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PROFILE

Crossing Science–Policy–Societal Boundaries to Reduce Scientific and Institutional Uncertainty in Small-Scale Fisheries

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Abstract The governance of small-scale fisheries (SSF) is challenging due to the uncertainty, complexity, and interconnectedness of social, political, ecological, and economical processes. Conventional SSF management has focused on a centralized and top-down approach. A major criticism of conventional management is the over-reliance on 'expert science' to guide decision-making and poor consideration of fishers' contextually rich knowledge. That is thought to exacerbate the already low governance potential of SSF. Integrating scientific knowledge with fishers' knowledge is increasingly popular and is often assumed to help reduce levels of biophysical and institutional uncertainties. Many projects aimed at encouraging knowledge integration have, however, been unsuccessful. Our objective in this research was to assess factors that influence knowledge integration and the uptake of integrated knowledge into policy-making. We report results from 54 semi-structured interviews with SSF researchers and practitioners from around the globe. Our analysis is framed in terms of scientific credibility, societal legitimacy, and policy saliency, and we discuss cases that have been partially or fully successful in reducing uncertainty via push-and-pull-oriented boundary crossing initiatives. Our findings suggest that two important factors affect the science–policy–societal boundary: a lack of consensus among stakeholders about what constitutes credible knowledge and institutional uncertainty resulting from shifting policies and leadership change. A lack of training for scientific leaders and an apparent 'shelf-life' for community organizations highlight the importance of ongoing institutional support for knowledge integration projects. Institutional support may be enhanced through such investments, such as capacity building and specialized platforms for knowledge integration.

Keywords Small-scale fisheries · Institutional uncertainty · Leadership · Scientific knowledge · Fishers' knowledge

Introduction

The governance of social–ecological systems (SES), such as small-scale fisheries (SSFs), is challenging due to the complexity and interconnectivity of social, ecological, political, and economic processes (Mahon et al. 2008). SSFs are assumed to have relatively low governability potential because of these complexities (Jentoft and Bavinck 2014) as management decisions are frequently made under conditions of uncertainty and unpredictability (Dewulf et al. 2005). Understanding these complexities is crucial due to the contribution of SSFs to local livelihoods and culture (Chuenpagdee et al. 2005), and for the role, they play in poverty alleviation and food security globally (Allison and Ellis 2001; Barnes-Mauthe et al. 2013; Garcia and Rosenberg 2010).

Conventional SSF management approaches are most often based on a top-down management model with centralized decision-making. A key criticism of these approaches is the positioning and dominance of science as the only important constituent of credible knowledge in the management process. In the conventional management context, an overly narrow use of scientific modeling

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outputs (e.g., MSY-oriented production models) has implicitly treated fisheries as relatively predictable and controllable (Mahon et al. 2008). Most conventional models have a biological focus (Kolding and van Zwieten 2011) but neglect key sources of uncertainty arising in ecological systems (Folke et al. 2005) and from the social, economic, cultural, and institutional contextual factors that influence SSF outcomes (Castrejón and Charles 2013; Garcia and Charles 2007). The detachment of science from local ecological and social realities has consequently exacerbated the low governability potential of SSF.

There is much evidence of the substantive benefits arising from the integration of fishers' knowledge and mainstream scientific knowledge. Including fisher's knowledge into management decision-making processes is thought to improve the quality and quantity of scientific observations (Johnson and van Densen 2007), provide new insights, information and knowledge (Edelenbos et al. 2011), and increase fishers trust in decision-making (Kaplan and McCay 2004). Uncertainty regarding the ecological and social dynamics affecting SSF management can, therefore, be reduced. However, fishers' knowledge still plays a very limited role in SSF management (Johnson 2010; Johnson and van Densen 2007; Kaplan and McCay 2004). The poor integration of fishers' and scientific knowledge has been attributed to intellectual and methodological differences among scientists (Simon and Schiemer 2015; Rudd 2015), a lack of consensus regarding what constitutes credible scientific knowledge (Hind 2012; Johannes et al. 2000), communication barriers (Dentoni and Klerkx 2015), and institutional and cultural differences between fishers and scientists (Johnson 2010).

Many organizations worldwide are thus increasingly advocating for a broadening of conventional management paradigms. Over the past three decades, there has been a noticeable increase in popularity of more community-based, participative, and bottom-up approaches to fishery management (Chuenpagdee et al. 2005; Cinner et al. 2012; Jentoft 1989). An important aspect of these approaches is the recognition of different knowledge types; bottom-up approaches theoretically facilitate ready integration of local fishers' knowledge into management decision-making processes. Successful knowledge integration often, however, requires a shift in how social actors value different knowledge types and an identification of the barriers that restrict the integration of fishers' knowledge (Soto 2006).

Leadership is crucial to SSF management (Gutierrez et al. 2011; Sutton and Rudd 2014, 2015, 2016). Successful leaders are able to instigate and catalyze management activities (Folke et al. 2005), ensure stability and accountability in times of change (Njaya 2007), and establish communication channels to external actors (Bodin and Crona 2008). As Jentoft (2004) recognized, although "knowledge is power," the presence of rich fishers' knowledge does not necessarily ensure effective paradigm broadening and knowledge integration. Therefore, local leaders, who have the power to make fishers' knowledge 'heard,' have a potentially pivotal role in knowledge integration projects.

Given the ecological and social importance of achieving SSF sustainability in coastal and inland fisheries, it is important to consider how fishers' and scientific knowledge can be more successfully integrated and incorporated into decision-making. In this paper, we report results from 54 semi-structured interviews with SSF researchers and practitioners from around the globe. Our objective was to increase understanding of the factors that influence knowledge integration in SSF management and the uptake of that knowledge into policy-making. We frame our analysis in terms of scientific credibility, societal legitimacy, and policy salience (Cash et al. 2003). Credibility is usually defined in terms of peer-approved methods of evidence production and claims to scientific objectivity, while legitimacy is shaped by perceptions of fairness, appropriateness, and acceptance by multiple audiences, and salience depends on the perceived relevance of evidence to the problems being addressed by societal interventions and discourse. Our focus is on how various participants associated with diverse SSF fisheries have been partially or fully successful in reducing biophysical and institutional uncertainty via push- and pull-oriented boundary crossing initiatives. While our main focus in the broader scope of our project was on leadership, here, we examine both the roles of individual leaders in, and more general issues surrounding, knowledge acquisition and use in the SSF context. This paper helps frame issues regarding the role of evidence and institutional design, and suggests possible solutions that contribute to alleviating the challenges arising from low SSF governability.

Methodology

Theoretical Approach

SSFs typically involve relationships between physical, ecological, and human systems, multi-scale feedback mechanisms, and substantial levels of uncertainty of different types (Berkes et al. 2001; Ostrom 2009; Sutton and Rudd 2015). Uncertainty about social and ecological systems can be reduced by formal scientific investigation and by the use of more informal local knowledge applied in specific contexts. Both can help increase our knowledge about how SESs function and the possible ways in which changes in human behavior or governance interventions might affect the system, thereby reducing uncertainty

regarding the outcomes of different types of human activity and management actions. In addition, there can be uncertainty about the actual goal of management actions; value-based disagreements can remain even when knowledge about social–ecological dynamics is relatively high (e.g., ongoing political controversy regarding the climate change 'debate' despite a tremendous body of scientific knowledge about the challenge).

One way to conceptualize the problem structuring and knowledge generation challenge is with a 2 × 2 matrix that considers, on the one hand, clarity regarding the nature of the policy challenge and, on the other hand, the level of knowledge about the problem (Hisschemöller and Hoppe 1995; Hoppe 2009; Rudd 2011). When clarity regarding the relevant policy questions and scientific understanding of the natural and human components of the system are both low, problems are unstructured (i.e., they can be viewed as belonging in a domain of uncertainty). If policy challenges are clear but scientific knowledge is still low, moderately structured problems are in a realm of evidence, where science aligned with problems of importance for policy and society can be directed toward key unknowns in the socio-environmental systems. On the other hand, if knowledge increases but policy challenges remain poorly articulated, unaligned research moves into another moderately structured quadrant, a domain of partisanship, where evidence is used strategically to advance policy solutions aligned with particular values and politics. Only when there is both clarity regarding important policy questions and high levels of knowledge are we dealing with well-structured problems for which we craft institutions, interventions, and investments in a domain of best practices. There are two main pathways, however, to reach that domain of best practices, either via knowledge-building and value-based contestation, or via policy problem articulation and subsequent knowledge-building activities aligned with policy needs.

The 2 × 2 clarity–knowledge matrix does not, however, directly incorporate factors relating to societal relevance, which will also affect the feasibility of developing transformative, evidence-based solutions for complex environmental challenges. We believe that it is also advantageous to incorporate a third element, societal legitimacy (Cash et al. 2003), to help frame how different approaches can be used for crossing boundaries between SSF stakeholders, policy-makers, and scientists. Adding a third factor increases the number of boundaries to consider between domains relative to the 2 × 2 matrix, but we believe that this is a worthwhile trade-off, because it helps in the categorization and organization of effective SSF boundary-crossing initiatives and suggests specific hypotheses for future research.

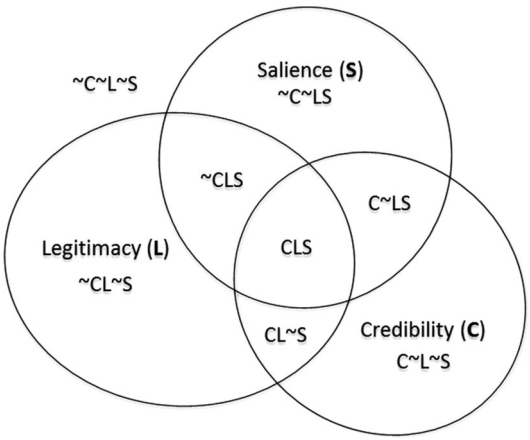

Fig. 1 Venn diagram illustrating overlaps between policy salience (S), societal legitimacy (L), and scientific credibility (C) (∼ denotes not a member of the set)

Following Rudd et al. (2014), Fig. 1 shows a Venn diagram that represents, in set theoretic fashion, the three factors that we consider essential for successful, sustainable SSF fisheries: societal legitimacy; policy salience; and scientific credibility (which we, henceforth, refer to simply as legitimacy, salience, and credibility in our figures and tables). Our core contention is that to be successful and sustainable, SSF governance must be legitimate, salient, and credible (the overlap at the core of the diagram). We also note that issues must first arise in one of the domains to become relevant to anyone (i.e., issues must arise either through scientific inquiry [e.g., 'blue skies' research], emergent policy salience [e.g., horizon scanning processes], or societal legitimacy [e.g., activism]).

