Methods to use fishers' knowledge for fisheries assessment and management

J.M. (Lobo) Orensanz, Ana M. Parma and Ana M. Cinti
Centro Nacional Patagónico (CONICET), 9120 Puerto Madryn, Argentina
J.M. Orensanz: lobo@uw.edu; A.M. Parma: anaparma@gmail.com;
A. Cinti: colocinti@gmail.com

ABSTRACT

Fisher's knowledge (FK) pertains to all the components of a fishery, conceived as a social-ecological system: the target resources and the ecosystems of which they are part, the fishing process, and the social, cultural, economical and governance subsystems. We consider FK from two different perspectives: utility and governance. The first focuses on the content and value of FK; the second emphasizes the role of fishers in assessment and the management process. Under the utility perspective, fishers are providers of information. Critical aspects are the assessment of reliability of the information provided, including the identification of various forms of cognitive biases, and the design of methodological approaches that minimize these biases. Under the governance perspective, collaboration is seen as an intellectual partnership between fishers, scientists and managers, in contrast to cooperative activities in which fishers assist in the execution of particular tasks but have no significant intellectual contribution. We discuss merits and limitations of the two related modes of fishers' engagement in assessment and management –as information providers and as collaborators– and illustrate them with a selection of examples from artisanal and industrial fisheries, mostly from the Americas. Finally, we highlight guidelines for the success of collaborative action derived from the cumulative experience from a number of projects, and emphasize the importance of the institutional context within which FK is communicated and used in assessment and management. Institutional ambits for collaboration need to be established at multiple scales, from the local scale of the fishing communities to the regional scale at which strategic management issues are addressed.

RESUMEN

El conocimiento de los pescadores (CP) es pertinente a todos los componentes de una pesquería, concebida ésta como sistema socio-ecológico: los recursos-objetivo y los ecosistemas de los que forman parte, el proceso de pesca, y los subsistemas social, cultural económico y de gobernanza. Aquí consideramos el CP desde dos perspectivas diferentes: utilidad y gobernanza. La primera se focaliza en el contenido y valor del CP; la segunda enfatiza el role de los pescadores en los procesos de evaluación y manejo. Bajo la perspectiva utilitaria, los pescadores son proveedores de información. La evaluación de la confiabilidad de la información provista, incluyendo la identificación de varios tipos de sesgo cognitivo, y el diseño de metodologías que minimicen esos sesgos son aspectos críticos de la perspectiva utilitaria. Bajo la perspectiva de gobernanza, la colaboración es entendida como una asociación intelectual entre pescadores, científicos y administradores, en contraste con las actividades cooperativas en las que los pescadores asisten en la ejecución de tareas particulares pero no tienen una contribución intelectual significativa. En este documento discutimos los méritos y limitaciones de los dos modos de involucrar a los pescadores en la evaluación y el manejo –como proveedores de información y como colaboradores- y los ilustramos con una selección de ejemplos, primariamente de las Américas. Finalmente, resaltamos algunas pautas para el éxito de acciones colaborativas, derivadas de la experiencia acumulada en un número de proyectos, enfatizando la importancia del contexto institucional dentro del cual el CP es comunicado y utilizado en la evaluación y el manejo. Los ámbitos institucionales para la colaboración deben ser establecidos a múltiples escalas, desde la escala local de las comunidades pesqueras hasta la escala regional a la cual se consideran los aspectos estratégicos del manejo.

INTRODUCTION

"Fisheries", whether industrial or artisanal, can be understood as complex social-ecological systems (SESs), composed of multiple subsystems: resource, users, governance and their interactions (Ostrom, 2007, 2009). This notion is congruent with FAO's Ecosystem Approach to Fisheries (FAO Fisheries Department, 2003). Attention to all the components that comprise a fishery is particularly relevant for the assessment and management of small-scale and artisanal fisheries (Berkes *et al.*, 2001; García *et al.*, 2008), where fishers, fishing communities, resources and the environment are inextricable for the purposes of analysis and praxis. In this context "fisheries assessment" pertains to all the components of the fishery, in contrast to "fisheries stock assessment", which has been the centerpiece of classical fishery science. The assessment of fisheries must be approached at a hierarchy of levels, from the construction of conceptual models of entire SESs to models (whether formal or conceptual) of specific subsystems (e.g. harvested resources). This process requires the organization of large amounts of heterogeneous information, both research- and experience-based. The latter, which includes fishers' knowledge (FK), is of particular significance in the case of "data poor" fisheries which, paradoxically, tend to be those in which complexity is often irreducible.

