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Editor's note

In the first paper, "Is community-based fisheries management realising multiple objectives? Examining evidence from the literature", Philippa Cohen and her co-authors examine locally managed marine areas (LMMAs). They review the literature on LMMAs from throughout the Pacific Islands region to determine their effectiveness. The authors find that LMMAs are often used to improve the long-term sustainability of fisheries, but that they are also implemented to achieve seven other overarching and interlinked objectives: 1) increasing short-term harvesting efficiency; 2) restoring biodiversity and ecosystems; 3) maintaining or restoring breeding biomass; 4) enhancing livelihoods; 5) reinforcing customs; 6) asserting access rights; and 7) community empowerment. Considering all of these objectives, the authors review empirical evidence of the effectiveness of different management measures or "tools" applied within LMMAs (i.e. permanent closures; periodically harvested closures; restrictions on gear, access or species; livelihood diversification strategies; and participatory and engagement processes). Despite reports of hundreds to thousands of active LMMAs in the Pacific, relatively few empirical cases provide rigorous descriptions of either management being implemented or outcomes demonstrated. Given the importance of community-based management in the Pacific for addressing small-scale fisheries concerns, the authors provide some direction for future research.

The second article, "A review of the past, the present, and the future of fishers' knowledge research: A challenge to established fisheries science", written by E.J. Hind, is reprinted here with the permission of the Oxford University Press. It was published originally in the International Council for the Exploration of the Sea *Journal of Marine Science*. Dr Hind explains that despite its relatively long history, the results of research on fish harvesters' knowledge remain on the margins of fisheries science. This comprehensive review article describes in broad terms the coverage of fish harvesters' knowledge literature. It then examines the five "waves" of such knowledge research that have developed during the last 100 years, and assesses the impact of each wave on fisheries science. The author concludes that fish harvesters' knowledge research will be a productive activity only "... 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".

In the final paper, K. Ruddle shares thoughts on some issues and problems that characterise tropical small-scale fisheries. There is no consensus about the category commonly referred to as "small-scale fisheries". And although millions of people worldwide depend on them, most small-scale fisheries are not well understood scientifically. Nevertheless, homogeneity of the category is commonly assumed, and beyond simple acknowledgement, the diversity, complexity and human ecological dynamics of small-scale fisheries are largely unexamined. Policies based on misplaced assumptions are unlikely to succeed when implemented in a complicated and changing world because the policy-making environment is rendered needlessly complex by the acceptance of naïve notions based on the idealisation of small-scale fisheries as representing both ecological sustainability and social justice. When considering the introduction of either new or replacement governance arrangements for small-scale fisheries it is necessary to appreciate that their diversity, complexity and dynamics preclude a "cookie cutter" panacea for all cases. Introduced governance will succeed only where those characteristics — plus the changing contextual factors that impinge on small-scale fisheries — are taken into account, and where the locally distinct range of "actors" involved is included.

Kenneth Ruddle

PIMRIS is a joint project of four international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the Pacific Islands Forum Fisheries Agency (FFA), the University of the South Pacific (USP) and the Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ('grey literature'); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.

PIMRIS

Pacific Islands Marine Resources Information System

Is community-based fisheries management realising multiple objectives? Examining evidence from the literature

Philippa J. Cohen[1,2], Stacy D. Jupiter[3], Rebecca Weeks[2,3], Alifereti Tawake[4,5,6] and Hugh Govan[5]

Introduction

Community-based and co-management approaches are key strategies for small-scale fisheries management (Evans et al. 2011; Gutierrez et al. 2011). The expansion of these approaches is particularly apparent in the Pacific, where communities rely heavily on small-scale fisheries (Govan 2009a) and concerns about sustainability are increasing (Bell et al. 2009; Brewer et al. 2009). Many community-based management initiatives are recognised within a regional practitioner's network referred to as the Locally Managed Marine Area (LMMA) network (Parks and Salafsky 2001). There are also likely to be hundreds to thousands of communities implementing management, outside the formal network, which do not appear on any official list (Govan 2009a). For simplicity, we use the term LMMA broadly to encompass local management that: 1) is applied to nearshore marine areas; 2) seeks to meet local management objectives; 3) employs locally negotiated rules that integrate customary or local governance institutions; 4) is adaptable via learning-by-doing approaches; and 5) includes circumstances where resident communities may be collaborating with partners such as non-government organisations, government agencies or research institutes (Govan 2009a). In this regard, the term LMMA is synonymous with community-based marine resource or fisheries management (CBRM and CBFM).

Throughout the Pacific, a diversity of customary institutions exist for controlling the use of fisheries resources, including tenure systems, closures of fishing grounds, and bans on sectors of society consuming or harvesting certain species (Cinner and Aswani 2007; Johannes 1982). Alongside other customary and local governance structures (e.g. chiefly systems), such customary institutions form the foundations of LMMAs (Govan 2009a; Johannes 2002; Ruddle 1998). However, in contemporary, competitive resource-use contexts, customary management institutions alone may be unable to ensure sustainable patterns of resource use without some integration of scientific knowledge, modern management practice or institutional support (Aswani and Ruddle 2013; Foale et al. 2011; Polunin 1984). LMMAs often represent efforts to integrate local and scientific knowledge, customary and contemporary management practices, and, in some situations, to provide legal or other institutional support to customary and local governance.

A recent review (Jupiter et al. 2014) highlighted that LMMAs were not only advocated and established to improve the long-term sustainability of fisheries, but also to achieve other overarching objectives: 1) increasing short-term harvesting efficiency; 2) restoring biodiversity and ecosystems; 3) maintaining or restoring breeding biomass; 4) enhancing livelihoods; 5) reinforcing customs; 6) asserting access rights; and 7) community empowerment. These objectives are often overlapping and, in some cases, can be conflicting. For example, LMMA objectives for enhanced fisheries-supported livelihoods may clash with some objectives for conservation of biodiversity, and LMMAs established to promote short-term increases in catch may not be able to also enhance long-term sustainability of fisheries. Here, we summarise cases from the Pacific that report on these objectives, and then discuss some particular synergies and trade-offs between objectives. By summarising the findings of Jupiter et al. (2014), we then review the effectiveness of management measures or "tools" for progressing fisheries sustainability in particular, as well as the seven other objectives identified.

Increasing the sustainability of fisheries — one of multiple LMMA objectives

LMMAs are commonly established to enhance the long-term sustainability of fisheries-associated livelihoods and food security, and are often initiated in

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response to concerns about resource decline and the sustainability of small-scale fisheries (e.g. Bartlett et al. 2009a; Parks and Salafsky 2001). In some cases, increases in resource abundance have been perceived or quantified over short time-scales and often within small, permanent or periodically harvested closures within LMMAs (e.g. Bartlett et al. 2009b; Cinner et al. 2005; Tawake et al. 2001). Other studies have suggested that human nutrition is improved as a result of such affects (e.g. Aswani and Furusawa 2007; Weiant and Aswani 2006). Yet, there is very limited empirical evidence that short-term or localised (i.e. within small closures) increases might lead to broader and long-term improvements to fisheries-supported livelihoods and food security.

