating as its own approach to fisheries science. Its practitioners have typically enlisted fishers as data collectors to gather quantitative biological information on their behalf (Morgan and Burgess 2005). Dobby et al. (2008), for instance, asked Scottish fishers to document their catches of two anglerfish species on datasheets designed specifically for the task. The information returned to them revealed underreporting of landings in the official catch data gathered using other methods. The practice of fishery-dependent data research actually predates the identification of the concept. From 1994, Canada's Department of Fisheries and Oceans (DFO) has trained fishers to collect at-sea data to support the development of indicators for the recovery of cod stocks. These data have

been partially integrated in mainstream fisheries science (DFO 2014). Both the Scottish and Canadian research mentioned here did not use any qualitative methods and did not require fishers to convey any experiential knowledge. They also did not call the data they collected fishers' knowledge or anything similarly termed. Notably, these studies, and those of many others practising this type of fishery-dependent research, have not appeared to reference the work of any of the practitioners in the first three waves of fishers' knowledge research. Yet, while these studies and others like them have remained independent to fishers' knowledge research and should not be considered part of it, other fishery-dependent studies have begun to be considered part of the approach.

At a 2010 conference entitled *Fishery Dependent Information: Making the Most of Fisheries Information, a session on the Application of Fisher Knowledge in Scientific Assessments and Fisheries Management* showcased a number of studies clearly recognizable as third wave fishers' knowledge research (e.g. Curtis 2010; Wize et al. 2010). Yet, it was a session (attended by the author) that also included quantitative studies that had asked fishers to collect data on behalf of biologists (e.g. Haukeland 2010; Jankovsky et al. 2010). These quantitative studies were not necessarily identified as fishers' knowledge research, but the

fact they existed in a session of this title organized by mainstream fisheries biologists from ICES and the FAO affiliated national fisheries science institutions of Ireland, the United States, and Norway, means they cannot be seen as entirely separate to it. The introduction to the conference proceedings actually identifies fishers' knowledge research as being part of the fishery-dependent data approach (Graham et al. 2011).

One of the earliest of the potential fourth wave case studies identified in Table 3 also classified data collected at-sea by fishers as fishers' knowledge. Maynou and Sardà's (2001) logbook study that engaged a section of the Spanish commercially fleet targeting *Nephrops norvegicus*, asked fishers to record quantitative data for several fields (e.g. cpue, nature of the wind, sea conditions, atmospheric conditions) just as Dobby et al. (2008) had done in Scotland.

Further evidence that researchers already working in the fisheries science mainstream have begun to visualize fishers' knowledge research as an approach where fishers contribute primarily quantitative biological information is seen in a 2010 issue of the official ICES magazine, which included a Danish case study of what was termed "fishers' knowledge". Asking fishers to respond to

Table 3. A sample of publications from the fourth and fifth waves of fishers' knowledge research.

Publication	Study location(s)	Fishery type(s)	Research approach(es)	Audience(s)	Publication type(s)	Relationship with mainstream
4th wave						
Wroblewski (2000)	Canada	C	NS	FS	BS	Co
Maynou and Sardà(2001)	Spain	C	NS	FS	J-F	Co
Meeuwig et al. (2001/2007)*	Philippines	A	ASS, NS	FS	BS, C-FK	Co
Rochet et al. (2008)	France	C	ASS, NS	FS	J-F	Co
Johannesen (2010)	Denmark	C	ASS, NS	FS	J-F	Co
Postuma and Gasalla (2010)	Brazil	A	ASS, NS	FS	J-F	Co
Lorance et al. (2011)	Europe	C	ASS, NS	FS	J-F	Co
Parada et al. (2012)	Spain	A	NS	FS	J-F	Co
Macdonald et al. (2014)	Scotland	C	ASS, NS	FS	J-MM	Co
Serra-Pereira et al. (2014)	Portugal	C	ASS, NS	FS	J-E	Co
5th wave						
Metzuals et al. (2008)	Canada	C	ASS	FS	BS	Co
Léopold et al. (2014)	New Caledonia	A	ASS	FS	J-F	Co
Beaudreau and Levin (2014)	United States	C, R	ASS	FS	J-E	Co
Tesfamichael et al. (2014)	Eritrea, Sudan, Yemen	A	ASS	FS	J-E	Co