The borders between the domains indicate which boundaries exist and need to be crossed to reach transformative and sustainable governance solutions (i.e., set CLS), those that are policy salient, socially legitimate, and scientifically credible. The most pressing environmental challenges typically involve complex feedbacks between coupled physical, ecological, and human systems (Liu et al. 2007), and are in need of transformative solutions that span geographical and temporal scales, involve collaborations among researchers from different disciplines, and between those scientists and others from governments, donors and funders, civil society, and the private sector (Hackmann et al. 2014; Weaver et al. 2014).

Each boundary can be fuzzy: the boundary between scientific credibility and societal legitimacy (the red boundary in Fig. 2) is particularly important in SSFs as it represents the active debate over what knowledge is viewed as scientifically credible compared with knowledge relegated to the realm of 'pseudoscience' (set ∼CLS). The boundary crossing process can be initiated by either a push or pull mechanism. In the case of the science–society

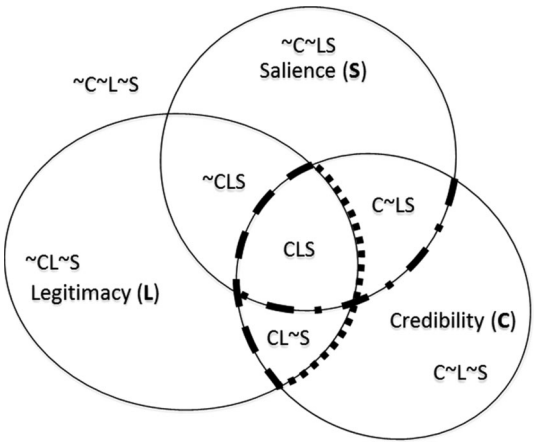

Fig. 2 Boundaries between scientific credibility and societal legitimacy (*dash*), policy salience and scientific credibility (*dot*), and societal legitimacy and scientific credibility (*dash-dot*)

boundary, for example, scientists can pull to engage societal stakeholders (e.g., through public awareness building, etc.), creating societal legitimacy for existing scientific endeavors (i.e., a science pull process to draw the set L closer and increase the overlap with C). Alternatively, they can push to extend the depth and breadth of their scientific activities to expand the scope of societally legitimate knowledge building (e.g., emerging research fields, such as environmental justice).

Similarly, one could consider the boundary between credible science and policy salience (the green boundary in Fig. 2), exploring how different boundary-crossing processed involved a push (e.g., policies that increased scope for evidence-based decision-making) or pull (e.g., shaping scientific focus by increasing funding for certain topics) by policy-makers or a push (e.g., conducting science more closely aligned with policy needs) or pull (e.g., stimulating demand for science by communicating possibilities for technical or governance innovation) by scientists. A third boundary, which involves societal engagement with science (i.e., pulling science into societally relevant research topics or expanding the types of issues that scientists feel fall within the bounds of science), is outlined in an orange boundary in Fig. 2. It is beyond the scope of this paper to categorize each boundary push and pull process; for now, we simply note that boundaries exist, they can be fuzzy or disputed, they can potentially be broached via either push or pull mechanisms, and that there are different pathways by which sustainable SSF governance can be achieved. In the material that follows, we introduce and discuss boundaries of particular relevance for our SSF case studies; we refer to boundary crossing in terms that indicates the initial realm, the boundary being crossed, and the direction of the push or pull.

Empirical Implementation

Interview Questions

To conduct our analysis on boundary arrangements and knowledge integration in SSF, we required detailed information from particular case studies. Given the diverse contexts within SSFs are undertaken, our strategy was to conduct semi-structured interviews that offered individuals intimately familiar with particular SSFs the opportunity to explore and develop issues they perceived as important (Longhurst 2010). The development of interview questions was theoretically guided and designed to facilitate the identification of factors that influence SSF leadership (the primary focus of the larger project within which this paper is situated—Sutton and Rudd 2015, 2016). Our list of questions to guide the conversation in semi-structured interviews included:

- How do individuals come to be community leaders?
- Why do people get involved with leadership roles?
- Are potential leaders prepared for leadership roles?
- Do individuals receive external assistance to enhance their leadership capacity and meet their responsibilities as a leader?
- Do you think there will be any challenges to leadership going on into the future?

Within this context, the issues that we examine in this paper—largely surrounding the credibility of knowledge and institutional uncertainty—were emergent themes that arose among many of our interviewees.

Sampling and Implementation

Case studies were selected systematically to ensure that we covered as broad range of possible case study configurations as possible and diversity in opinions from individuals with diverse experiences and expertise. We organized our sampling strategy around four contextual variables that have been important historically in SSF success: development status of the country where the fishery was located (we used the Human Development Index [HDI] as an indicator); whether fishers regularly participated in fisheries management at the local level; fishery complexity (for clarity, defined as single-species versus mixed-species fisheries); and management arrangement (i.e., how established SSF management was within the broader governance context—less than 10 years old indicates the system is relatively new and more than 10 years old indicates the system is relatively established). With these 4 variables, 16 different 'ideal' socio-ecological contexts were possible. We aimed to include at least one case study from each of those possible combinations.

Initial contact with potential interview respondents was made via email to ascertain their willingness to participate in semi-structured interviews and, for those who assented, arrange interview times. To be involved in this research, the individual had to either be a researcher of, or practitioner within, a focused SSF. AS such, our respondents included an even spread of academic researchers, government scientists, representatives from NGOs and leaders in community-based organizations. Interviews were conducted by Skype or Google Hangouts. Once as many combinations from the 16 case types were covered in at least one interview, we conducted interviews opportunistically across case types until we reached our target of at least 50 interviews in total. For a complete breakdown on case study selection and sampling, see Sutton and Rudd (2016).

Data Analysis

Interviews were fully transcribed and coded in NVivo (http://www.qsrinternational.com). Themes were identified based on recurring unifying concepts or statements within the data (Boyatzis 1998). A priori themes were defined drawing on leadership theory and empirical studies which recognized the importance of leadership. For example, we initially focused on themes regarding the origins of a leader (internal versus external candidates), systems of legitimization (e.g., through elections and nominations), motivations of a leader, and issues with succession. As additional interview transcripts were analyzed, themes and sub-themes were modified, refined, and combined to improve clarity, and new codes were defined to capture emergent themes outside of our a priori expectations.

Ethics Clearance

Interview questions and procedures were approved by the Environment Department Ethical Review Committee at the University of York in November 2014. Confidentiality agreements were signed by all interviewees, and transcripts were stored on a private device. For confidentiality purposes, respondents are numbered R1, R2, etc.

Results

Interview Respondent Summary

Of 200 individuals contacted by email, 54 respondents agreed to participate in our interviews between January and July 2015. Interviews lasted between 30 to 120 min, resulting in over 46 h of interview recordings being transcribed for contextual analysis. These represented 52 international SSFs (for two SSFs, we interviewed two individuals) and covered 15 of the 16 idealized case types. The most common case type, with a total of 11 interviewees, was the set [developed country; local fisher participation; single species focus; established fisheries management]. The only case type not represented was the set [developing country; no local fisher participation; single species focus; established fisheries management]. See Sutton and Rudd (2016) for a full sample breakdown. Given our focus on potentially successful and transformative efforts to cross boundaries, we here focus primarily on 18 cases where interviewees specifically raised issues regarding uncertainties of knowledge integration across at least 2 of 3 domains (credible evidence, societal legitimacy, and policy salience) and that influenced the effectiveness of SSF management. Those brief case studies are supplemented with comments and insights from some of the other interviews in the "Discussion".

Case Summaries

Nipissing First Nation

Freshwater pickerel or walleye (*Sander vitreus*) is a main source of nutrition and income for the Nipissing First Nation, who live on the shores of Lake Nipissing in northern Ontario (Bavington 2015). An agreement on aboriginal and treaty right for fisheries in Canada enabled the Nipissing to sell fresh pickerel commercially starting in 2008. In line with the treaty, the Nipissing First Nation asserted their sovereign rights to manage fisheries within their jurisdiction and refused to accept any externally designed or implemented restrictions. Fisheries decision-making is made at the local level, engages fishers, and draws on local knowledge. Aboriginal fishers are seen as experts who provide credible fishers' knowledge for fisheries management within the First Nations jurisdiction.

Regionally, the declining walleye fishery operates within a broader government management context (https://www.ontario.ca/page/fisheries-management-zone-11-fmz-11). When conventional fisheries science is needed locally, the Nipissing First Nation will employ external scientists or consultants to help them in data collection and analysis. R1 viewed the Nipissing First Nation's relationship with science as "not so much anti-science, but a return to a different way of science, a science of qualities instead of quantities." In terms of positioning within our framework (Fig. 3), the results from this interview suggest that this SSF may already be operating near the border of zones [CLS] and [$\sim$CLS] (societal legitimacy and policy salience are both clearly established in this case). Note that walleye population in Lake Nipissing has been declining and that the Ontario government introduced new

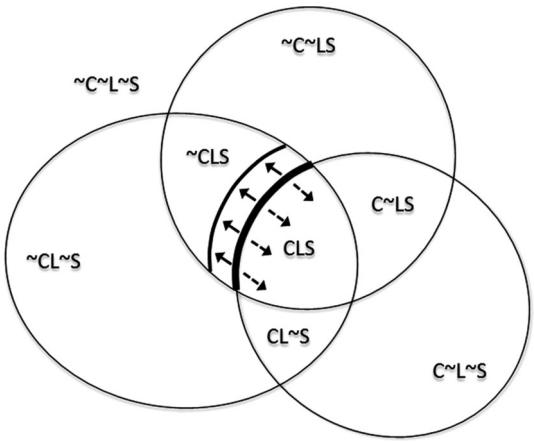

Fig. 3 Using science to increase local SSF management capacity

management rules in 2014; while Aboriginal consultations were conducted as part of the management review, changes were strongly informed by conventional fisheries stock assessment methods and accounted for diverse user groups active in the area (OMNRF 2014). Efforts to draw formal scientific information into the local Aboriginal management process (Fig. 3, solid lines) may help reinforce the perspective that the knowledge of Aboriginal fishers is credible (even if already legitimate from the Nipissing First Nation viewpoint, it may be viewed as pseudo-science [∼CLS] by scientists). A heavy focus on quantitative fishery models could, on the other hand, act as a counter force, acting to retract the boundary (Fig. 3, dashed lines) into a region where fisheries scientists are viewed as the sole providers of credible knowledge. For the Nipissing walleye fishery, our framework highlights that there is a fundamental tension over what is viewed as credible knowledge for SSF management.