Projections based on population growth rates suggest that coastal fisheries will not meet future needs of many Pacific Island countries, even if coastal fisheries are well managed (Bell et al. 2009). While improving management should help to minimise this deficit, factors operating beyond local levels (e.g. commercial fisheries, government policies) or outside of fisheries systems (e.g. market fluctuations, population growth, natural disasters) also strongly influence fisheries sustainability, and food security and livelihoods more broadly (Schwarz et al. 2011). Yet in the Pacific, where many centralised governments have relatively little capacity to effectively manage dispersed, diverse and dynamic small-scale fisheries, LMMAs will likely remain a key strategy. There are two important areas in which research can focus. First, testing the effectiveness of LMMAs for improving the performance and sustainability of fisheries or, perhaps more realistically in many cases, for achieving "primary management" (i.e. precautionary management designed to prevent the loss of benefits, rather than optimise benefits, Cochrane et al. 2011). Second, improving the understanding of how LMMAs might work in conjunction with centralised management and higher levels of planning to tackle small-scale fisheries concerns. We suggest that a first step in this direction is to develop a better understanding of the multiple objectives for which LMMAs are employed (discussed below), and the potential trade-offs created when managing for multiple objectives simultaneously.

Increase efficiency of harvests for short-term yield

Many communities use LMMAs, most commonly periodically harvested closures or taboo areas, to ensure a ready supply of fish and invertebrates for special occasions (Govan 2009a). Both fishers and scientists have observed that after a period of closure, catch efficiency (particularly of spearfishing) can increase (Cinner et al. 2006; Foale et al. 2011). This can be due to behavioural changes that cause fish to become less wary of fishers (Feary et al. 2011; Januchowski-Hartley et al. 2011). Increased catchability due to these behavioural responses means that a relatively small amount of effort is effective at removing biomass, which benefits fishers in the short term but could increase the likelihood of overharvesting (Feary et al. 2011, Jupiter et al. 2012). Longer-term sustainability is more likely to be effectively coupled with objectives of increased catch efficiency if catch rates are elevated because reproduction and growth have led to increased abundance and size of targeted taxa; this has been observed for some invertebrate fisheries (e.g. Cohen and Alexander 2013; Tawake et al. 2001). Whether short-term improvements in catch efficiency correspond with improved and sustainable yields in the longer term is a pressing question for managers, but will depend on rates of extraction (which, in turn, are affected by resource demand, gear efficiency, and other factors) relative to production (depending on life histories of targeted species, habitat suitability and status, ecological interactions).

Maintain and/or restore biodiversity and ecosystem functions

The conservation of biodiversity and ecosystems is reported as an objective of some LMMAs (e.g. Aswani et al. 2007; Bartlett et al. 2009a; Jupiter and Egli 2011). However, this is not typically a primary objective of communities (Govan and Jupiter 2013), and may emerge due to the influence of ideas about conservation from partner organisations. The LMMA network was founded on the assumption that successful implementation would lead to conservation outcomes, and many LMMA partners are conservation organisations (Cohen et al. 2012). Indeed, there is some evidence that LMMAs can have conservation benefits. Mills and colleagues (2011) demonstrated that national-level coverage of LMMAs in Fiji contributed substantially to the government's target to protect 30% of marine habitats. At local scales, applying tools that are designed to reduce fishing effort or destructive fishing methods may lead to cascading impacts on biodiversity and ecosystem function. For example, local protection from fishing (using reserves) may lead to an increase in prey abundance, which would then lead to increases in top predators (Goetze and Fullwood 2013).

While intact ecosystems and biodiversity support fisheries, there is a distinction between fisheries and conservation objectives (Foale et al. 2013). This distinction is illustrated by the fact that, while no-take marine reserves can perform well for conservation, in some cases (e.g. for species with home ranges that extend beyond reserve boundaries, or where fishing effort becomes intensified in open areas) no-take reserves will be relatively ineffective and inefficient for managing fisheries compared with other measures (Hilborn et al. 2004; Kearney et al. 2012).

Maintain and/or restore biomass and breeding populations

A common community-voiced objective of LMMAs is to restore the abundance and biomass of fish and invertebrate species that are important for fisheries. Supplementing local knowledge with contemporary scientific understanding of reproductive and ecological processes (i.e. through "awareness raising" activities) is a common element of LMMA initiatives (Parks and Salafsky 2001). The goal is to influence management practices so that they increase the likelihood that biomass and breeding populations are maintained, and that long-term sustainability objectives can be met (e.g. Foale et al. 2011). In some cases where community-based management partners have explained ecological processes, communities have readily established area closures (e.g. King and Fa'asili 1998) or spatial and/or seasonal management over breeding and nursery sites (e.g. Almany et al. 2013; Aswani and Hamilton 2004; Hamilton et al. 2011). Abundance and biomass increases are commonly observed within no-take reserves (e.g. Bartlett et al. 2009b; Hamilton et al. 2011). If, after a period of time, increases inside reserves lead to substantial adult spillover and larval export into areas accessible to fishers, then increased catch efficiency or improvements to the long-term sustainability of fisheries may be realised (e.g. Almany et al. 2013; Halpern et al. 2010). However, highly localised protection (i.e. closures of small areas of fishing grounds) will be less likely to lead to improvements in long-term sustainability if fishing effort outside protection zones is too great (e.g. Dumas et al. 2010).

Enhance economy and livelihoods through related activities

Rural Pacific Island communities rely heavily on fisheries for food and income, and in some cases have relatively few alternatives (Bell et al. 2009). Not surprisingly, many communities are attracted to the idea of LMMA establishment in the hope that local economies and livelihoods will be improved — often through means other than fisheries extraction. Livelihood objectives might be pursued through explicit arrangements (or expectations) to: receive payments to cease extraction of resources; develop land-based income generating activities; generate revenue from ecotourism; receive employment associated with management; or participate in alternative income-generating activities introduced by management partners.

For example, the potential for financial gain from tourism development in New Caledonia was a major driver convincing local communities to participate in management (Horowitz 2008). Other examples of economic incentives provided through LMMA-associated ecotourism include fees for diving in Fiji reserves (Weeks and Jupiter 2013), and a paid lease agreement to establish a no-take reserve in Indonesia (Niesten and Gjertsen 2010). In certain cases, tourism has provided additional income to community members through paid employment and boosted sales of fish and handicrafts (Horowitz 2008; Niesten and Gjertsen 2010; Vianna et al. 2012). However, tourism will be unlikely to provide substantive opportunities in remote or environmentally degraded parts of the Pacific. In one such area in Solomon Islands, management partners encouraged community buy-in through alternative livelihood activities (Aswani 2000). In practice, it is often found that the potential for enhanced sustainability of fisheries is not always incentive enough for communities to engage in, or sustain, management.

Maintain or reinforce traditional customs

Customary practices that control resource use (e.g. restricted access through tenure, protection of sacred areas, restrictions on harvesting particular species) are relatively common throughout the Pacific (Hviding 1989; Veitayaki 1997; Zann 1989). Yet, in modern contexts, many of these traditional practices are perceived to be eroding (Bartlett et al. 2010; Foale 2006) and LMMAs are often viewed as a way to strengthen or adapt customary practices (Johannes 2002). For example, in Fiji, a passage considered to be a sacred site was later instated as a closure within an LMMA (J. Cinavilakeba, pers. comm.), and elsewhere in Fiji a lagoon considered to be sacred was reinforced as a permanent no-take area within an LMMA (Veitayaki 2001). Periodically harvested closures or taboo areas (see section below) that have traditional origins are commonly applied and adapted in contemporary community-based management, and may be intended to enhance fisheries performance in both the longer and shorter terms (Cohen and Foale 2013). In other cases, customary marine tenure may be strengthened through LMMA formation to restrict who can access fishing grounds.