We use a working definition of "fishers' knowledge" (FK) that is deliberately broad: the body of experiential knowledge and insights that fishers have about a fishery, including the ecological resource base and the ecosystem, fishing practices, fishing communities and livelihoods, governance and markets, and their dynamic relationships. Our working definition of FK is wider in scope than the notions of Traditional, Local or Indigenous Ecological Knowledge (TEK/LEK/IEK), as knowledge may not be traditional in the sense of being handed down through generations by cultural transmission, and may or may not be shared . The main distinguishing characteristic of FK is that it is experience-based. Fishers' knowledge has long been used in stock assessment and other branches of fishery science, albeit often not explicitly. This is the case of logbook programs (whether voluntary or mandatory), usually rich in information about fishers' behavior (e.g. spatial or temporal patterns of fishing effort allocation), which is reflective of FK. More recently, indirect use of fishers' knowledge on stock distribution and habitat suitability has become available through GPA data-loggers (e.g. Fernández-Boan *et al.*, 2013) and Vessel Monitoring Systems (VMS, Lambert *et al.*, 2012). Yet, explicit acknowledgement of the value of fishers' knowledge, its potential use in many areas of assessment and management, and ways of integrating it with scientific knowledge did not gain momentum until the late 1990s (Johannes *et al.*, 2000).

Fishers' knowledge can be considered from two different perspectives (Daw 2008): (1) the **utility perspective**, under which it is important to determine whether fishermen can perceive, recall and report fish abundances in a way that is sufficiently reliable to support assessment or management, and (2) the **governance perspective**, emphasizing fishers' roles in fisheries assessment and the management process. Related to these two perspectives, two modes of fishers' engagement may be distinguished (Daw, 2008, p. 91): "extractive", and "participatory" or "collaborative" (in the sense of NRC, 2004; Kay *et al.*, 2012). The extractive mode emphasizes the utility of FK: fishers are a source of knowledge which, once collected, can be stored, processed, reported, "integrated" with other sources of information, and eventually used in assessment or management, separately from fishers themselves (typically by scientists and/or managers). There is an extensive scholarly literature that explicitly or implicitly adheres to this approach, emphasizing the capture of FK, the assessment of possible biases, and the extent to which FK coheres with other types of information (typically scientific knowledge). Results are usually discussed with regards to their potential significance, but in most cases are not immediately used in support of assessment or management. A subset of the literature addresses the *a posteriori* "integration" of scientific and fishers' knowledge, once the latter has been gathered. In contrast to the extractive mode, in collaborative approaches fishers themselves are involved in the identification of knowledge gaps and priorities, survey design, monitoring, and the conduction of research projects. Their knowledge is directly integrated in the context of participatory governance structures, where fishers contribute to the management process.

In this report we examine a number of cases in which the value of FK has been considered in relation to management and/or assessment, including both extractive and collaborative approaches, with an emphasis on fisheries in the Americas. We identify and illustrate aspects in which these approaches are most valuable, and draw some general conclusions as to how to apply FK to fisheries assessment and management.

HOW CAN FK BE INFORMATIVE?

Fishers' knowledge is a highly valuable source of information for many aspects of fisheries assessment and management, including target resources, the fishery and potential responses to regulations (TextBox). Thornton and Maciejewski Scheer (2012) made an extensive compilation of cases in which local and traditional knowledge (LTK) on the marine environment has been explicitly documented, with an emphasis on bridging LTK and science. Over the last decade, extractive surveys have extensively documented the scope of FK and its degree of consistency with other sources of information; a selection of examples is summarized in Table 1. Extractive surveys may include questionnaires, fishers and households interviews, focus group meetings, participatory mapping, workshops and participant observation (Table 1)[3]. Although not indicated in the table, fishers' knowledge derived indirectly through logbook programs or VMS records is a case of the extractive mode. The contribution of FK in the context of collaborative partnerships is discussed in a subsequent section. While "ecological" knowledge (whether local, traditional or indigenous) tends to be emphasized in the literature documenting extractive-type studies, FK useful for assessment and management also pertains to the merits of alternative regulations considered for implementation, to access and tenure systems, and to social, cultural and economical aspects- in other words, to all the subsystems of *fisheries* when considered as SESs (e.g. Kalikoski and Vasconcellos, 2003).

What specific aspects of assessment and management can be informed by FK?