Codes have been used to keep table compact: study location (I, indigenous); fishery type (A, artisanal; C, commercial; R, Recreational); research approach (ASS, applied social science; E, ethnography; NS, natural science); audience (FS, fisheries scientists; ME, marine ecologists; Un, unspecified scientists); publication type (B, book; BS, book section; C-E, ecology conference; C-F, fisheries conference; C-FK, fishers' knowledge conference; J-E, ecology journal; J-F, fisheries journal; J-MM, marine management journal; J-O, other journal; R, report; T, thesis); relationship with mainstream (Ch, challenges; Co, complements; I, independent from). This table includes all reviewed fourth and fifth wave publications identified by systematic means. *First published in 2001 as part of conference proceedings.

the question, “Has the abundance of cod changed since last year?” by stating “much less”, “less”, “no change”, “more”, or “much more”, those conducting the research concluded that fishers agreed with scientists’ perceptions of trends in a fish stock (Johannesen 2010). Canada’s DFO has also adopted such techniques, using telephone surveys to question fishers about changes in cod abundance (DFO 2014). Subsequently, they have only included brief qualitative findings from the survey to complement its quantitative outputs, much less comprehensive than those produced by third wave Canadian researchers working with the same cod fishers. However, they have not referred to their outputs as “fishers’ knowledge”. In stock assessment reports they have simply termed such information to be “stakeholder perspectives” (DFO 2014, p. 17). Other publications, seen in Table 3, have though identified the outputs of closed short-answer surveys with fishers as fishers’ knowledge. Serra-Pereira et al. (2014), for instance, successfully collaborated with Portuguese fishers to quantify skate habitat, but their structured surveys did not seek to gather the type of qualitative anecdotes recorded by second and third wave researchers.

The fourth wave of research is far from as prominent as the very much active third wave, but it can already be identified as distinct. As mentioned, its publications do most often appear in outlets that only comprise fisheries science research, and they do not ordinarily criticize mainstream fisheries scientists for under considering fishers’ knowledge (see Table 3). Its practitioners, perhaps because they themselves are primarily biologists employed in mainstream fisheries institutions, are speaking directly to the scientists and managers at the forefront of the fisheries paradigm. If the practitioners of this wave find an appreciative audience among their close colleagues, then it is likely this format of fishers’ knowledge research will expand rapidly in the next decade as it becomes adopted in more national fisheries institutions.

A fifth wave? Reconciliation – applied social science and quantitative biology

Recently, a fifth wave may have emerged within fishers’ knowledge research. A small number of researchers using applied social science methods seem to have reacted to both the lack of integration of third wave fishers’ knowledge research in mainstream fisheries science and the emergence of the more quantitative fourth wave. Tesfamichael et al. (2014), identified in Table 3 as part of this possible wave, have explained how their research in countries bordering the Red Sea has been an attempt to integrate fishers’ knowledge into mainstream fisheries science (see Table 4) by making greater efforts to report quantifiable information following

interviews with fish harvesters. Where third wave researchers have specifically designed questions to elicit fishers’ quantitative knowledge, they have been able to construct complete datasets (Hutchings and Ferguson 2000b). However, for other third wave scholars who have been able to report fishers’ knowledge for data fields such as cpue, their statistics have often been seen as too subjective for integration into professional population ecology calculations (Hauge 2011; Hind 2012). Tesfamichael et al. (2014), by ensuring that they elicited detailed data during semi-structured interviews, found that the fishers’ knowledge they were able to record correlated well with a previous biological study on shark cpue.

Tesfamichael et al. (2014) also reported that within the typically free-flowing forum of an interview, researchers often have to insert structured questions that can fragment conversation to elicit quantitative rather than qualitative fishers’ knowledge. The fragmentation can expend both researchers’ time and fishers’ patience, closing the window to collect other types of data. Therefore, fifth wave researchers have not had the same opportunities as their third wave colleagues to record either fishers’ qualitative anecdotes or their non-biological knowledge. The lesser breadth of this new approach is also evident in Léopold et al.’s (2014) geospatial questioning of New Caledonian fishers. Like Tesfamichael et al. (2014), they also reported almost entirely ecological results. The emergent fifth wave researchers do cite both second and third wave research as influential to their work, but their outputs are generally quantitative and biological like those of the fourth wave. The future publications of the fifth wave will need to be analysed as they growing volume to better discern linkages with the other waves.