Assert access rights

Tenure systems allow communities, clans or families with primary rights to a particular area to limit access and apply rules to the use of resources within the area (Macintyre and Foale 2007), and, thus, they form important foundations for LMMAs (Aswani and Ruddle 2013). Customary marine tenure systems are recognised in the constitution of some countries (e.g. Solomon Islands; Lane 2006); in others, there is legal recognition of traditional fishing rights (e.g. Fiji; Clarke and Jupiter 2010) or legal avenues for communities to establish management rights over coastal areas (e.g. Tonga; Govan 2009a). Tenure arrangements (i.e. the people who hold rights, the nature of those rights, and the areas to which rights are held) are often dynamic and are generally unwritten (Baines 1990). To some extent, arrangements are able to change in response to new

environmental pressures or altered social, economic or ecological conditions (Hviding 1998). Codifying and/or clarifying tenure claims may be an important, but perhaps not overtly stated, objective for establishing LMMAs and formalising management (e.g. Steenbergen 2011). Yet, in some cases, clarifying tenure claims to establish management (or local developments) can work in opposition to objectives of enhanced community cohesiveness, and instead lead to protracted negotiations and disputes (Macintyre and Foale 2007; McDougall 2005). Depending on how rights are assigned and how management is established, benefits and costs may be unequally distributed according to gender, clan or ethnicity, which can undermine management and/or hinder objectives of improving "community" well-being (e.g. Anderson and Mees 1999; Cohen et al. 2013; Vunisea 2008).

Increase community organisation, cohesiveness and empowerment

Many community-based management partners seek to empower communities and strengthen local governance through participatory processes employed for establishing and implementing LMMAs (Govan et al. 2008). These processes often include elements of education, awareness raising and learning for adaptation. Further, processes for establishing LMMAs frequently facilitate community-level consultations for identifying issues, visioning, planning, decision-making and consensus building (Govan et al. 2008; King and Fa'asili 1998). In one case in Solomon Islands, it was reported that as a result of such processes, a communities' LMMA committee was better able to deal with resource-use issues, but also developed into a forum for "addressing other community issues" (Govan 2009b; Leisher et al. 2007). While anecdotal reports of improved governance are relatively common, more critical evaluations of changes in governance capacity are warranted. In a further case, women's participation in decision-making about resources was reportedly enhanced through community-engagement and planning processes (Hilly et al. 2011; Leisher et al. 2007). This is an important outcome because despite women's common and various roles in capturing and marketing fisheries resources (Kronen and Vunisea 2007; Weiant and Aswani 2006), women frequently have limited voice in such decision-making (Vunisea 2008). Partnerships (i.e. those between communities and their management partner) may also bolster local management efforts and raise the profile of local issues. For example, in Solomon Islands a network of LMMA partners provided important pathways for information about resource management to reach communities, and also provided a mechanism for communities and their management efforts to be represented in higher level decision-making arenas (Cohen et al. 2012).

Management measures or "tools" used to progress objectives

Within an LMMA, management falls into six broad categories of fisheries rules and management measures: 1) permanent closures, 2) periodically harvested closures, 3) species-specific restrictions, 4) gear restrictions, 5) access restrictions, and 6) livelihood diversification strategies. Jupiter et al. (2014) used expert opinion alongside appraisal of the literature to rank the effectiveness of each type of management measure for achieving LMMA objectives. Here we refer to findings from mainstream fisheries practice and science, but focus on empirical evidence from the Pacific (reviewed by Jupiter et al. 2014) of the performance of these management measures for achieving LMMA objectives. These measures are not necessarily intended to be employed in isolation (and may achieve complementary objectives if employed in combination), but for simplicity we consider them separately, and highlight some examples where outcomes will be affected by the broader management context as well as differing social and environmental contexts. In addition to the application of these six types of management measures, the *processes* of LMMA formation and adaptation may also contribute to objectives such as "assert access rights" and "increase community organisation and empowerment", but these are not detailed or discussed in depth here (but see Albert et al. 2013; Govan et al. 2008; Jupiter et al. 2014).

Permanent closures

LMMA approaches frequently lead to the formation of small (median 0.1–1.0 km^2) no-take zones, often placed over coral reefs (Govan 2009a). Where these have included spawning aggregation sites, localised increases of some key fisheries species have been observed (Hamilton et al. 2011). However, for species with large home ranges or those with highly dispersing larvae, it is expected that small reserves will be less effective (Ferraris et al. 2005; White and Costello 2011). For example, small closures appeared to be insufficient for restoring breeding biomass and preventing overall population declines (even for relatively immobile invertebrates) in Vanuatu (Dumas et al. 2010). Perceptions of increased marine resources within closed zones are common within fishing communities, even if increases are not apparent from ecological monitoring data or are ecologically unrealistic (World Bank 2000; Yasue et al. 2010). However, there are suggestions that benefits of closures may transcend ecological impact by increasing interest, knowledge and awareness of the benefits of management more broadly (World Bank 2000). In some contexts, no-take areas have facilitated alternative income sources, typically those related to dive tourism (e.g.

Weeks and Jupiter 2013). Permanent no-take areas have also been established within LMMAs to help protect sacred sites or to conserve habitats and species (e.g. Jupiter and Egli 2011). Notably, many no-take zones within LMMAs are closed indefinitely (as opposed to permanently), where communities express the intention to harvest areas at some stage in the future if circumstances change (Govan 2009a). Intentions to someday open areas to harvesting, and the relatively small scale of tenure units are, in certain circumstances, barriers to effective implementation of permanent or larger closures (Foale and Manele 2004; Foale et al. 2011).

Periodically harvested closures

Periodically harvested closures are commonly implemented within LMMAs, and in some cases have been observed to be enthusiastically applied compared with other tools (Cohen et al. 2013; Léopold et al. 2013a), perhaps partly due to their historical origins (Johannes 1982). However, their application is highly variable and typically flexible. As a result, outcomes for enhancing fisheries sustainability, or progress towards biodiversity or ecological conservation and restoration objectives, is highly variable between cases (see review by Cohen and Foale 2013). Short-term elevated catch rates have been observed in periodically harvested closures due to increased abundance of invertebrates, in particular (Cohen and Alexander 2013; Tawake et al. 2001), and increased catchability of fish (Januchowski-Hartley et al. 2011).

In contemporary contexts, periodically harvested closures may play a role in maintaining traditional customs by helping to provide food and income for celebrations (Govan 2009a). One of the attractive features of periodically harvested closures is that loss of access to fishing areas is not permanent and benefits are realised from harvests when areas are opened (Cohen and Foale 2013; Foale 1998; Jupiter et al. 2012). During some opening events it has been observed that fishing effort is elevated and removal of biomass is relatively high, which in turn has led to substantial depletion of local stocks, suggesting that the long-term sustainability of fisheries may be compromised (Cohen et al. 2013; Jupiter et al. 2012). While in other cases, the relatively long periods of closure may result in a net reduction in fishing pressure applied to these areas, which facilitates sustained increases in abundance or biomass (Bartlett et al. 2009b; Cinner et al. 2005). Conservation benefits of periodically harvested closures have rarely been examined, but in one case where fishing was light and infrequent, no substantial benefits of periodically harvested closures were found on species richness, live coral cover and coral diversity (Cinner et al. 2005).

Species-specific restrictions

Application of species-specific size restrictions within LMMAs has met with mixed success. In Vanuatu, Léopold et al. (2013a) found very high levels of compliance with national minimum size limits for trochus but much lower levels of implementation of community-set size limits and other measures within LMMAs. This study suggested that local management and enforcement would need to be improved to promote long-term fisheries sustainability. Spatial or temporal restrictions that ban fishing of particular species during sensitive life history phases (e.g. spawning aggregations) have been shown to effectively maintain or enhance biomass and breeding stocks; for example, in Papua New Guinea, where a ten-fold increase in the density of the camouflage grouper was observed (Hamilton et al. 2011). Locally implemented bans on harvesting particular species have been reported (e.g. Cohen et al. 2013; Johannes 1998), but in many cases the outcomes have not been tested. The use of species-specific quotas is rare in Pacific community-based management (but see Léopold et al. 2013b and Nash et al. 1995 for examples of co-management where government has played a relatively strong role in guiding management), likely due to the high demand for data to appropriately set limits and a lack of capacity to monitor catches.