Assessment

- Design of monitoring, sampling and survey protocols
- Performance of fishing gear and fine-tuning of survey gear operations.
- Habitat mapping

Continued on next page

[3] Discussion of the various extractive methods is outside the scope of this paper.

Continued from next page

- Spatial distribution of target resources
- Temporal trends in resource abundance or ecosystem conditions
- Interpretation of catch statistics, and of CPUE and effort allocation data
- Parameterization of simulation models used for management strategy evaluation
- Evaluation of harvest controls (size, sex, season, rotation, spatial closures)

Management

- Perception and acceptance of management regulations; gauging behavioral responses of fishers to management action
- Baselines and recovery targets
- Planning of direct intervention to enhance productivity (habitat and prey manipulation, control of predators or competitors, recruitment enhancement)
- Design of spatially explicit strategies
- Evaluation of alternative methods to regulate access, including informal tenure systems
- Definition of access rights and privileges
- Design of marine protected areas

TABLE 1
Cases of FK gathered through the extractive approach, with indication of actual or potential use in assessment or management

System	Reference	Type of study	Subject of FK	Use of info-Assessment/ Management
HABITAT				
New England industrial fisheries, U.S.	Hall-Arber & Pederson, 1999	Questionnaires, focus group meetings, fishers' records	Importance of habitat for productivity; perceptions of changes in habitat as affecting fish abundance	Specific aspects on which FK could (or was) assisting with data collection identified; findings based on FK should be incorporated into the management process.
Lough Nea, Northern Ireland	McKenna & al., 2008	Interviews and written questionnaires	Mental map of substrate types	
SPATIAL AND TEMPORAL DISTRIBUTION OF RESOURCES				
Small-scale fisheries, northern Gulf of California, Mexico	Moreno-Baez *et al.*, 2010	Interviews, participatory mapping and post-survey workshops	Spatial distribution of different fisheries	Information incorporated to GIS platform; potential support for management discussed
Artisanal fisheries, gulf of Honduras	Heyman & Granados-Dieseldorff, 2012	Interviews and participant observation	Status and trends in marine resources, spatial and temporal dynamics of fishing	Brings to attention fishers' suggestions for improved conservation and management, many already implemented
Benthic fisheries, Region X, S Chile	Chinquihue Foundation, 2010	Participatory mapping	Spatial distribution of various benthic resources	Study required by the fisheries authority; information compared and combined with survey data
Artisanal fishery, Los Patos Lagoon estuary, Brazil	Schafer & Reis, 2008	Participatory mapping and collaborative fieldwork	Location, categories and extension of fishing areas; landmarks and toponyms	Incorporation of georeferenced FK to GIS platform; potential implications considered
Scallop fishery, Alaska	Turk, 2000; Orensanz *et al.*, 2005	Skippers' logbooks	Location and boundaries of fishing beds	Trawl survey design shown to be inadequate for assessing scallop stocks
LIFE HISTORY, ECOLOGY, MIGRATIONS				
Small-scale fisheries, Sao Paulo, Brazil	Leite & Gasalla, 2013	Interviews	Temporal/spatial occurrence of mature females and juveniles. Fishing grounds identified, essential fish habitats defined and seasonality specified for three fisheries	Delphi-method used to consolidate results from interview program; specific guidelines offered for future management (zoning, gear regulations, seasonal closures)

TABLE 1 (CONTINUED)