Lake Hjälmaren, Sweden

Lake Hjälmaren in Southern Sweden is home to a traditional small-scale pike–perch (*Sander percidae*) fishery. Fishers are organized into a collective that is culturally and socially established within the community. Local individuals are well informed about the status and the biology of the fishery, and collect their own data to generate statistics. In 2006, the fishery was awarded the world's first freshwater fisheries Marine Stewardship Council (MSC) certification in recognition of sustainable fishing processes. The World Wildlife Fund (WWF) was an important player in the initial MSC certification process. In 2013, again encouraged by the WWF, local fishers applied for a second MSC certification.

To help with the second application, the local fishing collective teamed up with a national freshwater fishers' interest organization and WWF helped with technical and administrative aspects of the application. R2, who represented the WWF, noted that the fishers had to overcome substantial barriers in collecting stock data. A major issue was the lack of support from national governing bodies and a local university, who refused to give fishers important data from their archives, perhaps due to opposing motivations. At that point, this case study lay near the boundary of [∼CLS]. The fishers' organization had attempted to pull science farther into the domain of societal legitimacy albeit with limited success.

The WWF eventually organized a meeting between key stakeholders which enabled more transparent data collection and sharing. For brevity, we will not include figures for each of the 18 case studies, but we believe that the efforts helped shift the case, so that it was positioned within the [CLS] overlap. This case study shows an example of a pull by fishers [facilitated by an environmental non-governmental organization (NGO)] to encourage governmental and academic input to increase the scope of what was considered credible knowledge. Table 1 summarizes the information for the 18 case studies that are our main focus in this paper.

Southwest Inshore Fisheries Group, Scotland

Inshore Fisheries Groups (IFGs) are non-statutory organizations located around the coast of Scotland. IFGs aim to improve the management of inshore fisheries up to six nautical miles and give fishers a voice in management issues. The Southwest IFG is supported in administrative tasks by the Firth of Clyde Forum, in management activities by the Solway Firth Partnership, an independent local charity, and in technical issues by the University of Shetland. The IFG is currently involved with two projects, a trial introduction of creel escape panels and a lobster v-notching scoping study. Creel escape panels are designed to allow juvenile crab and lobsters to escape creels unharmed and v-notching helps to identify and protect breeding females from harvest. Both initiatives are voluntary, enabled by IFG project funding, and aim to conserve valuable commercial stocks. By collecting evidence on the use of traditional fishing grounds and developing a better understanding of lobster stocks, local fishermen may be able to contribute more effectively to management and planning processes.

Despite the IFGs success in instigating local partnerships, R3 expressed concerns of fishers' continued distrust of governmental actors. That was caused by constant policy change: "fishers are wary of any government agency and changes in policy…if you have been in the industry for 20 or 30 years, you will have seen an awful lot of changes." Distrust can hinder participation in management activities

Table 1 Summary of case configurations and boundary crossing conditions for 18 cases

Case	Country	Contextual conditions				Boundaries of interest	Comments
		Development status (in HDI)	Local participation	Fishery complexity	Management arrangements		
Nipissing First Nation	Canada	Very high	Yes	Single species	Relatively new (2008)	CLS/∼CLS (some pull on science)	Nipissing First Nation employs external advisors to assist them in data collection and analysis. Questions as to what defines credible knowledge in a regional context
Lake Hjälmaren	Sweden	Very high	Yes	Single species	New (2013)	∼CLS/CLS	Pull by fishers to get governmental and academic input to build credible knowledge, facilitated by a NGO
Southwest IFG	Scotland	Very high	Yes	Multi species	New (2013)	CLS/CL∼S (needs either policy pull or legitimacy push)	IFG supported in research by the Solway Firth Partnership and the University of Shetland. Salience uncertain due to frequent changes in policy direction
Lamlash Bay MPA	Scotland	Very high	Yes	Multi species	Relatively new (2008)	CLS/CL∼S (social pull on saliency and credibility)	COAST is actively pulling policy into a situation where scientific credibility and social legitimacy are strong. Despite a degree of support, the government shows a lack of political leadership. Other local stakeholders distrust research conducted by Marine Scotland
OMMRFI marine reserve	Spain	Very high	Yes but the reserve is currently operating as a 'paper park'	Multi species	Established (early-mid 2000s)	CLS/CL∼S	Leadership of a local actor was paramount to initial discussions; he pushed to expand the focus of scientific knowledge to include local knowledge. OMMRFI achieved CLS, however, broader political and economic contexts degraded the boundary to CL∼S
Isle of Scilly IFCA	England	Very high	Yes	Multi species	New (2011)	CLS/CL∼S	Partnerships with universities and local participation increases legitimacy and credibility. Institutional uncertainty in the funding stream will potentially reduce saliency and credibility into the future
Khong District co-management	Lao PDR	Medium	Yes (but project on hold)	Multi-species	The project is now over: at the time it was relatively un-established (1993–1999)	CLS/CL∼S	With the support and push of NGOs, CLS was achieved. Using existing local leadership was crucial. Institutional uncertainty reduced saliency. However, lessons learnt through project activities are still being practiced to a certain extent
NZRLIC	New Zealand	Very high	Yes	Single species	Established (1996)	CLS/C∼LS	Incentive structures of regional leaders impact the level of research conducted. Institutional uncertainty which impacts property rights reduces policy saliency and influences local level behavior
Negombo Lagoon aquaculture	Sri Lanka	High	Yes	Single species	Established (early 2000s)	CLS/C∼LS	Although final decision-making resides at the government level, the community plays a significant role in data collection and design of the crop calendar. Corruption and discrimination reduces social legitimacy
MEABR loco fishery	Chile	Very high	Some (but decreasing)	Single species	Established (1991)	CLS/C∼LS	The continuation of an overly top-down approach has reduced social legitimacy. Leadership that can operate across boundaries (vertically and horizontally) is crucial

Table 1 continued

Case	Country	Contextual conditions				Boundaries of interest	Comments
		Development status (in HDI)	Local participation	Fishery complexity	Management arrangements		
Taunton Bay lobster fishery	USA	Very high	Yes (but project on hold)	Multi-species	Relatively new (2007–2010)	CLS/C ~ LS	Government effort to pull fishers into management system to improve credible science. Taunton Bay achieved CLS, however economic contexts and the loss of a leader degraded the boundary to C ~ LS
Aqaba commercial fishery	Jordan	Medium	Yes (Increasing)	Multi-species	New (2013–2014)	C ~ L ~ S/C ~ LS	Strong push by a science to improve saliency and legitimacy. Trust was built through project activities and feedback. Legitimacy is still uncertain due to the lack of participation of fishers in decision-making which reflects limited capacity and awareness
WD-DACE project	Kenya	Low	Yes	Multi-species	New (2010)	C ~ L ~ S/C ~ LS	Strong push by science to improve saliency and legitimacy. Credibility was enhanced through the use of models, however, legitimacy and saliency are disputed
Galapagos National Park	Ecuador	High	Yes (but potentially decreasing)	Multi-species	New (new management structure came into force in 2015)	CLS/~C ~ LS	Fractious relationships between leadership groups caused by uncertainty in mandate. Concerns about legitimacy and credibility due to the dissolving of the CDF and PMB
APAPM artisanal fishers	Argentina	Very high	Some (but decreasing)	Multi-species	Established (1993)	~C ~ L ~ S	Original pull from fishers to facilitate more credible policy. Legitimacy, saliency and credibility dissolved due to poor transparency, poor integration and fluctuating support from the state
Community fisheries of Belo Sur Mer	Madagascar	Low	Yes	Multi-species	Relatively new (2009)	CL ~ S	Science-oriented NGO pushing to expand social legitimacy and scientific credibility. There is currently a lack of government involvement, therefore, poor policy saliency
VicWZ abalone fishery	Australia	Very high	Yes	Single species	Established (2001)	CLS (industry members pushing for legitimacy)	Limited engagement with government but strong property rights in place (therefore saliency) and fishers are experienced in research. Strong local leadership facilitates discussions with the government
Gooseneck barnacle fishery	Spain	Very high	Yes (but decreasing)	Single species	Established (1994)	CLS	The implementation of co-management and property rights has increased credibility, saliency and legitimacy. The participation of local users and their knowledge has increased flexibility, resilience and adaptability

and compliance with regulations imposed by the government, and reduces the likelihood of future knowledge integration. The challenge for this case is related to institutional uncertainty arising from shifting policies, presumably due to changing political goals (n.b., policy direction could also shift due to new or evolving government science advice). Recalling Fig. 2, this case could be positioned at the [CLS]/[CL ~ S] boundary. The relatively high level of policy uncertainty, and the symptoms such as distrust that arise due to that uncertainty, implies that the policy salience set in the Venn diagram may be barely overlapping with the societal legitimacy set. R2 flagged capacity building as an approach to alleviate policy uncertainty; capacity-building through research with external partners increases fishers' levels of awareness and capability of communicating effectively with political actors. R3 noted that as the IFG is relatively new, it has the potential to provide a platform where different stakeholders can interact and learn of opposing perspectives on SSF management.

Lamlash Bay MPA, Scotland

The Community of Arran Seabed Trust (COAST) is a community-based marine conservation organization. COAST works to protect and restore the marine environment around the Isle of Arran and the Clyde in Scotland. COAST has four aims: to improve the local marine environment for the benefit of everyone; help sustain the livelihood of those dependent on fishing and tourism; increase the popularity of the area for diving and tourism; and educate future generations (http://www.arrancoast.com/). They were instrumental in creating a no take zone (NTZ) in Lamlash Bay in 2008 and are now campaigning for legislation to establish an MPA around the south of the island.

To lobby for the implementation of the NTZ, COAST established strong links with several universities around the UK. They also collected anecdotal knowledge from local stakeholders and worked closely with Scottish Natural Heritage, a part of Scottish government, in research. This ensured rigorous, independent research of marine life in the Clyde. Engaging in diverse communication methods, such as social media (Facebook and Twitter), radio, and newspaper, allowed COAST to dissipate important information to a broad audience.

COAST has made significant progress in protecting local ecosystems and livelihoods. Despite this, other local groups have showed a lack of support for the NTZ and MPA, which led to their dropping out of working groups, and a level of distrust in research conducted by Marine Scotland. In addition, R4 recognized government apathy in providing political leadership has placed increased responsibility on COAST. COAST is actively pulling policy to be more socially legitimate and scientifically credible; however, due to government apathy, this case study is positioned in the [CLS]/[CL ~ S] boundary. We also note that it may be insufficient to consider 'societal legitimacy' in unitary terms, implying that it may be important to explicitly consider multiple 'publics' in some SSF contexts (e.g., fishers who use different gear types).