Gear restrictions

Within LMMAs, restrictions may be promoted to limit the use of destructive methods (e.g. the use of dynamite and fish poisons) or highly efficient gear (e.g. small-mesh nets, or torch lamps and spear-guns for night fishing) (Govan et al. 2008; Johannes 2002). Such measures are expected to improve fisheries sustainability by maintaining habitat structure, ecosystem function and breeding capacity (Fernandes et al. 2012). Assessments of gear restrictions from the Pacific are sparse, although studies from other tropical regions suggest locally implemented gear-based management can be effective for improving fisheries performance (e.g. Hicks and McClanahan 2012). Yet, as with species restrictions, issues with local enforcement and compliance with gear restrictions have been noted in Pacific LMMAs. Léopold et al. (2013a) found that while many communities in Vanuatu initially set gear-based restrictions when they established LMMAs, very few of these restrictions continued to be implemented (similar to findings of Cohen et al. 2013 in Solomon Islands).

Access restrictions

Restricting access is a common input control measure used to manage fisheries (King 2007), and can support the implementation of other concurrent management measures (World Bank 2000). Customary marine tenure provides the

principle mechanism in many Pacific Island countries by which to limit access to inshore fishing grounds (Johannes 2002; Macintyre and Foale 2007). However, implementing access restrictions in isolation to other tools "will not necessarily change the volume harvested, just who harvests it" (Polunin 1984). In this regard, it is also important to note that those who have been excluded may face increased hardship. Further, without concurrent management measures (such as effort restrictions), clarifying access rights may simply shift the distribution of effort and not address the root causes of resource decline. Where demand for local resources is high and use is intense, improving fisheries-supported livelihoods and food security, enhancing fisheries sustainability, or maintaining biomass will likely not be achieved through access restrictions alone.

Livelihood diversification strategies

To reduce fishing effort, or to offset costs associated with management, management partners sometimes promote livelihood diversification strategies alongside LMMA initiatives (O'Garra 2007). Deployment of fish aggregation devices (FADs) is a relatively common strategy that has a long history in the Pacific. In Solomon Islands, fishing at FADs led to increased catch per unit of effort due to enhanced catches of pelagic fish, and fishers perceived that effort on coastal (previously heavily fished) locations had decreased (Prange et al. 2009). However, very few documented examples demonstrate that alternative or supplemental livelihoods, even FADs, have led to more sustainable fisheries practices or improved ecological conditions (Gillett et al. 2008). Further, if hopes for improved income from livelihood diversification strategies are not fulfilled, resource management may stall or fail, and in certain instances conflict may arise due to inequitable distribution of benefits (e.g. Aswani and Weiant 2003; Niesten and Gjertsen 2010). Furthermore, while it is intuitively important to facilitate broader community developments alongside management efforts, there is concern that livelihood projects may create a culture and expectation of payment for participation in management (Foale 2001; Gillett et al. 2008).

Conclusions

LMMAs are widely recognised as a key strategy for managing small-scale fisheries in many Pacific Island contexts. Yet here we highlight that it is important to also recognise the diversity and multiplicity of objectives for which LMMAs may be implemented. The acceptance and proliferation of LMMAs across the Pacific can be attributed, at least in part, to the flexibility with which they can be implemented: the selection and application of management tools can be adapted to different contexts, and adjusted through time to account for social and ecological changes or as new knowledge emerges from experience. Nevertheless, the diversity of social and ecological contexts, and also the resultant form of LMMAs, means that providing best-practice guidance to optimise fisheries through LMMAs is challenging. The multiplicity of objectives for implementing LMMAs (Jupiter et al. 2014) means that trade-offs between objectives may occur, and that "success" can have multiple meanings. As a further complication, community objectives might not be made explicit to management partners, and may only emerge later during implementation. The longevity of any LMMA will ultimately depend on whether communities and other key stakeholders perceive that there is progress toward their objectives, and that the benefits of management outweigh the costs (Lal and Keen 2002).

Our review has also highlighted that, despite reports of hundreds to thousands of active LMMAs in the Pacific, most local management proceeds with little documentation or critical evaluation. As a result, there are relatively few empirical cases that: 1) describe how objectives and management tools are negotiated, 2) report on objectives being pursued, 3) describe the management tools ultimately employed, and 4) test outcomes towards fisheries sustainability or other objectives. Given that LMMAs are an important approach for improving small-scale fisheries management within the Pacific Islands region, improving the understanding of objectives, management measures, and outcomes are important areas for ongoing research and improved reporting.

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A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science[1]

Edward J. Hind[2]

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

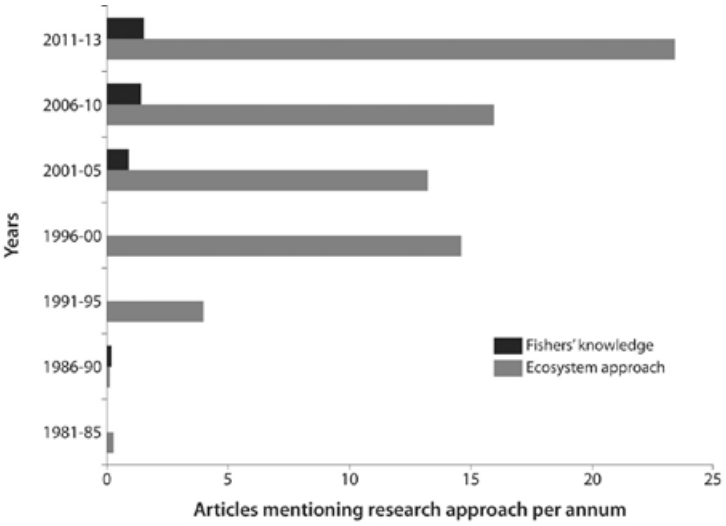

Figure 1. Change in publication rate of fishers' knowledge research and the ecosystem approach in the journals Fish and Fisheries, Fisheries Oceanography, and The ICES Journal of Marine Science. These are three of the top five (by impact factor) "fisheries" journals in the 2013 ISI Journal Citation Reports 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 Johannes1985; 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-E, 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-E 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-E, 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 if a scientists [. . .], 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 "decontexualized" 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

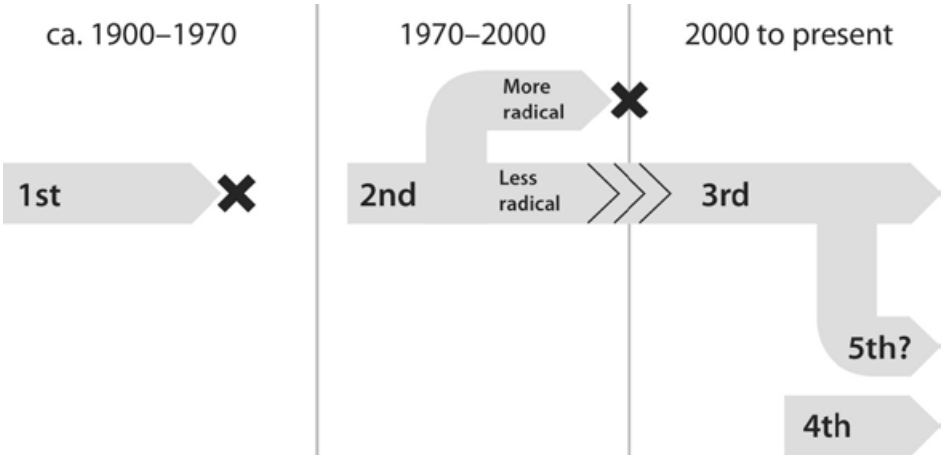

Figure 2. The progression of the five waves of fishers' knowledge research.