The present: finding space for fishers’ knowledge research in a contested paradigm

The title of this paper deliberately attempts to speak predominantly to those already working within the mainstream of fisheries science and management. It is a title that aims to highlight that not all is stable within the fisheries paradigm and that fishers’ knowledge researchers want to see the data they collect inform fisheries management. Since the mid-1980s or early 1990s fisheries science has been undergoing something of a crisis as fish populations have in general declined internationally (FAO 2014). Following the high profile collapses of scientifically managed fish stocks like the Peruvian anchoveta (*Engraulis ringens*) and the Canadian northern cod, the population ecologists who have dominated the paradigm of fisheries science for the last century (Caddy and Cochrane 2001; Rozwadowski 2002) have rightly or wrongly been taking blame for the failings of the data collection methods

Table 4. Researcher quotes describing the potential nature of mainstream integration for fishers' knowledge.

Wave	Publication	Quote
1st	Nordhoff (1930, p. 138)	The time is ripe for some trained enthusiast to settle in these islands, learn the language, and devote four or five years to a complete account of fishing, inside and outside the reefs. Such a work would assume proportions almost encyclopaedic, and bring to light a mass of curious data, of interest to ichthyologists, I should think, and of some comparative value to students of mankind in the Pacific. But no doubt the task will never be undertaken — the subject is too obscure to justify the effort required.
2nd	Ruddle (1994b, pp. 199–200)	Practical, fish-behaviour-orientated local knowledge, which focuses on the economically most important species, can provide a particularly important information base for managing tropical multispecies and multigear fisheries and their habitats, because scientific knowledge of tropical inshore fisheries is relatively poor, and data required for conventional management are usually either scanty or nonexistent.
	Ruddle (1994b, p. 197)	Once collected, this [local knowledge] must be verified and also blended with more technical forms of biological research, like population dynamics, population genetics, physiology, and microbiology, among others, before it can be put to best use.
	Berkes et al. (1995, p. 295)	Resource management based on Western scientific knowledge often generates simplified ecosystems, either directly through excessive resource extraction and monoculture-based production, or through pollution and degradation that cause ecosystem stress. [...] Resource management characterised by [traditional ecological knowledge] systems allows unpredictable perturbations to enter the system, instead of locking them out.
	Johannes et al. (2000, p. 268)	This kind of humility on the part of a scientist [. . .], in the presence of a native expert possessing knowledge that is in some ways superior to his own, will remain uncommon, however, until more biologists accept the value of such knowledge, as well as the methods for studying it, and cease to promote narrow neo-positivist versions of 'the scientific method' as the only basis for structuring ecological research.
3rd	Neis et al. (1999, p. 1962)	Finding ways to make comparisons between fishers' observations and data drawn from more traditional scientific sources could improve the potential for more informed and more accepted decisions on stock status and management.
	Murray et al. (2008a, p.118)	As with any knowledge system, the picture LEK produces will be partial. However, we have found that LEK can be an invaluable addition to scientific and historical archival resources that are also partial. Harvesters are and were the central human actors in these social ecological systems and their observations and interpretations can contribute significantly to our efforts to understand the interactions in these systems.
	Ruddle and Davis (2011, pp. 897–898)	As was demonstrated [. . .] the fisheries biological and oceanographic aspects of the hypothesis can be ascertained only by elaborate scientific sampling. Clearly, strong guidance in this can be provided by [local ecological knowledge], especially that related to the timing and location of the target species.
4th	Johannesen (2010, p. 28)	The [North Sea Stock Survey] has been collecting data on fishers' perceptions of the status of eight fish stocks in the North Sea since 2003, through a voluntary annual survey in Belgium, Denmark, England, the Netherlands, and Scotland. The aim is to provide a means for fishery scientists and managers to incorporate fishers' knowledge into their assessments.
5th	Tesfamichael et al. (2014, abstract)	It is suggested that analysis of approximate data, quickly acquired at low cost from fishers through interviews, can be used to supplement other data-recording systems or used independently to document the changes that have occurred in the resource base over a lifetime of fishing. The results can be used to guide the assessment and management of resources to conserve ecosystems and livelihoods.

they have employed (Hilborn and Walters 1992; Daw and Gray 2005). Quotes in Table 4 show that it has been the contention of fishers' knowledge researchers (to varying degrees) that the consideration of fishers' knowledge by fisheries managers would allow them to act to arrest fishery declines.