Galicia, Spain

The Os Miñarzos Marine Reserve of Fishing Interest (OMMRFI) was proposed as a solution to social and environmental concerns (Perez de Oliveira 2013). Concerns included overfishing and illegal fishing, as well as environmental disasters, such as the Prestige oil spill. The idea of establishing an MPA was envisaged in 2002 and was developed by the local fishers association (*cofradías*) in partnership with biologists, social scientists, environmentalists, and the autonomous government of Galicia. An important component in the successful development of the MPA was the community's capacity for collective action. Capacity had been developed through earlier collaborations between the fishing community and a team of scientists from the local university.

The role played by a local anthropologist based at the local university was crucial. This leader had in-depth knowledge of local idiosyncrasies. With his encouragement and the development of a specialized working group, fishers started participating in management activities. Local fishers were involved in the designing of various aspects of the MPA, such as its size, location, regulation, and access. The inclusion of local knowledge on fishing grounds and breeding areas, combined with scientific knowledge, was paramount to building trust between fishers and scientists and promoting mutual respect. After a year and a half of discussions, the Galician Administration gave the MPA its approval and support.

R5 stated that the OMMRFI was "initially amazing." However, in 2011, a government party change which coincided with an economic crisis resulted in a significant reduction of funds for MPA surveillance (Perez de Oliveira 2013). Despite local protest, R5 reported that the MPA is now functioning only as a 'paper park.' Due to the diminishing success of the MPA and growing distrust among community members, the leader of the local cofradías lost motivation to continue working for the reserve. Legitimacy, saliency, and credibility were achieved in the initial stages of the OMMRFI as a result of a pull from the local anthropologist to engage local stakeholders. Institutional uncertainty arising from political leadership change placed this case study in the [CLS]/[CL ~ S] boundary. Despite the current status, awareness

has been increased as a large extension to the MPA is being planned.

Isle of Scilly, England

The Isle of Scilly Inshore Fisheries and Conservation Authority (IFCA) was established by the UK Secretary of State and came into force in 2011. The IFCA is responsible for the regulation and management of all fishing activities within six nautical miles of the coast. Eight individuals make up the IFCA which include elected council members, individuals from the local community, and Natural England's and Marine Management Organization officers, which are both a part of the UK government. All members have full voting rights and make decisions on enforcement, bylaws, and conservation objectives.

Numerous research projects were organized by the IFCA, including lobster and crawfish tagging, and data logging. The goals of the projects were to provide evidence on the viability of shellfish stocks and to ensure that harvesting is sustainably managed. The lobster and crawfish tagging program was initiated as a joint venture between the Isle of Scilly IFCA and the nearby Cornwall IFCA, with input from marine biologists at local universities. Fishers also participated in research which enhanced understanding about local ecological processes. The data logging program was a 3-year partnership with Plymouth University. Four stations that are scattered around the island digitally record temperature, turbidity, and salinity. R6 hoped that additional funding is secured to extend data logging for an additional 3 years to provide a longer record on environmental processes.

The Isle of Scilly IFCA interviewee highlighted several efforts to increase the formal integration of scientific and local knowledge through the participation of local stakeholders. In doing so, the IFCA is increasing the overlap of the legitimacy and credibility sets in the Venn diagram (Fig. 2). The IFCA received much of its funding from the government but as R6 noted "at the moment we are fine, we are fine until March 2016 when technically the money runs out, and when on paper there is no more funding support…there are two issues here, one is the general election coming up and second, is that whatever government is in, there's bound to be a comprehensive spending review." Institutional uncertainty positions the case in the [CLS]/[CL ~ S] boundary. In the future, the production of credible science might be reduced due to diminishing funding opportunities for research,; consequently, this case could potentially shift toward [~ C ~ SL].

Co-management in Khong District, Champasak Province, Lao PDR

Between 1993 and 1999, 63 villages in the Khong District established co-management regulations to sustainably manage and conserve aquatic resources (Baird 2007). Co-management was supported by two NGO supported projects, first, the Lao Community Fisheries and Dolphin Protection Project, and second, the Environmental Protection and Community Development in Siphandone Wetland Project (EPCFSWP). The project aimed to enhance management decision-making by building upon the broad local knowledge base and by creating a more standardized approach to monitoring. Extension workers ran workshops in which project officials made short presentations about co-management and facilitated the exchange of fishers' knowledge within and between communities (Baird 2000, 2007). At these workshops, village leaders also presented draft co-management regulations developed by the community (Baird 2000). Revisions were made by communities with recommendations made by government and project representatives. An important aspect of the EPCFSWP was the use of existing local institutions instead of creating parallel authoritative groups.

Co-management in the Khong District was strongly community focused. It appears that this case initially achieved membership in [CLS] as communities designed management plans with the input of government and project representatives. Despite detailed planning and implementation, a misunderstanding between NGO researchers and the local government over long-term funding arrangements led to the early conclusion of project activities. R7 remained optimistic about the impact project activities had on local behavior and reported that "while some of the practices that were introduced for management purposes have decreased, because people have stopped enforcing them, other things have continued…I think the local government has maintained an interest…so I think there are periodic attempts by the government to strengthen things." Consequently, this case study is operating in the CLS/CL ~ S boundary due to the influence of institutional uncertainty.

New Zealand Rock Lobster Industry Council

The rock lobster (*Palinuridae achelata*) industry in New Zealand is represented by the New Zealand Rock Lobster Industry Council (NZRLIC). It is made up nine regional commercial stakeholder groups known as CRAMACs which derives from rock lobster (CRA) and Management Area Councils (MAC). Each CRAMAC is allocated a share of the total allowable catch and appoints a director to NZRLIC, which itself is managed by an Executive Director who coordinates research and management activities, represents the industry, and provides advocacy regionally and nationally. Through the NZRLIC, there is a well-defined set of property rights which allows fishers to access and

utilize the resource, and we designed to encourage custodial attitudes and stewardship among resource users.

In 1997, the NZRLIC became the accredited research provider to the Minister of Fisheries. Since then, the NZRLICs contribution to research has been extensive and positive. Research programs include catch sampling, vessel logbooks, and lobster tag, release and recapture projects. Some CRAMACs are more active in industry generated data collection, which R8 attributed to incentive structures and personal motivations of regional leaders. For example, the potential profits from running a sustainable fishery have provided an incentive for the Southern CRAMAC, the largest and most valuable regional grouping, to participate in data collection programs.

Decreasing access to space is an emerging concern for New Zealand's fisheries. The government in 2014 announced plans to introduce recreational fishing reserves. R8 reported this is causing much uncertainty and concern for the NZRLIC: "there is a reserve that will impact on my rock lobster fisheries, and there are currently no proposals for any redundancy agreement or opportunity adjustment, you basically get locked out." The key issue here was that the impact institutional uncertainty could have on the behavior of local fishers. R8 noted that the rights of fishers "are rights of access and utilization rather than rights of ownership…you don't own the fish…those rights are meant engender a custodial attitude and stewardship of the resource, when you create so much uncertainty about the continued use of those rights, you start to erode the custodial attitude and stewardship, and that defeats the real positive side of the property rights based management system." The NZRLIC case study is operating in the [CLS]/[C ~ LS] boundary, due to the impact of institutional uncertainty on social legitimacy.

Negombo Lagoon, Sri Lanka

Sri Lanka has a long history of collective action (Galappaththi and Berkes 2014). Small-scale shrimp fisheries in Negombo, northwest Sri Lanka, are managed by rural fishing cooperatives (Galappaththi and Berkes 2015b). Fishers gained technical knowledge working for large-scale aquaculture companies in the boom years before the bust in the mid-1990s. Community cooperatives currently manage aquaculture through a zonal crop calendar with government oversight and collaboration. Fishers are represented by their associations, which are then organized into zonal associations with Sri Lanka Aquaculture Development Alliance (SLADA) at the apex of vertical linkages (Galappaththi and Berkes 2015a). SLADA in turn works in a horizontal partnership with the National Aquaculture Development Authority, a department of central government which provides technical expertise, coordination, and oversight.

R9 reported that community associations meet during and after each crop season to discuss, evaluate, and adjust the calendar. These feedbacks and suggestions are relayed via community leaders and zonal representatives to decision-makers at the national level. The zonal calendar is a continuous learning process and is, therefore, highly adaptable. R9 believed that the management system is self-sustaining and that although final decision-making resides at the government level, the community plays a significant role in data collection and design of the crop calendar.

Although the system is effective, R9 recognized issues of corruption and discrimination. Rich local actors often bribed leaders within SLADA, thereby influencing their decisions. Here, the challenge is ensuring social legitimacy remains intact despite the influence of local elites. Consequently, this case can be positioned within the [CSL]/[CS ~ L] boundary. The presence of corruption implies that the legitimacy set in the Venn diagram (Fig. 2) is offset against the sets of credibility and saliency.

Benthic Resources in Chile

In the late 1980s, the SSF industry in Chile experienced extensive overexploitation (Marín and Berkes 2010). Exploitation was attributed to social and economic instability, and the emergence of a black market. In response to the crisis, the government imposed a 4-year ban on catching fish and in 1991 established the Management of Exploitation Area for Benthic Resources (MEABR). The MEABR recognized the rights of organized artisanal fishers to regulate territorial user rights in their management areas. Under the co-management system, formal fisher organizations sign a 4-year agreement with the state. The contract is grounded on baseline resource assessments and a management plan which is prepared by biological consultants hired by fishers (Marín and Berkes 2010).

Pilot studies for co-management agreements were designed to be highly collaborative. Since the pilot studies, there were, however, numerous user complaints about the continued top-down nature of management and the lack of horizontal linkages between fisheries associations. The combination of bureaucracy and the rigidity of the law which defines the state-drive management system have hindered bottom-up learning and innovation (Marín and Berkes 2010). The Chile case study shows an original pull from government to improve legitimacy and credibility of SSF. However, the continuation of a top-down management style has eroded social legitimacy and moved the case study into the [CLS]/[C ~ LS] boundary. To improve legitimacy, R10 recommended that local leaders should

"negotiate with high-level actors but also establish alliances with similar local groups."