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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Tropical small-scale fisheries — some interwoven issues

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Introduction

Managing and working with tropical small-scale fisheries is complicated because even less is known about them than their temperate counterparts. The science-based models used for their management reflect this; in tropical regions management is conducted through almost direct application of models designed for temperate waters, and relatively few specific attempts have been made to address the so-called "fisheries problem" in the global South. Rather, fisheries scientists have generally simply extended standard fisheries science as developed in Western societies to embrace tropical fish stocks. The situation is reinforced by cultural, economic and political hegemony.

In Western societies, fisheries science and fisheries management have been intimately linked from the early 20th century. Their co-evolution has paralleled approximately the stages in the development of the world's fisheries resources, from "developing" (when management focused on identifying stocks and expanding production), through "mature" or "fully exploited" (when management focused on yield maximization), to "overexploited" (when sustainability was emphasised as a main goal of management). With the advent of the Code of Conduct for Responsible Fisheries (CCRF) (FAO 1995a), the term "sustainability" began to also include ecological sustainability and, to a far lesser extent, social sustainability. That was brought comprehensively front and centre in 2002, when the World Summit on Sustainable Development ordained an ecosystem approach to fisheries management.

Further, in Western societies, the development of resource management, including fisheries, has long been based on the assumption that relationships between society and nature can be managed rationally by a dedicated bureaucracy that reduces all issues to value-free technical problems scientifically resolvable to achieve specific objectives. Although such an approach underwrote the core of Western fisheries science and management for the last century, such rationality is undermined by the issues of social and cultural "values", and biological or economic "uncertainty". "Values" legitimise management by providing its basis within a given cultural and social context, something that cannot emerge from science-based management itself. Hence, for example, when the scientific basis for a given management decision conflicts with fishermen's cherished beliefs based on their own empirical knowledge, the former may become delegitimised in their eyes. Delegitimisation can also result when uncertainty undermines science-based management decisions. Uncertainty, an inherent problem in estimating and forecasting focused on natural sciences, is conventionally countered in Western resources science by using ever more data to refine measurements and elaborate models. This approach has morphed into "risk management", as exemplified in fisheries by the "precautionary principle" that underlies the CCRF (FAO 1995a), and associated stochastic models that seek to quantify it (e.g. FAO 1995b).

Even when attempts are made to adapt the main fisheries biology models to the realities of tropical situations, only the biological and general environmental factors are adapted, and not the social and cultural context of a given locality. The main aspects of the tropical small-scale fisheries context are not usually understood well — if at all — by many (and possibly most) Western fisheries and social scientists (Ruddle 2007; Ruddle and Hickey 2008; Ruddle and Satria 2010).

Selected problems and issues in tropical small-scale fisheries

1. Some sources of confusion with definitions

A major inconsistency is that the terms "artisanal", "inshore", "subsistence" and "traditional" fisheries are sometimes regarded as being either synonymous with, or as subsets of, "small-scale" fisheries (e.g. Berkes et al. 2001). Synonyms, as well as the term "small-scale fisheries", are widely used by policy makers and planners, and sprinkled liberally throughout the fisheries social science and scientific literature. However, a focused justification is rarely

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made for using a particular term. This is unfortunate because it assumes that small-scale fisheries are clearly bounded conceptually, which is manifestly not the case, and because the term and its various elements take on different characteristics depending on the fishery being described. Moreover, the term "small-scale fisheries" is a relative category, because what is small in scale in one place may be quite different elsewhere.

Moreover, terms other than "small-scale" generally have either a more specific meaning or more complex implications. For example, given its various meanings and nuances, the term "traditional" is particularly problematical in legislative and policy contexts. Above all, it conveys a sense of time, so that a phenomenon is "traditional" only if it has a demonstrably long history of both usage and intergenerational transmission. This temporal sense has frequently been extended, and "traditional" is often used to identify pre-modern cultures. This introduces confusion, because different societies apply different criteria to resource use activities and associated behaviours. Cultural behaviours and activities that are routine to members of a non-mainstream group are classified and viewed as "traditional" by the larger society. There is much confusion and conflation of the concept "traditional" with a fishery type, and usually with subsistence fishing, as Davis and Ruddle (2009) explain.

2. Unhelpful notions about commonality

Embedded in much of the Western fisheries management literature, and concisely expressed by McConney and Charles (2010:533), is the notion that there exists "...an important pattern of commonality amongst small-scale fisheries worldwide that may allow them to be distinguished from other scales of fishery". However, without a more thoroughly documented analysis and comparative study it is not immediately obvious that

> "... this pattern is important as it allows us to share experiences, lessons and policy or management interventions across diverse settings. Although small-scale fisheries are more deeply embedded in distinct socio-cultural conditions than are larger scale fisheries... there is *no reason to consider them so unique as to be intractable for governance and management*" (emphasis added) (McConney and Charles 2010:533).

Such a statement is facile, and not supported by *in situ* research.

Johnson (2006:748) observes that "...governance requires striving for clarity of the principles by which it is guided. Principles of the ethical and of the normative guidelines that define what is right, just, or should be done". All well and good, but on what and whose cultural and social perspective would these principles themselves be based? Johnson emphasises biodiversity, complexity and the local relevance of designing systems. These, of course, should be also guiding principles on which to base ethical and normative guidelines, not on some preconceived Western notions.

The Food and Agriculture Organization of the United Nations elaborated on ethics in fisheries, observing that:

> ... [a]s fisheries represent an interaction between humans and the aquatic ecosystem, fisheries ethics deals with the values, rules, duties and virtues of relevance to both human and ecosystem well-being, providing a critical normative analysis of the moral issues at stake in that sector of human activities. When actual moral values, rules and duties are subjected to ethical analysis, their relation to basic human interests shared by people, regardless of their cultural setting, is particularly important.... A more recent task of ethics is to resist those tendencies of globalization, marketization and technologization that erode both biodiversity and valuable aspects of cultural identity – and may even have effects that threaten human rights. Although these tendencies are often presented as value-neutral, they carry with them hidden assumptions that are potential sources of inequity and abuse (FAO 2005:3).

This brief statement conveys interesting potential contradictions. For example, the notion that "shared basic human interests, regardless of their cultural setting" jars when set against the call to "resist those tendencies of globalization, marketization and technologization that erode both biodiversity and valuable aspects of cultural identity". It would be well to remember that "[a]lthough these tendencies are often presented as value-neutral, they carry with them hidden assumptions that are potential sources of inequity and abuse" (FAO 2005:3).

A universal definition of small-scale fisheries and its subsets, like artisanal fisheries, is so full of exceptions that it is not desirable to develop one with global applicability. In contrast, agreeing on a narrow definition for specifically limited purposes is often desirable. In that process, the policy objectives of governments are of particular importance. These would include a central focus on poverty alleviation, food security, and resource development and management. Such closely related topics would

need to be key elements of definitions formulated for practical purposes.