System	Reference	Type of study	Subject of FK	Use of info-Assessment/ Management
Artisanal snapper fishery, Brazil	Begossi *et al.*, 2011	Interviews	Fish habitat, reproductive season and diet	Possible generic implications discussed
Bluefish, Brazil	Silvano & Begossi, 2010	Interviews	Fish diet, reproduction and migrations	Research project seen as contributing to development of co-management
Cod, Newfounland and Labrador, E Canada	Murray *et al.*, 2008	Interviews and workshops, combined with scientific information	Stock complex with multiple populations; evidence of movements and stock structure at the local scale	Complement science-based information at small (local) scale. Hope study will assist active ocean stewardship; fisheries authority emphasizes joint stewardship and devolution of management responsibility
Inshore cod, Newfoundland and Labrador, E Canada	Wroblewski & al., 2005	Interviews, summary of previous studies	Cod migration and color phenotypes; existence of inshore and nearshore stocks inferred	Hypothesis on recolonization of offshore spawning grounds by inshore cod; support for development of local co-management
Land crab gathering, Puerto Rico	Govender, 2007	Interviews	Gatherers have clear understanding of crab ecology, tuning harvest schedules in accordance to crab life cycle	Recommended that TEK be considered to modify management plan, disregarded by gatherers
TRENDS IN SIZE AND ABUNDANCE				
Interrtidal chiton harvests, Kenai Pa., Alaska	Salomon & al., 2007	Interviews	Abundance of several benthic invertebrates declined serially since 1960s, coincidentally with changes in human behavior and reestablishment of sea otters	
Fisheries of lower Tocantins River, Brazilian Amazonia	*Hallwass et al., 2013*	Interviews, combined with field and historical data	Long-term impacts of dam construction on fish abundance	Potential use of LEK in management discussed
Reef fishes, eastern Brazil	Bender *et al.*, 2013	Interviews	Decline of several fish species, mostly snappers and groupers	Setting a baseline of fish abundance; baseline offered as support for recovery targets and future management strategies in an MPA
Multiple marine species, northern Gulf of California, Mexico	Ainsworth, 2011	Interviews, and CPUE from logbooks (a few boats)	General decline in species abundance across fished and unfished taxa, with a few exceptions	Support for EBFM-oriented modelling; merit of combining multiple sources of information, fuzzy logic approach
Artisanal fisheries, Colombian Caribbean coast	Cuello & Duarte, 2009	Interviews conducted as part of participatory workshops	Change in composition of the catch and reduction of individual size	Support for possible temporal or partial closures
Gulf grouper, Gulf of California, Mexico	Saenz-Arroyo & al., 2005a	Interviews combined with ofther sources of information	Abundance and size started to decline well before statistics started to be recorded	Reconstruction of past levels of abundance (baselines)
Scallop diving fishery, San Jose Gulf, Argentine Patagonia	Orensanz *et al.*, 2006	Interviews	CPUE decline and post-closure recovery	Support for consensus about status of the fishery in a participatory management context
SPECIES INTERACTIONS				
Lobster fishery, Gulf of St. Lawrence, E Canada	Davis *et al.*, 2004	Collaborative field work	Fishers' perceptions suggest hypothesis of white hake predation affecting lobster recruitment	Possible consideration of predator-prey interaction in assessment dismissed
Lobster fishery, Gulf of Maine, east coast of US	Boudreau & Worm, 2010	Interviews	Cod is a significant lobster predator	
RESOURCE QUALITY				
Sea urchin diving fishery, South Chile	Barahona *et al.*, 2005; Moreno *et al.*, 2006	Participatory mapping	Geographic pattern of sea urchin roe quality (color)	Interpretation of fishing intensity patterns; implications for zoning (including reproductive reserves) considered in participatory context

TABLE 1 (CONTINUED)

System	Reference	Type of study	Subject of FK	Use of info-Assessment/ Management
ACCESS AND TENURE				
TURF system for benthic fisheries, Chile	Cinti, 2006	Interviews and questionnaires	Collaboration among fishers, income derived from the TURFs, occupational security, participation in management, taxation, and equity	An enhanced role of fishers in management decisions was recommended
Bivalve fisheries, Seri people, Gulf of California	Basurto, 2005	Participant observation and interviews	Informal tenure system documented, including rules to grant access to outsiders	
FISHERS PREFERENCES AND RESPONSE TO REGULATIONS				
Shellfish diving fishery, Bahia Kino, Gulf of California, Mexico	Cinti *et al.*, 2010	Interviews and participant observation	Support for implementing regulatory measures	Assessment of management system, access rules, monitoring, enforcement; preliminary baseline for specific management plans, as required by Mexico's fisheries act
Shrimp trawl fishery, southern Gulf of California, Mexico	Foster & Vincent, 2010	Interviews	Fishers identify problems generated externally, distancing themselves from responsibility for management	Identification of candidate trawl-free areas that might find acceptance among fishers; conclusions relative to viability of trawl-free areas and capacity reduction
SS reef fishing in MPA, Veracruz, Mexico	Jiménez-Badillo, 2008	Questionnaires, field obs., focus group discussions	Socioeconomic characterization of fishery in MPA used to develop management system balancing livelihoods and conservation needs	Regulations unviable, fishing gear inoperative in zones where fishing would be allowed. Proper communication channels not established, recommended
Small scale fisheries, Paraty, Brazil	Lopes & al, 2013	Interviews and participatory mapping	Fishers perception of MPAs	Changes suggested in the design of MPAs that would likely reduce conflict between fishers and enforcement agencies
Scottish demersal fisheries, UK	Rossiter & Stead, 2003	Interviews		Fishermen favored an effort control system (days at sea) and abolition of quotas
LIVELIHOODS				
Hook-and-line fishing in lakes, Yucatan Peninsula, Mexico	Arce-Ibarra & Charles , 2008	Fishers interviews	Minor significance of fishing for subsistence; recreation significant	
Caiçara communities, coastal Brazil	Hanazaki & al., 2013	Household interviews	Fishing is a livelihood activity for 70 % of the households, main declared activity for 16 %; food insecurity transitory	External threats to SS fishery identified; provide baseline against which future livelihood resilience and food security may be measured
Aquarium fish, Peruvian Amazonia	Moreau & Coomes, 2008	Participant observation, household interviews	Fishery described in two villages of the Peruvian Amazon; differences in participation, reliance and organization explained	Understanding microeconomic conditions at multiple levels (household, village, region) considered essential to adjust management to fishers' needs and avoid inadequate interventions
SOCIAL NETWORKS				
TURFs in benthic fisheries, Chile	Marín & Berkes, 2010	Participant observation, questionnaires and interviews	Networks of actors, functions of actors in co-management, and fishers' perceptions about Chile's co-management arrangement	Highlights challenge in this top-down system of implementing adaptive management to deal with problems as they come up