Taunton Bay, USA

In Taunton Bay, Maine, a local ecosystem-based management project was initiated by the Maine Department of Marine Resources. The project aimed to increase knowledge on how to balance resource use with long-term protection of the environment (Sowles 2011). Initial project activities were deliberate and time-consuming, and included an iterative round of assessment, feedback, and adjustment involving the government representative and the local community. The engagement of community stakeholders was imperative to the project. Through the Taunton Bay Advisory Group, citizens provided local knowledge, expertise, perspectives, and advice to the State of Maine. R11 attributed successes to the inclusion of fishermen in survey design and data collection, which assured them of credible and trust-worthy science, and of the unwavering support of the State Commissioner. Once the final report had been published, the management plan received facilitating legislation.

Due to push from a particular government representative and initial project successes, the Taunton Bay case study initially achieved full membership in the set [CLS]. However, a budget cut coinciding with the government representative's retirement resulted in reduced project activity cumulating in a 'passive management plan'. Consequently, the case is currently operating in the [CSL]/[C∼LS] boundary region due to apathy among community members to engage in the management process. R11 remained positive and reported that "the foundation had been laid and so the story isn't over…at some point in the future, if there is enough interest locally, somebody can reinvigorate it and bring new life to it, so it's a starting point."

Aqaba, Jordan

Compared with some other cases in our study, Jordanian SSFs have received little research attention. As such, there was limited information available in Aqaba, Jordan regarding the size of fish stocks, catch composition, and the number and behavior of fishers. The German organization, Gesellschaft für Internationale Zusammenarbeit (GIZ), in partnership with the Jordan Royal Ecological Diving Society (JREDS), has been working to support the Jordanian government in fisheries research since 2013. Using new approaches, the aim of the Jordan Fisheries Project was to raise awareness among Jordanian people about the environment, foster environmentally sustainable behavior, strengthen data collection, and increase the availability of credible science in Jordanian fisheries.

GIZ facilitated numerous Project activities in Jordan and supported capacity-building at JREDS and other NGOs. An initial step of the Project was to build partnerships between Project assistants at JREDs and local fishers. Fishers in Jordan were naturally distrustful of science and scientists; R12 recognized that local fishers believed, "if I don't say anything, they can't use that information against me." Consequently, a primary project objective was to build strong relationships on knowledge rather than rumors.

The Project is still in the beginning stages but successes have already been noted. The Jordan case shows that a strong push from science for saliency and legitimacy can be facilitated by extensive trust building efforts. R13 recognized that trust was enhanced after JREDS ensured fishers were the first to hear of project results and that results were made freely available to all participants. The legitimacy may be questioned as the participation of local fishers was confined to data collection rather than decision-making; therefore, this case study is positioned in the [C∼L∼S]/[C∼LS] boundary. Increased overlap with the legitimacy set may be achieved as the project becomes more established, and levels of local awareness and capabilities increase.

Gazi Bay, Kenya

The Whole Decision-Network Analysis of Coastal Ecosystems (WD-NACE) project, which was funded by a UK research grant and led by academics, developed fishery models for a small artisanal fishery in Kenya. Project aims were to generate generic and comparable studies about how decisions for policy and action were made at the local level. The first step in developing the models was to find out how people used information to make their decisions, the state of local environments, the current financial situation, and local people's social standing in the community. To address these questions, the project built upon existing information in the Gazi Bay by working with local teams and connecting them with policy-makers, practitioners, and local people who depend directly on fishery resources.

WD-NACE intended to provide decision-makers at multiple levels with useful models to facilitate understanding about critical social–environmental relationships. R14 recognized that models are important as they ease understanding and potentially secure the attention of governments. Due to a push from scientists in an attempt to extend scientific knowledge, science became more credible. However, it is unclear if and how local people participated in decision-making, and the longevity of project results is uncertain. This case study is, therefore, situated in the [C∼L∼S]/[C∼LS] boundary.

Galapagos, Ecuador

An ecosystem-based spatial management approach was adopted by the Galapagos Marine Reserve. This approach was developed to help with ecological, socioeconomic, and political challenges related to fishing and tourism (Castrejón and Charles 2013). Increasing conflicts and ecological degradation led to the creation of the Galapagos Special Law (GSL) and the Galapagos Marine Reserve Management Plan at the end of the 1990s. Under the GSL, two authoritative institutions were created, the Participatory Management Board (PMB) and the Institutional Management Authority (IMA) who respond to the Minister of Environment within national government. The PMB was composed of local stakeholders, including fishers, members of the tourism sector, conservationists, and the Galapagos National Park. R15 highlighted that decision-making was made by consensus within the PMB, and if consensus was not reached the IMA took over. Scientific input was provided by a local NGO, the Charles Darwin Foundation (CDF).

In 2008, the government approved a new constitution that created a new authority called the Galapagos Governing Council (GGC), which aims to govern Galapagos as a whole. The GGC has caused uncertainty about the function of lead institutions and increased conflict. To overcome conflicts and uncertainties, a reform was made in 2015. However, R15 voiced concerns that these reforms may reduce the number of fishing representatives involved in decision-making due to the status of the PMB being changed from a cooperative to a consultative form of co-management. The CDF has also contented with economic and political disruption and will conclude in 2016. With the new reforms, this case has shifted from [CLS] to [∼C∼LS] due to the conclusion of the PMB and CDF.

Puerto Madryn, Argentina

The Argentine hake (*Merluccius hubbsi*) is the backbone of the Argentinian fishing industry. The Association of Artisanal Fishers of Puerto Madryn (APAPM) was initiated in 1993 when Argentina experienced severe reductions in the numbers of hake. By 2000, APAPM had secured formal legal status, had membership of 60 % of local fishers, and played a proactive role in fisheries management (Orensanz et al. 2007). APAPM was involved in lobbying to reduce unrealistically high catch allocations for the 2000 fishing season. Fishery managers approached the provincial government looking for scientific advice, but there was a lack of data and high uncertainty regarding fish stock population dynamics. Due to the uncertainties of ecological SSF process, it became apparent that extensive discussions between scientists, managers and stakeholders were required. In response, the provincial government created a technical advisory board comprising of technical staff, scientists, and representatives from APAPM in 2001. This facilitated scientist-fisher collaborations in data collection which informed catch quota recommendations. In 2005, the advisory group was expanded to incorporate representatives from the Natural Protected Area Peninsula Valdes and the provincial authority of tourism.

Despite the achievements of the co-management structure at developing partnerships between stakeholders, relationships have disintegrated. R16 raised concerns about the legitimacy and transparency of collaborations, and the adaptability of quotas to reflect stock activity. In addition, there illegal constraints, a weak judiciary system, and a lack of coordination between agencies (Orensanz et al. 2007). The perceived lack of scientific credibility and institutional support influenced behavior at the local level. R16 reported: "the most frustrating factor is the lack of support from the state…because fishers started with a lot of motivation and strength, but those same people who are still in the fishery are really tired…it's really difficult to maintain the motivation if you don't have responses from the agencies." The initial pull on science from fishers, who had lobbied for more credible science, moved this case study into [CLS], but the case since shifted to occupy [∼C∼L∼S] due to poor integration and fluctuating support from the state. Recalling Fig. 2, one could envision this case as having the three sets not overlapping at all, with the case positioned in a gap between the sets.

Belo Sur Mer, Madagascar

A non-governmental organization (NGO) called Blue Ventures (BV) started work in Belo Sur Mer in 2009. To increase scientific knowledge and to engage local communities, BV has evaluated and established community-based mangrove conservation through both push and pull mechanisms. BV supported locally led initiatives and partnerships by offering advice, organizing meetings, and facilitating the legislation of customary laws. Partnerships have been created between resource users from Belo sur Mer and neighboring villages.

Several mangrove fishery closures located and designed by the community have been implemented since 2011. Research was conducted to determine the appropriate minimum landing size for mangrove crabs, with the aim of eventually informing national fisheries policy. Over the past 5 years, nine reserves have been established and are now flourishing. In addition, BV established community-based health activities and alternative livelihood possibilities, such as sea cucumber aquaculture.

Our Belo sur Mer case highlights an example of a case study in the [CL∼S]. At the time of our interview, BV

was operating without the input of government and was focused on encouraging behavioral change through increasing community awareness and capacity. R17 reported "I can't tell communities "here is the magic number", I don't have it…it's more of a mentality or behavior change." It is possible that once project activities become more established, BV will be able to work to encourage policy saliency by creating partnerships with government agencies.

Victoria, Australia

Abalone (*Haliotis*) is a primary commercial species in Australia. Since the 1960s, there has been an increasing use of private-property rights to regionally manage Australian abalone fisheries (Gilmour et al. 2013). In the Victoria Western Zone (VicWZ) fishers' organization, three quarters of abalone license holders belong to a divers' association. An executive officer was hired externally and R18 noted that that this individual had helped the group to become more professional and facilitated improved interactions with the State government.

Due to declining levels of abalone abundance, VicWZ members sought the advice of an external consultant in 2001. Working with local divers through a series of workshops, the consultant facilitated industry-based stock assessment and bottom-up management changes. Outcomes from those workshops included an agreement to increase abalone size limits across the fishery, implement reef codes (sub-zonal partitions for recording catch and effort), and impose a cap on abalone landings. R18 reported that the VicWZ also worked closely with local universities but received little research support from the government. R18 emphasized that abalone fishermen gained much experience in data collection over the last 10 years: "they have learned a lot of lessons and they have come a long way."

The VicWZ abalone fishery has a strong property rights system in place and enjoys the participation of industry members and scientists in research. Although there is limited engagement from the government, fishers are capable of conducting research with the help of scientists and consultants. Strong leadership in the Abalone Divers Association allows the group to participate with government counterparts and for industry members "to get their voices heard." As such, this case study is operating in the [CLS] boundary, with a push from industry members for social legitimacy and scientific credibility. This case provides an example of how the use of consultants can be used to increase the credibility of knowledge in a science-pull boundary crossing effort.

Asturias, Spain

The gooseneck barnacle (*Pollicipes pollicipes*) fishery in Asturias is important to the artisanal fleet. In 1994, a co-management system between the government agency and local cofradías was implemented. By 2001, seven co-management agreements had been established along the Asturian coast. Each region had its own specific management plan, each of which was developed in conjunction with the fishery association. Under the arrangement, only licensed fishermen can exploit the resource, which has led to a sense of entitlement and a perceived need by fishers to protect their resource (Rivera et al. 2014). Co-management has allowed for an adaptive learning-approach and fine-scale management of the fishery.