Apart from either satisfying a bureaucratic sense of aesthetics, fulfilling the requirements of donor conditionalities, or both, it is not always immediately obvious why a generic definition should be deemed either necessary or practical. After all, small-scale fisheries were formed and developed in each locality or country, as humans accumulated knowhow and responded gradually to specific biological habitats, target species behaviour, and cultural, economic and social conditions. Rather than attempting to "straitjacket" small-scale fisheries into an administratively convenient, standardised definition, their diversity should be regarded as a great strength that provides practical models of likely value during present and future crises. Loss of this essential quality should be resisted with the same vigour as the loss of biodiversity, particularly because cultural heritages are now being deliberately extinguished by neoliberalism. Small-scale fisheries embody and represent much more than catching fish and making fishery products to be measured in biological and economic terms. Their multi-functionality represents alternative lifestyles in the coastal and inland aquatic areas that could undoubtedly provide valuable practical lessons (Ruddle and Satria 2010).

3. Marginality and marginalisation

Small-scale fisheries are (or are perceived to be) marginal in a number of ways, some of which are not readily apparent and, therefore, not usually considered in the literature. Despite the now familiar importance of small-scale fisheries, they continue to be a marginal topic for fisheries science and social science. For example, the economic, geographical, political, and social remoteness of small-scale fisheries from national decision-making centres is intensified by perceptions of remoteness. It is well known that in tropical coastal zones the hamlet and village landing points of small-scale fishers are widely dispersed geographically along isolated coastlines; despite decades of development, they remain marginal, isolated by a lack of physical access and infrastructure. Isolation is also heightened by a lack of alternative economic opportunities and employment, and by localised resource depletion. This may force people to migrate — either permanently or seasonally — in search of alternative employment, or to access fisheries that remain productive. But migrants are handicapped in finding jobs by being socially and economically remote, which often results from their being a member of a minority ethnic or social group and generally of low social status, with limited formal education. Elites, including decision-makers, have negative perceptions of these characteristics of small-scale fishers and their families, thereby reinforcing their already low social status.

Marginalisation is also reinforced at the political level by the commonly low status accorded to fisheries within national administrative structures. Apart from the major fishing nations and those archipelagic nations composed mostly of atolls, such as Kiribati or the Maldives, where fish are the principal natural resource and terrestrial resources are extremely limited, in most countries fisheries departments are relatively small, recently established entities, reflecting the comparative lack of importance associated with fisheries in national economies (Marriott 1990). Further, because they generally lack political clout, their interests are usually subordinated to those of other economic sectors. Thus, fisheries departments are commonly linked with agricultural, forestry and other natural resources within a single ministry. Little has changed since the observation in the 1980s by Everett (1983) of the low overall status of most national fisheries departments, where administration is often not of a high standard, staff morale is low, and turnover rates relatively high. Further, fisheries departments do not generally attract the ablest recruits to administration, whose career aspirations are better served in more important ministries. Fisheries marginalisation is reinforced by the marginalisation of the science and scientists studying them, and fisheries are not generally perceived of as a prestigious field by and for the elite.

4. Issues with data

In general, small-scale fisheries are characterised by data problems, such that precise and reliable quantitative data are lacking (FAO 2010; Kato 2003). This is partly because the collection of reliable statistics is physically and logistically difficult in most countries, where catches are unloaded at a myriad of points scattered along vast, remote coastlines. Geographical remoteness is a principal reason for the absence of comprehensive fisheries statistical systems in many countries (Saila 1988; Johannes 1998; King and Lambeth 2000; FAO 2002; Lunn and Dearden 2006). This, of course, precludes conventional Western fisheries management, based on standard data-demanding criteria. Further, because many small-scale fishers both sell their products locally and consume their catches in their own households, their landings are usually under-represented in statistics (Seilert and Sangchan 2001). The result is that in developing countries, and consequently in FAO and other global estimates, official statistics, national accounts, and economic development initiatives generally focus on commercial, often export-oriented fisheries, which are commonly perceived to be the major economic contribution of fisheries. For example, a study of

American Samoa and the Commonwealth of the Northern Mariana Islands by Zeller and colleagues (2007) found that the contributions of small-scale fisheries to gross domestic product may have been underestimated by more than five-fold.

Further, fisheries administrations often lack a clear objective for collecting conventional statistics. They formerly focused on production data, mainly for recording purposes, but have not recognised that an appropriate statistical system is necessary for aspects of conventional fisheries management, such as entry control and policy-making (Kato 2003). Especially troublesome is the reporting of species composition — increasing quantities of a category termed "not elsewhere included" amounted to 30% of capture production in the Asia-Pacific region in 2008. This may reflect the increasing capture of smaller species, including low-value and so-called "trash" species, and of juveniles of higher-value species, which together are regarded as not worth detailed reporting. On the other hand, it could represent a general decline in the quality of catch landing data. An additional problem is that in Southeast Asia reported increases in landings may mask a serial depletion of large demersal and pelagic species, as well as sharks and rays, and a simultaneous increased harvest of faster recruiting species from a lower trophic level. Interpretation is hampered by poor and highly imprecise landing data by area, as well as by a lack of determination of the status of specific marine stocks (FAO 2010).

A further source of incompleteness is that statistical data on economically important and major employment-generating components of the production system are invariably lacking for small-scale fisheries. These include data on upstream industries for inputs such as boats, gear, and fishing trip supplies, as well as downstream post-harvest components, such as processing, distribution and marketing of marine resources. Although occasionally some of the upstream inputs might be gleaned from censuses of manufacturing industries, data on downstream activities are usually harder to come by. Often this is because they are performed frequently as part-time or seasonal activities, and usually by women or dependent children of fishers' families; therefore, they would not generally be captured where censuses or other routine data collection categorises individuals only by primary or full-time occupation.

Another huge source of data collection and management problems in tropical developing countries is the fragmentation and lack of coordination among the many agencies responsible for different aspects of the fishing and related industries and administrative sectors. One result is that roles and responsibilities are unclear, with officials in one branch of administration unaware of what their counterparts elsewhere are doing (WWF 2008).

For example, the administration of capture fisheries in Vietnam is complex and fragmented among government departments. Decentralisation has been limited. The Ministry of Agriculture and Rural Development (MARD) is responsible for national fisheries governance. Within it, the Department of Capture Fisheries and Resources Protection (DECAFIREP) handles resources management, including control and monitoring, and fishing boat registration. The Department of Science, Technology and Environment collaborates with DECAFIREP. In principle, the Informatics Centre for Agriculture and Rural Development services the information needs of MARD decision-makers. Under MARD, the Research Institute for Marine Fisheries (RIMF) performs marine resources assessment, fishing ground identification and related tasks. The Vietnam Institute of Fisheries Economics and Planning (VIFEP) advises MARD on fisheries policy, planning and general development. The Department of Agriculture, Forestry, Fisheries, Salt Processing and Trade administers seafood processing and export, while the National Agro-forestry and Fisheries Quality Assurance Department (NAFIQAVED) handles quality control, seafood inspection and food safety. The Department of Seas and Islands, of the Ministry of Environment and Natural Resources (MONRE), is responsible for governance of the marine environment, policy making and planning for integrated costal zone management. At the provincial level, the Department of Agriculture and Rural Development (DARD) replicates the national functions of MARD.