Population ecologists have been able to counter criticisms of their work by citing clear evidence of where their science has helped fish stocks to recover (Murawski 2010), or by referring to recent theoretical (Dickey-Collas et al. 2010) and technological

improvements (McElderry et al. 2008) in their research approaches that have eliminated previous perceived shortcomings. Nevertheless, the point at which fisheries science was an uncontested discipline has passed. Perceived shortcomings continue to be noted in contemporary approaches to fisheries science, not least the scientific uncertainty and lack of coverage that prevents stock assessments being made for the most commercially fished species (Kleisner et al. 2013). With a lack of capacity to address the perceived shortcomings in their research approaches, professional fisheries scientists

have been unable to convince, going forward, that it should be only their expertise informing fisheries management. This situation has created a space where practitioners advancing non-established approaches for gathering fisheries information or for managing fisheries can solve at least some scientific uncertainty. This is the space that fishers' knowledge researchers can use to advance their own approach to fisheries science in attempts to have it mainstreamed.

The rise of new approaches to fisheries science and management is well documented (Caddy and Cochrane 2001; Jacquet 2009). Economists have proposed several bioeconomic solutions to the fisheries crisis, suggesting how the introduction of management mechanisms such as individual transferable quotas (Squires et al. 1995; Péreau et al. 2012) and catch shares (Costello et al. 2008) could relieve some of the pressure of having to precisely calculate fish stocks. More recently, ecologists have advanced ecosystem based fisheries management as an alternative, where the setting up of refugia from fishing effort automatically protects all species within an area, negating the need for single-species stock assessments (Pikitch et al. 2004). Figure 1 shows, that since its emergence in the mid-1980s, the ecosystem approach has received significant attention in this and other fisheries journals, an indicator that as an approach it has become part of the mainstream fisheries paradigm. It also shows that fishers' knowledge research, regardless of its long history, has not to date received the same acceptance.

Some of this lack of acceptance has been put down to issues of utility. Natural scientists working in fisheries institutions have found it hard to integrate a knowledge culture so different from their own (Soto 2006). The often qualitative, non-standard format of much fishers' knowledge contrasts substantially with the systematic quantitative data, with set spatiotemporal scales, to which many fisheries scientists have been accustomed. In addition, politicization of fishers' knowledge by policymakers electorally courting the fishing industry has seen it uncritically accepted when inaccurate, subsequently raising questions over whether it is an information source that can be faithfully integrated. During the collapse of Canada's northern cod stock, the beliefs of politically powerful commercial fishers, that stocks were not in serious decline, were cited by fisheries managers as a reason for not acting to protect the stocks although less empowered small-scale fishers and some fisheries scientists contested this belief (Neis 1992; Finlayson and McCay 1998). Similarly, dependence on fishers' knowledge has also been queried as a result of it being on occasion over-romanticized. The case studies of the second wave demonstrated that fishers could inform sustainable management

of fisheries solely with their knowledge, but the idea that fishers' knowledge should be viewed sacredly as a data source that when integrated will always underpin sustainable management is one that has not prevailed (Davis and Ruddle 2010). Recent research in Fiji, for instance, has documented how some fishers' growing knowledge of new harvesting technologies and export markets has informed their overexploitation of fisheries that they and their peers had previously managed within safe harvest limits (Golden et al. 2014).

The continued non-acceptance of fishers' knowledge by the fisheries science mainstream has also been seen by many scholars to be based on prejudice. Soto's (2006) review of these scholars' work reveals that the qualitative information documented during fishers' knowledge interviews has often not been deemed real science, that fishers' experiences not collected through rigorous hypothesis testing and systematic experimentation have been regularly perceived as too subjective to include in official datasets, and that the knowledge of non-experts (i.e. fishers not trained in the scientific method) has been seen by some as simply inferior. These prejudices held by certain individuals, and indeed institutions, have been documented to be embedded within the structures of mainstream fisheries science.