POTENTIAL BIASES OF FK

The analysis of the reliability of information provided by fishers is critical from a utility perspective. The information provided [i] is often not neutral relative to the interests and expectations of the providers (e.g. it may influence regulatory measures), [ii] may depend on the context in which it was generated and the specific experiences of the providers (e.g. different groups of fishers or fleet sectors, permit holders vs. deck-hands), and [iii] can be influenced by survey design. Interviewed subjects, for example, may gauge the social desirability of their answers, and may attempt to match expectations of the interviewer, eventually led (even if inadvertently) by the latter (Bodreau and Worm, 2010).

Perhaps the most serious impediment for the effective integration of FK in fisheries assessments is the notion that intentional bias can be expected in favor of fishers' vested interests, to the extent that the information retrieved may influence regulations and opportunities (Hall-Arber, 2003; Daw, 2008). Although it is in the best interest of fishers to attend to the long-term viability of resources and fisheries upon which their livelihoods depend, many factors (e.g. poverty, indebtedness, lack of access security, uncertainty about management, distrust) result in a short-term view and a tendency to seek out increased short-term catch opportunities. This short-term view may consciously or unconsciously introduce an optimistic bias in fishers' reports with regards to abundance trends and resource status (Daw, 2008), or a tendency to blame factors other than fishing (e.g. pollution, environmental effects) for declining catch rates.

The high variability in catch rates experienced by fishers limits the ability to discern general trends in abundance from the effects of spatial variability, weather, technological improvements, etc. and may easily lead to a wide range of perceptions (van Densen, 2001). In addition, the ability to recall quantitative information about historical events is generally limited, and cognitive research indicates that respondents faced with questions about "how much", "how long ago", or "how often" resort to inference mechanisms that can be very unreliable (Bradburn *et al.*, 1987). Given these uncertainties and memory limitations, biases in perception may be easily introduced, for example, to reduce uncomfortable incongruence between opinions and actions (i.e. "cognitive dissonance", see Festinger, 1985), deflecting responsibility for declining trends or failing to recognize indicators of "bad news" (Daw, 2008).

There are various other forms of cognitive biases that may impact FK, especially, but not exclusively, the perception of historical trends in resource and ecosystem status. A well-documented source of cognitive bias is the so-called shifting-baseline syndrome (Pauly, 1995), whereby the state of a population or ecosystem used as reference to judge current status shifts over time as populations/ecosystems change, reflecting people's own experience in a form of "generational amnesia" (Papworth *et al.*, 2009). Numerous examples exist in which the magnitude of a reported declining trend in fish abundance or fish size increases with the age and years of experience of an interviewed subject (Saenz-Arroyo *et al.*, 2005b; Bunce *et al.*, 2008; Ainsworth *et al.*, 2008; Ainsworth, 2011); when coupled with evidence of actual biological trends, the change in perception with age is indicative of a shifting-baseline syndrome (Papworth *et al.*, 2009). In this case, relying on more recent accounts of past trends would underestimate the extent of resource depletion relative to unexploited levels.