Management of the seafood trade is even more complicated. Nationally, the Ministry of Commerce and Industry (MOIT) is responsible for all trade management. However, as the sector management agency under MARD, the newly formed Department of Agriculture, Forestry and Fisheries Processing and Trade focuses on State management of seafood trade and processing. NAFIQAVED is responsible for food safety issues, whereas data on imports and exports is managed by the Customs Office. WTO matters are handled by the Department of Commerce and Industry Policies for Multiple Boundaries, under MOIT. However, the non-profit civil societies VCCI and VASEP play a strong role in the seafood trade. Although it is becoming of urgent concern, no central government organisation actively engages in eco-labelling for capture fisheries, although NAFIQAVED undertakes seafood safety and hygiene certification. At the national level, the Vietnam Association of Seafood Exporters and Processors (VASEP) plays a major role in seafood export and processing. Also, the Vietnam Chambers for Commerce

and Industry (VCCI) is a professional organisation responsible for the private sector-related to trade and industry in general, including seafood enterprises. However, VASEP and VCCI focus more on processing and exporting companies, rather than on small-scale marine resource harvesters. Also, relations between VASEP and the Vietnam National Association of Fisheries (VINAFISH) are limited in terms of linking fishermen to processing plants. Controlled by MARD, DECAFIREP is the central agency responsible for capture fisheries management. Other institutions under MARD have joint management with DECAFIREP in related issues. For example, seafood safety is controlled by NAFIQAVED, and seafood processing and trade is under the Directorate of Trade and Processing for Agriculture, Forestry, Fisheries and Salt (DAFFS). However, cooperation and communication is limited among DECAFIREP, VASEP and VINAFIS regarding resources management, fisheries production and processing, and exports. VINAFISH is relatively weak in resource management, and VASEP is focused only on processing and export. At the provincial level DECAFIREP is responsible for fisheries management, and, as a local fisheries management institution at the field level, it collaborates with the Coast Guard and Marine Police to control illegal fishing and foreign vessels operating in territorial waters. Under the Provincial People's Committee, the Department of Industry and Trade (DOIT) is responsible for trade and industry management at the provincial level. However, no organisation at DARD focuses on seafood trade. Only VCCI and VASEP have branches in the ecological-economic regions (e.g. the Mekong), but not at the provincial level. Also, the Small-Medium Enterprises Association has many seafood companies as members. Depending on the province, cooperation among those institutions related to trade and processing at the central and local levels is limited and informal. This is but one example of administrative complexity, redundancies and management system confusion evident throughout the tropics.

5. The "greening" of small-scale fisheries

The wholesale depletion of many of the world's major fisheries is almost always ascribed to industrialised fleets. As a consequence, in Senegal, India and the Philippines, for example, small-scale fisheries have changed from being protected by legislation to being promoted by both national and provincial governments at the expense of industrial fisheries. This occurred partly from a sense that small-scale fisheries provide more economic, social and ecological benefits than do large-scale, industrial fisheries, and partly in acknowledgement of the failure of an earlier model based on investment in the latter (Tvedten and Hersoug 1992). This perception is shared by donors, aid agencies, and diverse advocates of "green fisheries". Policies for the two fisheries sectors are sometimes linked, as in Southeast Asia, where the promotion of offshore fishing is common, the principal linked motives being a transfer of effort out of overexploited inshore areas to improve conditions for fishers working them, and the realisation of the potential of supposedly underexploited offshore areas. However, the limited data available give no reason for optimism regarding the benefits of such a policy (FAO 2010).

Although small-scale fisheries are generally regarded as being "greener" than the industrial subsector, they often threaten their own sustainability. For example, they are often associated with highly destructive fishing techniques, particularly poisoning and "bombing", especially in Indonesia (Satria and Adhuri 2010) and the Philippines (Pauly et al. 1989). In Indonesia, more than half the coral reefs are estimated to have been damaged by destructive fishing, including blast fishing. In the Spermonde Archipelago of South Sulawesi, for example, more than 75% of small-scale fishers use blast fishing with "bombs" made from diesel fuel mixed with ammonium nitrate fertiliser. Motivated to increase income to "modernise" their lifestyle in a situation where alternative income sources are not available, a high global demand for fish encourages fishermen to take shortcuts to raise income from fishing, despite being aware of the long-term negative impact of destructive and unsustainable techniques (Chozin 2008).

A key argument found in the social science and human ecological literature on small-scale fisheries is their ecological sustainability, and particularly the contrast they may provide to industrial fisheries, when embedded within pre-existing management systems. The implication that small-scale fisheries have something to teach us is not valid universally, and needs case-by-case verification. This aspect of valuable lessons was embedded in the CCRF. Although small-scale fisheries receive but scant mention in the CCRF, it emphasises their role in employment, food security, livelihood importance, fisheries conservation, management, and development (FAO 1995a:7 and 1995a:33). This may be true at a global comparative level, but each fishery needs to be investigated at the local level to verify those assertions. In particular, social relationships are sometimes far from being fair and just, although often they are automatically perceived to be just (Ruddle 2011). Despite a wealth of literature beginning in the 1970s extolling the virtues of local management systems and access restrictions, it should be noted that not all of these function well, and that many are instituted to reduce conflict, among other desired outcomes (Polunin 1984; Ruddle and Satria 2010), rather than to manage resources.

It is generally assumed that the catch of an individual small-scale fishing unit is much less than that of a large-scale commercial counterpart. Although precise data on the number of small-scale fishers is lacking, FAO estimated that there are some 34 million worldwide.[2] Assuming that one small-scale fisher catches a tonne of fish per year, fish production by small-scale fishers as a whole could be on the order of 34 million tonnes, or about 40% of the global catch. One small-scale fisher catching 10 kg per day for 100 days per year has a total annual catch of 1 tonne. From that, it can be estimated that globally, small-scale fishers produce 34 million tonnes of fish per year, or 38% of total fisheries global production. That is not negligible (Kato 2004).

Kato (2004) provided a straightforward model of the relationship between incomes and operating costs changing in line with the level of resource exploitation, for both industrial and small-scale fisheries. The operational costs for commercial fisheries increase with travel to distant fishing grounds, which extends their operating time and investment in gear or equipment required to increase or maintain their catch, especially when resources are declining. Despite such efforts, their long-term operations will no longer be financially viable when the resource condition deteriorates. At that point, industrial fishers will cease operating — "profitability" thus functions as a built-in management and self-regulating mechanism. However, such a self-regulatory management mechanism is less obvious in small-scale fisheries. Because their operating costs are much lower than those of industrial fishers, small-scale fishers can continue to operate at resource levels where industrial fisheries could not make a profit. By continuing operations in such circumstances, they would have a more negative impact on coastal resources than industrial fisheries, with the latter's effort reduced or abandoned owing to unprofitability. When incomes cannot meet needs, small-scale fishers resort to using destructive fishing gear such as fine-mesh nets (even mosquito nets), blast fishing and poisoning. Undertaken in areas normally worked by small-scale fishers, which include inshore spawning and nursery grounds for commercially important species, unregulated small-scale fishing can destroy both coastal resources and those on which industrial offshore fisheries depend.

A tabulated dichotomy between the attributes of large-scale industrial fisheries and those of small-scale fisheries is a widely used device that attempts to show the relative global advantages of small-scale fisheries, in terms of their relative economic efficiency, ecological sustainability, and their support of much greater populations for less resources per capita than other fisheries (Smith 1979; Berkes et al. 2001; Charles 2001; Thomson 1980; Johnson 2006; Pauly 2006). As rhetorical devices, "... the tables are strikingly effective [but] it is impossible to know whether they are anything more than just rhetorical devices for the value of small-scale fisheries" (Johnson 2006:753). A conceptual difficulty in this approach is that the compilers of these tables do not define the boundaries between the categories of small- and large-scale fisheries. Also, with the exception of Pauly (2006), they fail to mention either the data sources for the tables, or the data gathering methodologies. These are serious flaws in light of the diversity, complexity and dynamism of both small- and large-scale fisheries. This contrasts markedly to the uniform neoliberal perspective and incessant drive towards individual-based, industrial fisheries, which impose the regulatory outcomes of market-imposed discipline on harvesting intensities and practices.