The neo-liberal focus of westernized fisheries management solely on proprietorship is judged to have eroded the local organizational structures and cultural norms that have been so closely associated with the production of fishers' knowledge (Davis and Ruddle 2012; Ruddle and Davis 2013a). In addition, the tendency of those in the fisheries science mainstream to see fisher-informed management systems as alternative is given as a reason that western fisheries science is still seen as normal despite its failures. Ruddle and Satria (2010) document that in the tropics where first and second wave scholars "discovered" fisheries that had been sustainably managed by fishers, such fisher-informed systems have often been replaced by scientist-led western management. In the developed world fisheries of the European Union, similar preference for scientist-led fisheries management has been assessed. Griffin (2009) describes how Regional Advisory Councils (RACs) set up to foster fisher input into fisheries management have in fact helped perpetuate some fisheries scientists' unwillingness to allow fishers to generate their own data. The RACs have primarily been used thus far as simply a forum to ask fishers to comment on preexisting data collected by biologists.

For Holm (2003), the lack of mainstream acceptance does not matter, as like some of the radicals of the second wave of fishers' knowledge research

he believes that applied social science approaches and those that are highly quantitative should not simply be used to please those working in mainstream fisheries science. Such research, he says, has “decontextualized” fishers’ experience to an extent where it has lost its qualitative uniqueness and subsequent utility. Neis (2003), in response to Holm, says that he fails to either consider the differing objectives of fishers’ knowledge researchers or the externally impacted networks of influence in which they operate. For example, the fishers’ knowledge researchers of the third wave have considered population ecology as essential and have deliberately produced outputs that work in synthesis with it. The abandonment of the second wave detailed in this paper suggests that Holm’s view is one that fishers’ knowledge researchers have come to see as untenable. Future attempts by fishers’ knowledge researchers to mainstream their work seem more likely to be reformist or reconciliatory than they are radical.

The future: three scenarios for the future of fishers’ knowledge research

Figure 2 summarizes the direction taken by fishers’ knowledge research to date, showing that only the third, fourth, and fifth waves are currently active. It also shows that it is too early to tell whether the fifth wave is truly a new direction for the research approach or is instead a few isolated publications sitting near to the fourth wave while remaining ideologically between that wave and the third. The questions to be answered in the final section of this review paper then are: do any of the active waves of fishers’ knowledge research represent the future of the research approach, and if so, how will they impact the mainstream fisheries paradigm? Three possible scenarios can be theorized in response.

Fishers’ knowledge research could become obsolete

Despite the growth in the fishers’ knowledge research literature, especially during the third wave, analysis here confirms the outlook shown in Figure 1. Even with a consolidation of research waves that has indicated a growing desire of fishers’ knowledge researchers to support the work of other fisheries scientists, the integration of fishers’ knowledge research into mainstream fisheries science has been low. In particular, ethnographic and social science approaches to fishers’ knowledge research have largely been ineffective in producing outputs that have gone on to inform real-world marine management. If integration of fishers’ knowledge is not achieved soon, following increasingly more intense efforts over the last century to achieve just this, will those that research it choose instead to direct their research efforts elsewhere?

Fishery-dependent data research may be the only approach mainstreamed in fisheries science

Fishery-dependent data research may not compare to fishers’ knowledge research in terms of longevity or publication output, but it is beginning to double up as the fourth wave of fishers’ knowledge research, and is already located within the fisheries science mainstream. As it shares few linkages with the third wave of fishers’ knowledge research, this integration, while not precluding the similar integration of the longer established wave, will not necessarily facilitate it. Its shared quantitative characteristics and closer linkages with the potential fifth wave may however partially catalyse the integration of that wave and its applied social science methods. Multiple approaches to fishers’ knowledge research