Local users regularly participate in data collection and management decision-making. Cofradías regularly report daily landings and effort data, which provide scientists with fine-scale data to use in modeling. R19 noted that fishers have the responsibility of deciding the location of fishing activity and of reporting the quality of the resource. The government partner checks over proposed activity for the following year with the help of scientists. In the gooseneck barnacle co-management system, fishers' knowledge has been considered from the onset, and there were high levels of resource user participation in SSF management (Rivera et al. 2014). Consequently, this case study is positioned firmly in [CLS]. The flexibility of co-management policies and adaptive strategies adopted by the fishers has enhanced resilience in times of changing management measures and during an economic crisis (Rivera et al. 2016).

Other Opinions of Relevance for SSF Management

From among and beyond (i.e., from our analysis of interview transcripts for interviewees from the 36 other cases not specifically outlined above) the cases on which we have so far focused, our respondents highlighted additional themes: knowledge and valuation of SSFs; the credibility of science; and the uncertainty of institutional processes (Table 2).

Knowledge and the Value of SSFs

Our respondents reiterated the importance of scientific and local knowledge for effective SSF management (Table 2). R11 highlighted the importance of scientific knowledge. "I want to emphasize that science is the underpinning of all of this…for stewardship and adaptability, science is an integral part and it has to be credible." He also recognized the attributes of local knowledge: "fishermen are very astute; they are out there in all kinds of weather that scientists aren't in…their anecdotal knowledge or local knowledge is

very strong, profound…these guys are curious, excited about their resource…they understand biology far better than we give the credit for." Similarly R9 who worked with small-scale aquaculture fisheries in northwest Sri Lanka stated "local people are resilient…they are confident in their knowledge, local knowledge about their environment, specifically unique to their community."

The tension between scientific and local knowledge was also evident. In her work on Canadian fisheries, R20 experienced little interest in local knowledge among the scientific community. R21 attributed scientists' apathy toward local knowledge to the training scientists are provided in universities; "they're not taught to appreciate local knowledge, and in fact, when they come out of university they can be suspect of it…and suspect of the ability of locals to perform tasks they consider as their own domain." Fishers were also found to be suspect of scientific knowledge. R4 highlighted that fishing communities on the west coast of Scotland lack the understanding or willingness to accept scientific results; "there seems to be a dearth or lack of understanding of actual science…certain people don't seem to trust the science or the implication of it." A lack of trust in science and scientific methods was also experienced in Jordan.

SSF stakeholders have different priorities and beliefs which shape how they value SSF. There was consensus among our respondents that current valuations hinder attempts for sustainable SSF management. In Patagonia, Argentina R16 noted that "not many people appreciate the value of having fish…in a busy area, with lots of people, fishermen are not well seen". R16 added, "People are just there to catch as much fish as possible, so they don't care about conservation measures." R22 highlighted that Bajau fishers in Indonesia purely value fish as a food sauce and often question why tourists "would want to come and see something that is just food?" In contrast, fish stocks are a culturally valuable resource for communities in Madagascar, which has helped facilitate the implementation of an MPA (R23). R1 reported that for many fishing communities "fish are more than just money, they are thing to eat, and they are culture, these intangible things." To improve SSF management, R1 went on to recommend an inversion of current valuations of fish, from a system that places the most value on the exchange rate to one that places the most values on the existence of fish.

Ecological and Social Knowledge Limits

The credibility of science that currently guides SSF decision-making was called into question (Table 2). Especially important was the impact uncertainty had on the production of credible knowledge. Limited scientific data in many SSF contributed to uncertainty. In the Elephant Marsh SSF, Malawi, R24 reported "as we are, it is like managing in the dark, we don't know much about the fishery, what the issues are, what's the maximum harvest, how many fishermen can really be in the fishery to exploit the resources from it." In South Africa and along the coast of many West African countries, poaching has reduced the ability to calculate credible stock assessments due to the lack of accurate catch and effort data (R25 and R26). R25 stated that "scientific processes are definitely flawed, but we don't have any other way of managing the stock."

Complexity of ecological processes adds to the uncertainty of credible science. R21 highlighted that obtaining an annual quota for complex multi-species fisheries remains difficult and results in measurement errors. In addition, R21 recognized that lack of consideration for natural fluctuations can add to uncertainty; "I think the important decisions are the decisions tied to the biology of the species…it goes back to the problem of governing fisheries, whether you see fluctuations as a problem to be fixed or something you can adapt to." R27 reported that in the Caribbean context, while fishers are accustomed to uncertainty, fisheries science is based on assumptions guided by predictability and certainty, and that this fundamental difference has been a cause of tension between fishermen and scientists.

Concerns about the credibility of science are also attributed to the separation of SSF decision-making from local users and social realities. R1 highlighted that a major issue with SSF management is that science "tends to be technically oriented…which often doesn't have a good knowledge of its history." Similarly, R21 reporting on salmon fishing in West USA noted that "our current management is not strongly tied to place; it is not tied to specific populations and watersheds; conventional management is too divorced from local realities."

Concerns About Governance Effectiveness

Uncertainty generated by the activity of institutions at all levels pose difficulties for effective collaborative research (Table 2). The impact of migratory fishers was reported as a limiting factor by our respondents. Migratory fishers who operate along the coast of West Africa are able to travel great distances, utilize efficient technology, and exploit new fish stocks. R26 reported that fish caught can equal up to 30 % of the overall catch which is problematic: "it doesn't appear anywhere in the statistics or records…it's a big issue for management because you are managing ghost fishermen, you don't know who they are or where they came from." Consequently, management approaches based on maximum sustainable yield (MSY) can be problematic.

Our respondents also commented on the effects of high-level institutional uncertainty and the paradigms under

Table 2 Summary of other themes important for SSF management

Findings	Tally
Knowledge and the value of SSFs	
The merits of different knowledge types are recognized	4
Tensions between knowledge types	11
Difference in valuation of SSF resources	5
Ecological and social knowledge limits	
Limited amount of scientific data (including effects of poaching)	6
Issue of complexity and uncertainty	4
Disconnect from social realities	5
Concerns about governance effectiveness	
The impact of migratory fishing	5
The paradigms that governments hold	9

which government departments operate. Governments can be unwilling or unable to facilitate effective collaborations, lack will to devolve power to lower levels, and overly depend on single stock assessments. For example, R20 believed that "the institutional rationalities that governments operate under inhibit many effective policies and leadership." Similarly, R25 asserted that "being stuck in a particular paradigm and not being able to get out of it, is probably the root cause of failed governance in this fishery."

Discussion

Reducing biophysical and institutional uncertainty is crucial if SSFs are to contribute to positive social outcomes, such as poverty alleviation and coastal sustainability. Key to reducing uncertainties is the integration of scientific knowledge and local knowledge, and the uptake of integrated knowledge by policy-makers in decision-making. We found SSFs that were successful or partially successful in reducing biophysical and social uncertainty through knowledge integration. However, our analysis also highlighted the dynamic nature of SSF governance systems, and we found numerous instances where successful SSF governance processes and structures degraded over time. Recurring issues expressed by our respondents involved the framing of knowledge and the credibility of science, and the factors that influenced institutional uncertainty.

Key Issues

Blurred Boundary on Scientific Credibility

The way in which SSF stakeholders frame different knowledge influences knowledge integration. Framing refers to an individual's ideas, beliefs, and discourses (Fischer 2003), which determines their valuation of knowledge. Frames bind like-minded actors together in social groups (Parry and Murphy 2013), for example, fishing communities who share common knowledge, and academic research clusters who agree on specific scientific methodologies. Within SSF management systems, the dominant frame has largely been scientific knowledge, which has reduced the credibility of fishers' knowledge. In some cases, scientists can be actively hostile to the idea of incorporating fishers' knowledge into policy advice (Soto 2006). Despite increased efforts to encourage knowledge integration, our results highlighted that a blurred boundary on what constitutes credible knowledge still exists.

How stakeholder groups can come to agree on a common definition of credible knowledge is, therefore, an important research question. Leadership, which is crucial to SSF plays an important role in knowledge integration. We found leaders who are outward looking, and forward thinking had the potential to push boundaries on restrictive frames to encourage new ways of valuing knowledge. In our case studies, leaders who were able to break conventional frames and facilitate knowledge integration came from community organizations (Lamlash Bay, Lake Hjälmaren and Southwest IFG), NGOs (Bel Sur Mer), research institutions (Galicia, Aqaba), and government departments (Taunton Bay).

Leadership from scientists and research institutions is especially important to knowledge integration. Our results suggest that the success of knowledge integration can depend on a scientist's willingness to engage in transdisciplinary research that engages community stakeholders and government officials. In Taunton Bay, for example, a government scientist pushed to increase credibility and legitimacy by engaging local stakeholders in survey design, data collection, and decision-making, which had an impact on the final management plan. In other cases, however, it was 'business as usual' as scientists continued to use well-practiced scientific methods and pre-defined research

questions, with local communities only being engaged in data collection stages.

A key issue affecting the effectiveness of scientific leadership is the training young scientists receive in universities and research institutions. Our respondents recognized that current training practices often produce scientists who are suspicious of local fishers' knowledge and are thus less inclined to push for a broadening of management paradigms. Encouragingly, Rudd (2015) noted that in other cases, there is evidence of changing attitudes among young ocean scientists regarding engagement in policy-salient research.). This points to the possibility of enhancing knowledge integration through interdisciplinary research and partnerships. Broadening paradigms to achieve greater consensus in what constitutes credible knowledge will require greater alignment in how people frame knowledge. In many cases, this will entail revising assumptions and worldviews through increased awareness, respect, and understanding of opposing values and beliefs. Obviously, there is no simple prescription for changing individuals' framing of knowledge generation and enhancing integration, given often entrenched discourse and advocacy coalitions (e.g., Weible and Sabatier 2005; Caveen et al. 2013; Nursey-Bray et al. 2014; Rudd 2015). However, long lasting and adaptable capacity-building projects, especially within research and governmental agencies where it is often severely lacking, are crucial. In addition, several of our respondents noted the benefit of creating specialized platforms for collaboration and partnership building. For example, the WWF organized a meeting which ended tension between fishers, scientists, and policy-makers in Sweden. Such platforms need to be unique for each context and take into account environmental issues, policy landscapes, physical locations, and characteristics of stakeholders involved (Bracken and Oughton 2013). An important characteristic of platforms is adaptability, especially given the speed at which successful integration projects can become unsuccessful integration projects.

Institutional Uncertainty

Institutional uncertainty was a limiting factor to knowledge integration projects in our case studies. Uncertainty resulting from shifting policy objectives, fluctuating leadership and support for devolved SSF management, and funding opportunities were found to considerably influence the sustainability of community-based organizations and behavior of actors at the local level. A major concern is the potential for institutional uncertainty to reduce the credibility, legitimacy, and saliency of knowledge integration projects even if full overlap in [CLS] has been achieved. This could involve efforts to increase the coherence of policies and regulations across agencies, and integrate coastal and marine ecological research within the emerging nexus of social, human health, and environmental research (i.e., as laid out in new the Sustainable Development Goals—Gaffney 2014).