These rhetorical tables, therefore, present a valiant alternative image. Provided that users do not fall prey to unsubstantiated romanticism and the false perception of homogeneity, it is well demonstrated that small-scale fisheries provide a very valuable example of a realistic alternative approach in a time of massive and variegated change. At the global level, promotion of small-scale fisheries is largely an activity of political advocacy, which is important in challenging the prevailing approaches of modernisation, neo-colonialism and neoliberalism. However, such rhetorical tables are of no practical value at the local level, which requires full appreciation of diversity, complexity and dynamics.

Beyond that, because the only worldwide generic characteristic of small-scale fisheries is that they are not industrial in scale, tables based on such a dichotomy are neither useful or substantive, because all that such listings of attributes do is demonstrate how large-scale and small-scale fisheries are dissimilar. In fact, "the examination of small-scale fisheries as a category reveals that they can only be identified in relational terms, which creates a constant impression of elusiveness and categorical imprecision" (Johnson 2006:751). The basic conceptual problems are that the criteria for and importance of the selected characteristics are neither explained nor ranked in terms of importance. Further, varying characteristics would be required for different purposes. Also, the romantic yet delusional notion that small-scale fisheries are ecologically sustainable, socially just, or both, obscures that as a category, small-scale fisheries exhibit highly diverse social and ecological impacts. Their usefulness is

[2] It was estimated roughly by FAO that the total number of people involved in fisheries is 38 million, and that 90% of these (34 million) are small-scale fishers, of whom 90% are from Asia (31 million) (Kato 2004).

diminished because the compilers have conflated tropical and extra-tropical fisheries. In fact, "tropical" makes little sense as a (sub)category because every tropical region is different, based on biological, physical, and particularly historical and sociocultural aspects of resource use. Depending on the use to which such an array of characteristics is intended, at a minimum Southeast Asia, South Asia, Pacific Islands, Africa, Latin America, and Caribbean regions need to be distinguished. However, even these regional categories are too coarse to be meaningful for practical uses.

6. Hegemonism and its impact

An underlying cause of problems facing small-scale fisheries in tropical countries is the hegemonic behaviour of the core nations of the "global North". Hegemonism is manifestly at work when the approaches to the administration and management of fisheries applied in Western countries are advocated for use in the vastly different and highly varied ecological, cultural, social, and economic conditions of the tropical world, where, in contrast, there are many examples of pre-existing systems that have long worked well. Either directly through development assistance, or indirectly through international organisations or increasingly through commercial means, Western nations continue to promote Western systems while denying the usefulness of proven non-Western systems. The reasons that could underlie and account for such a situation need to be uncovered. Nor is it unreasonable to advocate an end to that approach, and seek to replace Western approaches with pre-existing, non-Western systems that are updated to address modern conditions.

During the colonial era, non-Western models were openly disparaged, whereas now they are commonly dismissively labelled as "traditional" or "special" cases. During the 1950s and 1960s, a massive and experimental packaged transfer of social, economic, financial, educational, and legal systems (that were often predicated on misguided theories), together with their underlying cultural values and aspirations regarded pre-existing economies, management systems, and often social and cultural systems as obstacles to modernisation (Ruddle and Satria 2010). Modernisation provided the justification for the foreign designers of fisheries management schemes to claim that pre-existing systems were primitive, unsustainable or often "non-existent". This was reinforced by a general ignorance of the tropics and prejudice on the part of scientists and educators, whose careers were enhanced by work in temperate regions.

In addition to the erroneous assumption that tropical fisheries are "open access" and not managed by pre-existing systems, and therefore, require externally imposed management systems to protect resources from collapse and lift fishing communities out of poverty, the Western approach to fisheries "development" and management also fails to recognise that (Ruddle and Satria 2010):

1) pre-existing systems are as much, if not more, concerned with the community of fishers and their families, not just fisheries, and their principal role is ensuring community harmony and continuity;

2) pre-existing systems can involve multiple and overlapping rights that are flexible and adapted to changing needs and circumstances (Khumsri et al. 2008);

3) fisheries are just one component of a community resource assemblage, with fisheries managed in their ecological context — dependent on the good management of linked upstream ecosystems, and risk management — thereby maintaining the balance of the community's nutritional resources; and

4) pre-existing systems are greatly affected by interacting external pressures for change. If these cultural, ecological, economic, political and social context factors are not appreciated, any "imposed management system" would likely fail from the outset to achieve its goals.

That is exacerbated because Western fisheries biologists and social scientists often fail to appreciate differences between temperate-zone industrial fisheries, which are familiar from their own training and research, and tropical small-scale fisheries. Their interpretations are passed on to donors and international assistance personnel. Further, there is an extremely negative connotation to the term "tropics" among fisheries scientists based in temperate latitudes (Pauly 1994). For example, it is not widely appreciated that in tropical small-scale fisheries harvesting is limited mainly to nearshore areas and local resources that are defined socially. Such geographical and social territoriality is widespread, which, in addition to its positive aspects in terms of resource management, limits the mobility of small-scale fishers geographically and socially, and prevents access to fishing communities by outsiders. It is also not commonly appreciated that tropical nearshore fisheries are biologically and technically complex compared with those in temperate areas, and are typically far more varied in terms of catch composition or areas fished and gear types employed. Hence, they have a complexity that is unfamiliar to temperate region scientists and planners, who typically deal with single-species fisheries. As in small-scale fishing regions in temperate countries, employment options in the tropics are limited and alternative jobs scarce at best. It needs to be more widely appreciated that

these factors combine to create market imperfections such that tropical small-scale fishers may receive less than the free-market price for their catch, yet pay excessively for inputs and usuriously for loans. These are the principal ways in which rents are extracted. They are also extracted by the requirement to share catches in small, customary communities and among kin, as well as by other customary practises, such as ritual performance and donation (Ruddle 2007; Ruddle and Hickey 2008; Ruddle and Satria 2010).

Concluding remarks

There is a general agreement that tropical small-scale fishing societies are marginalised by their position in the economic, political and administrative structure of most nations. There is also general agreement that the data on all aspects of small-scale tropical fisheries are incomplete, imprecise and unreliable, and therefore, of little or no value in any Western scientific approach to fisheries management. Nevertheless, there has been no shortage of unsubstantiated and misplaced optimism, as exemplified by the "greening" of small-scale fisheries, when contrasted with industrial fisheries. Such romanticism is unhelpful.

Similarly, based in large part on the repetition of unsubstantiated assertions that small-scale fishers in the tropics are among the poorest of the poor, since the mid-1990s a focus on poverty and vulnerability has emerged. Apart from clearly having advanced certain academic careers and imbuing "development practitioners" with a sense of doing something particularly humane and worthwhile, there is little evidence that the poverty focus has achieved any concrete results. To achieve such results, it is necessary to document and account for a political economic context wherein small-scale marine harvesters are subject to exploitation and structured inequities that deny them, their families and communities a fair share of economic values.

Confused thinking and conflicted approaches characterise Western dealings with small-scale fisheries. The advocates are in full-cry, but precisely over what has so far defied consensus. Quite likely the situation is grounded in confused and contradictory Western approaches to and models for fisheries development. Far more systematic and controlled comparative research is needed to assemble the evidence required to value and document the diversity of small-scale fisheries as a means of addressing these deficiencies.

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