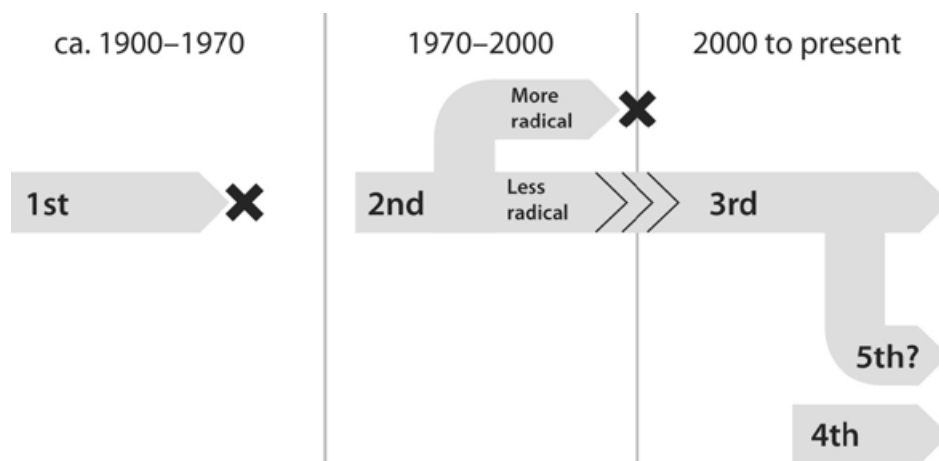


Figure 2. The progression of the five waves of fishers’ knowledge research.

may be mainstreamed in fisheries science. This final scenario is the “integration project” that Soto (2006) says most fishers’ knowledge researchers must successfully negotiate if their research is to be impactful within mainstream fisheries management. With the fourth wave already likely heading to this kind of integration, this scenario is more relevant to the third and fifth waves. For this integration to occur, ideological objections to fishers’ knowledge in the fisheries science mainstream will need to be dropped or mitigated. Dissemination of qualitative and nonbiological outputs may also have to be rethought by third wave researchers so that they are more accessible to quantitative biological scientists.

Shaping the future: renewed wake-up calls

It is how mainstream fisheries scientists and fishers’ knowledge researchers now proceed that will determine which of the three scenarios becomes reality, an eventuality that will most likely be determined by how each listens to wake-up calls that have already been made. The warning of Robert Johannes’ et al. (2000) to any fisheries scientist who continues to ignore all or some dimensions of fishers’ knowledge is still pertinent. The sizeable literature reviewed in this paper includes many examples of where referencing fishers’ knowledge did prevent or could have prevented further fish stock declines when mainstream fisheries science had failed to provide answers. It is likely that future fishers’ knowledge literature will provide further examples of how the consideration of fishers’ knowledge could complement existing biological, ecological, and economic approaches to fisheries science to deliver better management outcomes. With the fisheries paradigm unstable and under increasing criticism, can such information be ignored?

Davis and Ruddle’s (2010) request to fishers’ knowledge researchers to get their “house in order” remains valid. The preference of this community for publishing to date in outlets that focus on fishers’ knowledge itself, or that have an ecological or general conservation focus rather than a fisheries one has resulted in progress. Without the consolidation that resulted when reformist second wave and third wave scholars looked inward, the now dominant approach in which fishers’ knowledge researchers seek to collaborate with mainstream fisheries scientists may not have developed. In a paradigm which seems resistant to collapse, working with those in the epistemic community is an important part of integration for a new knowledge culture (Haas 1990). With ecology and conservation being larger fields than fisheries science, targeting the research outlets of these fields has introduced fishers’ knowledge to new audiences that have found further applications for the data source. The identification of greater utility for fishers’ knowledge increases its chances of

integration (Hind 2012). However, less regular targeting of the outlets of mainstream fisheries science is reducing the potential for integration in the specific field where it has been described as most applicable. To further get their “house in order”, fishers’ knowledge researchers may therefore need to focus more on how they outwardly communicate findings. The fisheries scientists who are currently not fully aware of the utility of fishers’ knowledge are ultimately those most able to integrate new information sources within fisheries management (Jentoft 2005).

The fisheries science mainstream is open to a paradigm change that includes the increased adoption of social science research approaches and the greater consideration of new knowledge cultures, as the current Head of Programme Advice for ICES has been among those to have stated (Degnbol et al. 2006). The next decade will likely tell whether fishers’ knowledge research, and of course fishers’ knowledge, will be part of that change.

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