Many SSF knowledge integration projects rely on government funding. Uncertainty in the longevity of those funding channels reduces credibility, legitimacy, and saliency. In Galicia and Taunton Bay, membership in [CLS] was attributed to the engagement of local communities and the inclusion of fishers' knowledge in decision-making. However, in both cases, legitimacy and saliency were reduced due to the combination of an economic crisis and the loss of a strong leader. In the Isles of Scilly, for instance, uncertainty in the continuation of funding for research projects, after national elections, has the potential to reduce the credibility of knowledge used in decision-making.

Policy change was found to adversely affect the ability of leaders to retain community followers. Government representatives in Scotland were required to change regulations in line with changing policy objectives, which caused distrust among local fishing communities. In Galicia, suspicion of the local leader grew due to diminishing MPA successes after a cut in funding was made for surveillance. Others have also found that a leader's legitimacy is lost if they are perceived to be too close to regulatory processes and are, therefore, unable to fully serve community interests (Johnson 2011; Schut et al. 2013). Consequently, it is imperative that leaders remain accountable to all those they represent (Hoppe 2010).

In turn, institutional uncertainty influences the behavior of local level actors. Like Ostrom (1996), we found that frequent policy change reduces the motivation of highly effective leaders. Maintaining the motivation of a leader is particularly important given the influence they have on the overall sustainability of an organization (Giberson et al. 2005). In Argentina, the motivation of local leaders decreased due to fluctuating support from government partners. Institutional activity also determines the likelihood of fishers participating in SSF management activities (Sutton and Rudd 2016). Case studies from Sri Lanka and Galicia highlighted that fishers are more likely to participate if they have had positive experiences of working in collaboration. Unsurprisingly, Scottish fishers who participated in unsuccessful projects are less inclined to participate further due to their distrust of governmental leaders and apathy toward management activities.

Relation to Boundary Spanning Research

Our findings mirror some core findings from broader boundary spanning research. Science–policy–societal boundary arrangements determine the effectiveness of

knowledge integration. As our case studies demonstrated, boundary arrangements are embedded within social, economical, and political contexts. Changing contexts cause boundaries to be negotiated and renegotiated over time (Schut et al. 2013; van Paassen et al. 2011). Several case studies highlighted projects that succeeded in gaining credibility, legitimacy, and saliency [CLS]; however, due to changing contexts, the boundary dissolved. Our respondents remained positive that [CLS] could be renegotiated if circumstances became more favorable.

Integrating science and local knowledge requires the involvement of different stakeholder groups. Partnerships between local communities and research institutions were paramount to knowledge integration in our case studies. The degree of scientist involvement in those partnerships depends on the capabilities of local actors and the stage of the research project (van Paassen et al. 2011). Communities from Madagascar and Jordan, which have little experience of SSF management projects, required assistance from external organizations in research and management activities. In contrast, abalone fishers in New Zealand and shrimp aquaculture fishers in Sri Lanka have many years of experience in data collection and are thus able to conduct independent research. Scientists play many roles in fisheries policy and management, ranging from conventional information providers (Rudd 2015) to collaborative policy actors, to public intellectuals.

Path dependence determines the success of boundary arrangements. Path dependence assumes that boundary arrangements are influenced (either enable or constrained) by past collaborations between stakeholders and researchers (Leuuwis 2004). Perceptions, which are stored in the social memories of community members, change in response to experiences of previous projects and outcomes (Schut et al. 2013), and direct behavior in future projects. Apathy toward management processes was evident in case studies from Scotland and Argentina which deterred further participation and compliance. Therefore, the outcomes from past projects should be analyzed before new projects are implemented to gage local perceptions.

Conclusions

The objective of this contribution was to increase understanding of factors that influence the integration of scientific knowledge and fishers' knowledge LEK, and how this can be incorporated into SSF decision-making. In the context of our broader research project on SSF leadership, we collected information from 54 interviews from around the globe, and featured in this paper 18 case studies that specifically raised issues regarding the uncertainties associated with knowledge integration. We recognize that this study relied on the experiences and opinions of our interview respondents, which may have introduced potential biases (i.e., there is certainly a degree of self-selection arising,, because we could only interview respondents still active in SSF research or management). To minimize biases, we ensured data that were collected from a broad range of case studies and were backed up by the peer-reviewed literature. We also note the importance of conducting further analysis on how the characteristics of respondents (e.g., developed versus developing country) affects views on the credibility of science. While this is beyond the scope of this paper, we encourage further work to decipher those relationships, using medium-*n* set theoretic methodologies (e.g., Sutton and Rudd 2015).

Our results emphasized the complexity, uncertainty, and dynamic nature of science–policy–societal systems. By focusing on the dimensions of credibility [C], legitimacy [L], and saliency [S], we were able to identify the evolution of systems in their efforts to achieve full overlap in [CLS]. Several systems achieved membership in the [CLS] overlap; however, it was evident that staying in [CLS] was more difficult. Credibility, legitimacy, and saliency were lost due to changing economic, political, and social contexts. Our work suggests that community-based organizations may have a 'shelf-life' but can have the potential to perpetuate if new ideas, resources and energy become available, and if the experiences of past projects remain in mind. Capacity building and the creation of specialized platforms for knowledge integration are potential mechanisms to enhance institutional support.

Major issues affecting knowledge integration are a blurred boundary on what constitutes credible knowledge and institutional uncertainty. To improve knowledge integration, capacity building for actors within research organizations and governmental departments is important to break down pre-conceived ideas and encourage actors to consider the merits of different knowledge types. As complicated socio-ecological systems, SSFs are dynamic and will need constant attention from both ecological and social perspectives, and a constant upgrading of integrated scientific and contextual local knowledge. Managers must not expect that a set of interventions will permanently 'fix' SSFs. Given their immense importance globally as a source of food and livelihood—and the constant pressure for 'successful' SSFs not to stray out of the intersection of credibility, salience and relevance—it is crucial that effective efforts are taken to create the enabling conditions that can provide multiple benefits from SSFs.

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References

Allison EH, Ellis F (2001) The livelihoods approach and management of small-scale fisheries. Mar Policy 25:377–388. doi:10.1016/S0308-597X(01)00023-9

Baird IG (2000) Towards sustainable co-management of Mekong River Inland aquatic resources, including fisheries, in Southern Lao PDR. Evaluating Eden series discussion paper no. 15. International Institute for Environment and Development, Biodiversity and Livelihoods Group. Available online at http://pubs.iied.org/7818IIED.html

Baird IG (2007) Local ecological knowledge and small-scale freshwater fisheries management in the Mekong River in southern Laos. In: Haggan N, Neis B, Baird IG (eds) Fishers' knowledge in fisheries science and management. UNESCO, Paris, pp 247–266

Barnes-Mauthe M, Oleson KLL, Zafindrasilivonona B (2013) The total economic value of small-scale fisheries with a characterization of post-landing trends: an application in Madagascar with global relevance. Fish Res 147:175–185. doi:10.1016/j.fishres.2013.05.011

Bavington D (2015) Marine and freshwater fisheries in Canada: uncertainties, conflicts, and hope on the water. In: Mitchell B (ed) Resource and environmental management in Canada. OUP, Canada

Berkes F, Mahon R, McConney P, Pollnac R, Pomeroy R (2001) Managing small-scale fisheries. International Development Research Centre, Ottawa

Bodin O, Crona BI (2008) Management of natural resources at the community level: exploring the role of social capital and leadership in a rural fishing community. World Dev 36:2763–2779. doi:10.1016/j.worlddev.2007.12.002

Boyatzis R (1998) Transforming qualitative information: thematic and code development. Sage Publications, Thousand Oaks

Bracken LJ, Oughton EA (2013) Making sense of policy implementation: the construction and uses of expertise and evidence in managing freshwater environments. Environ Sci Policy 30:10–18. doi:10.1016/j.envsci.2012.07.010

Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB (2003) Knowledge systems for sustainable development. Proc Natl Acad Sci 100:8086–8091. doi:10.1073/pnas.1231332100

Castrejón M, Charles A (2013) Improving fisheries co-management through ecosystem-based spatial management: the Galapagos Marine Reserve. Mar Policy 38:235–245. doi:10.1016/j.marpol.2012.05.040

Caveen AJ, Gray TS, Stead SM, Polunin NVC (2013) MPA policy: what lies behind the science? Mar Policy 37:3–10

Chuenpagdee R, Bundy A, Charles A, Christie P, Fanning LP, Gonzales P, Houston J, Liguori L, Nandakumar D, Ricard D, Rudd MA, Pauly D, Salas S, Smith J, Sumaila UR, Turnipseed M, Tyedmers P, Vanderzwaag D, Zwanenburg KCT (2005) Creating a positive future for fisheries and coastal communities worldwide. In: Chuenpagdee R, Bundy A (eds) Innovation and outlook in fisheries. UBC Fisheries Centre, Vancouver. Fisheries Centre Research Report 13(2), pp 77–88

Cinner JE, McClanahan TR, MacNeil MA, Graham NAJ, Daw TM, Mukminin A, Feary DA, Rabearisoa AL, Wamukota A, Jiddawi N, Campbell SJ, Baird AH, Januchowski-Hartley FA, Hamed S, Lahari R, Morove T, Kuange J (2012) Co-management of coral reef social-ecological systems. PNAS 109:5219–5222. doi:10.1073/pnas.1121215109

Dentoni D, Klerkx L (2015) Co-managing public research in Australian fisheries through convergence–divergence processes. Mar Policy 60:259–271. doi:10.1016/j.marpol.2015.07.001

Dewulf A, Craps M, Bouwen R, Taillieu T, Pahl-Wostl C (2005) Integrated management of natural resources: dealing with ambiguous issues, multiple actors and diverging frames. Water Sci Technol 52:115–124. Available online at http://wst.iwaponline.com/content/52/6/115

Edelenbos J, van Buuren A, van Schie N (2011) Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. Environ Sci Policy 14:675–684. doi:10.1016/j.envsci.2011.04.004

Fischer F (2003) Reframing public policy: discursive politics and deliberate practices. Oxford University Press, Oxford

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour 30:441–473. doi:10.1146/annurev.energy.30.050504.144511

Gaffney O (2014) Sustainable development goals: improving human and planetary wellbeing. Glob Change 82:20–23

Galappaththi EK, Berkes F (2014) Institutions for managing common-pool resources: the case of community-based shrimp aquaculture in northwest Sri Lanka. Marit Stud 30:13. doi:10.1186/s40152-014-0013-6

Galappaththi EK, Berkes F (2015a) Can co-management emerge spontaneously? Collaborative management in Sri Lankan shrimp aquaculture. Mar Policy 60:1–8. doi:10.1016/j.marpol.2015.05.009

Galappaththi EK, Berkes F (2015b) Drama of the commons in small-scale shrimp aquaculture in northwestern, Sri Lanka. Int J Commons 9:347–368. doi:10.18352/ijc.500

Garcia SM, Charles AT (2007) Fishery systems and linkages: from clockworks to soft watches. ICES J Mar Sci Journal du Conseil 64:580–587. doi:10.1093/icesjms/fsm013

Garcia SM, Rosenberg AA (2010) Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives. Philos Trans R Soc Lond B Biol Sci 365:2869–2880. doi:10.1098/rstb.2010.0171

Giberson TR, Resick CJ, Dickson MW (2005) Embedding leader characteristics: an examination of homogeneity of personality and values in organizations. J Appl Psychol 90:1002–1010. doi:10.1037/0021-9010.90.5.1002

Gilmour PW, Dwyer PD, Day RW (2013) Enhancing the agency of fishers: a conceptual model of self-management in Australian abalone fisheries. Mar Policy 37:165–175. doi:10.1016/j.marpol.2012.04.015

Gutierrez NL, Hilborn R, Defeo O (2011) Leadership, social capital and incentives promote successful fisheries. Nature 470:386–389. doi:10.1038/nature09689

Hackmann H, Moser SC, St. Clair AL (2014) The social heart of global environmental change. Nat Clim Change 4:653–655

Hind EJ (2012) Last of the hunters or the next scientists? Arguments for and against the inclusion of fishers and their knowledge in mainstream fisheries management. PhD dissertation, The National University of Ireland Galway, Ireland

Hisschemöller M, Hoppe R (1995) Coping with intractable controversies: the case for problem structuring in policy design and analysis. Knowl Policy 8:40–60. Available online at http://works.bepress.com/robert_hoppe1/7/

Hoppe R (2009) Scientific advice and public policy: expert advisers' and policymakers' discourses on boundary work. Poiesis Prax 6:235–263. doi:10.1007/s10202-008-0053-3

Hoppe R (2010) Lost in translation? Boundary work in making climate change governable. In: Driessen PPJ, Leroy P, van Vierssen W (eds) From climate change to social change: perspectives on science-policy interactions. International Books, Utrecht

Jentoft S (1989) Fisheries co-management: delegating government responsibility to fishermen's organisations. Mar Policy 13:137–154. doi:10.1016/0308-597X(89)90004-3

Jentoft S (2004) Institutions in fisheries: what they are, what they do, and how they change. Mar Policy 28:137–149. doi:10.1016/S0308-597X(03)00085-X

Jentoft S, Bavinck M (2014) Interactive governance for sustainable fisheries: dealing with legal pluralism. Curr Opin Environ Sustain 11:71–77. doi:10.1016/j.cosust.2014.10.005

Johannes RE, Freeman MMR, Hamilton RJ (2000) Ignore the fishers' knowledge and miss the boat. Fish Fish 1:257–271. doi:10.1111/j.1467-2979.2000.00019.x

Johnson TR (2010) Cooperative research and knowledge flow in the marine commons: lessons from the Northeast United States. Int J Commons 4:251–272. doi:10.18352/ijc.110

Johnson TR (2011) Fishermen, scientists, and boundary spanners: cooperative research in the U.S. Illex Squid Fishery. Soc Nat Resour 24:242–255. doi:10.1080/08941920802545800

Johnson TR, van Densen WLT (2007) Benefits and organization of cooperative research for fisheries management. ICES J Mar Sci Journal du Conseil 64:834–840. doi:10.1093/icesjms/fsm014

Kaplan IM, McCay BJ (2004) Cooperative research, co-management and the social dimension of fisheries science and management. Mar Policy 28:257–258. doi:10.1016/j.marpol.2003.08.003

Kolding J, van Zwieten PAM (2011) The tragedy of our legacy: how do global management discourses affect small scale fisheries in the south? Forum Dev Stud 38:267–297. doi:10.1080/08039410.2011.577798

Leuuwis C (2004) Communication for rural innovation. Rethinking agricultural extension. Blackwell Science, Oxford

Liu J, Dietz T, Carpenter SR, Alberti M, Folke C, Moran E, Pell AN, Deadman P, Kratz T, Lubchenco J, Ostrom E, Ouyang Z, Provencher W, Redman CL, Schneider SH, Taylor WW (2007) Complexity of coupled human and natural systems. Science 317:1513–1516

Longhurst R (2010) Semi-structured interviews and focus groups. In: Clifford N, French S, Valentine G (eds) Key methods in geography. Sage Publications, London, pp 117–132

Mahon R, McConney P, Roy RN (2008) Governing fisheries as complex adaptive systems. Mar Policy 32:104–112. doi:10.1016/j.marpol.2007.04.011

Marín A, Berkes F (2010) Network approach for understanding small-scale fisheries governance: the case of the Chilean coastal co-management system. Mar Policy 34:851–858. doi:10.1016/j.marpol.2010.01.007

Njaya F (2007) Governance challenges for the implementation of fisheries co-management: experiences from Malawi. Int J Commons 1:137–153. doi:10.18352/ijc.21

Nursey-Bray MJ, Vince J, Scott M, Haward M, O'Toole K, Smith T, Harvey N, Clarke B (2014) Science into policy? Discourse, coastal management and knowledge. Environ Sci Policy 38:107–119. doi:10.1016/j.envsci.2013.10.010

OMNRF (2014) Lake nipissing fisheries management plan: "valuing a diverse fishery". Ontario Ministry of Natural Resources and Forestry, Toronto. Available online at https://dr6j45jk9xcmk.cloudfront.net/documents/4387/lake-nipissing-final-fishmp-rd-approval-2014-09.pdf

Orensanz JM, Parma AM, Ciocco N, Cinti A (2007) Achievements and setbacks in the commercial diving fishery of San José Gulf, Argentine Patagonia, Fisheries Management. Blackwell Publishing Ltd, Oxford, pp 68–87

Ostrom E (1996) Crossing the great divide: co-production, synergy, and development. World Dev 24:1073–1087. doi:10.1016/0305-750X(96)00023-X

Ostrom E (2009) A general framework for analyzing sustainability of social-ecological systems. Science 325:419–422. doi:10.1126/science.1172133

Parry S, Murphy J (2013) Towards a framework for analysing interactions between social science and environmental policy. Evid Policy 9:531–546. doi:10.1332/174426413X13836455133196

Perez de Oliveira L (2013) Fishers as advocates of marine protected areas: a case study from Galicia (NW Spain). Mar Policy 41:95–102. doi:10.1016/j.marpol.2012.12.024

Rivera A, Gelcich S, García-Florez L, Alcázar JL, Acuña JL (2014) Co-management in Europe: insights from the gooseneck barnacle fishery in Asturias, Spain. Mar Policy 50(Part A):300–308. doi:10.1016/j.marpol.2014.07.011

Rivera A, Gelcich S, García-Flórez L, Acuña JL (2016) Assessing the sustainability and adaptive capacity of the gooseneck barnacle co-management system in Asturias, N. Spain. Ambio 45:230–240. doi:10.1007/s13280-015-0687-z

Rudd MA (2011) How research-prioritization exercises affect conservation policy. Conserv Biol 25:860–866. doi:10.1111/j.1523-1739.2011.01712.x

Rudd MA (2015) Scientists' framing of the ocean science–policy interface. Glob Environ Change 33:44–60. doi:10.1016/j.gloenvcha.2015.04.006

Rudd MA, Ankley GT, Boxall A, Brooks BW (2014) International scientists' priorities for research on pharmaceutical and personal care products in the environment. Integr Environ Assess Manag 10:576–587. doi:10.1002/ieam.1551

Schut M, van Paassen A, Leeuwis C (2013) Beyond the research–policy interface. Boundary arrangements at research–stakeholder interfaces in the policy debate on biofuel sustainability in Mozambique. Environ Sci Policy 27:91–102. doi:10.1016/j.envsci.2012.10.007

Simon D, Schiemer F (2015) Crossing boundaries: complex systems, transdisciplinarity and applied impact agendas. Curr Opin Environ Sustain 12:6–11. doi:10.1016/j.cosust.2014.08.007

Soto CG (2006) Socio-cultural barriers to applying fishers' knowledge in fisheries management: an evaluation of literature cases. PhD Thesis, Simon Fraser University, Burnaby, Canada. Available online at http://summit.sfu.ca/item/2401

Sowles J (2011) Evaluation of a community ecosystem-based natural resource management plan for Taunton Bay, Maine. Available online at http://www.maine.gov/dmr/council/tauntonbay/finalrptsowles.pdf

Sutton AM, Rudd MA (2014) Deciphering contextual influences on local leadership in community-based fisheries management. Mar Policy 50(Part A):261–269. doi:10.1016/j.marpol.2014.07.014

Sutton AM, Rudd MA (2015) The effect of leadership and other contextual conditions on the ecological and socio-economic success of small-scale fisheries in Southeast Asia. Ocean Coast Manag 114:102–115. doi:10.1016/j.ocecoaman.2015.06.009

Sutton AM, Rudd MA (2016) Factors influencing community fishers' leadership engagement in international small-scale fisheries. Front Mar Sci 3:116. doi:10.3389/fmars.2016.00116

van Paassen A, Werkman R, Pedroli B, van den Berg J, Steingrover E, Leeuwis C (2011) Conclusion: from knowledge for action to knowledge in action. In: van Paassen A, van den Berg J, Steringrover E, Werkman R, Pedroli B (eds) Knowledge for action. The search for effective collaborative research for sustainable landscape development. Wageningen Publishers, Wageningen

Weaver CP, Mooney S, Allen D, Beller-Simms N, Fish T, Grambsch AE, Hohenstein W, Jacobs K, Kenney MA, Lane MA, Langner L, Larson E, McGinnis DL, Moss RH, Nichols LG, Nierenberg C, Seyller EA, Stern PC, Winthrop R (2014) From global change science to action with social sciences. Nat Clim Change 4:656–659

Weible CM, Sabatier PA (2005) Comparing policy networks: marine protected areas in California. Policy Stud J 33:181–201. doi:10.1111/j.1541-0072.2005.00101.x