Other forms of retrospective bias may have the opposite effect of exaggerating reported trends. For example, fishers reports of past catch rates may be biased towards extreme, more memorable events (Daw, 2010; O'Donnell *et al.*, 2010a) due to "availability heuristics" (Tversky and Kanheman, 1973), a form of memory illusion that results from a tendency to evaluate probability of events based on the ease with which an event comes to mind. Also, interview data has been shown to underestimate the frequency of zero catches, when compared with more systematic collections of data such as from logbook programs, leading to overestimation of "normal" catch rates (O'Donnell *et al.*, 2012a). Discrepancies between different sources of data (e.g. interviews versus logbook) may be indicative of such biases, but care needs to be taken to account for the effects of spatial coverage and other sources of variability that affect all types of data compared, whether reported by fishers or collected through monitoring programs. Unfortunately, interviews with fishers are often the only source of information available to set a historic baseline. Questions can be phrased to reduce these biases by enquiring about low, medium and high catch rates separately (Daw *et al.*, 2011), and sensitivity to different assumptions and interpretations of past data need to be evaluated (O'Donnell *et al.*, 2010a,b). Availability heuristics may also affect other types of FK by overestimating the importance of observations that have special meaning for users, for example the impact of predation of some species on the target resource (e.g. Davis *et al.*, 2004).

As argued by Davis and Ruddle (2010), "rational skepticism" needs to be exercised when interpreting and applying FK, similar to any kind of scientific data. This requires critical analysis and the establishment of a firm basis of evidence before a claim is accepted as valid. The importance of following a systematic methodology to gather FK, including explicit establishment of the bases for identifying and selecting informants (Davis and Ruddle, 2010), and contrasting results with other data sources whenever possible, cannot be overemphasized.

COLLABORATIVE RESEARCH, ASSESSMENT AND MANAGEMENT

In addition to research projects designed with the explicit goal of extracting and documenting FK, partnerships between scientists and fishers often provide effective channels through which FK is shared and applied; two-way cross-fertilization between experience-based and research-based knowledge develops as a result. This is generally the case when fishers participate in the assessment and management process, whether or not partnerships are institutionalized through formal co-management arrangements. Regular interactions often lead to collaboration in the development of survey or fishing gear, participation of fishers in survey design and monitoring, direct input in interpretation of fisheries data, and evaluation of management alternatives. Cash *et al.* (2003: 8089) explain how "*collaboration creates a process more likely to produce* ***salient*** *information because it engages end-users early in defining data needs. It can increase* ***credibility*** *by bringing multiple types of expertise to the table, and it can enhance* ***legitimacy*** *by providing multiple stakeholders with more, and more transparent, access to the information production process*."

It is opportune to make a distinction between **cooperative** and **collaborative research** (NRC, 2004). While collaborative research involves an intellectual partnership between fishers and scientists, cooperative activities are defined as those where fishers assist in the execution of particular tasks with no significant intellectual contribution (Wendt and Starr, 2009). An example of a cooperative activity is the chartering of fishing boats to conduct surveys or deploy equipment. In the Chilean system of territorial use privileges granted to artisanal fishers' organizations (AMERBs), assessments are conducted by hired "consultants", who are required by the fishery administration as a condition for approval of mandated baseline studies, management plans and follow-ups (Schumann, 2010). While consultants of the AMERB system were initially envisioned as co-management agents that would facilitate true collaborative partnerships, many of them have become by default quota appraisers, enlisting fishers and their boats to cooperate in conducting diving surveys according to a pre-established design (González *et al.*, 2006; San Martín *et al.*, 2009). Merits of cooperative and collaborative research were reviewed in detail by a panel appointed by the U.S. National Research Council (NRC, 2004), which evaluated case studies from industrial fisheries from the U.S. and other countries (New Zealand, Canada) and developed guidelines for successful collaborative research.

In recent years there have been initiatives in different countries towards the promotion of partnerships between fishers, scientists and other stakeholders. The California Collaborative Fisheries Research Program (CCFRP) is an interesting case in the development of collaborative fisheries research. Formally created in 2006 as a group of scientists, fishers, and resource managers (Wendt and Starr, 2009), the

CCFRP was motivated by provisions of the California's Marine Life Protection Act with the goal of engaging the expertise of fishers and skippers in the development and execution of research programs, and to collect data that could be utilized in stock assessments of nearshore species. One of the most interesting initiatives to foster partnerships between fishers and scientists is the Fishermen and Scientists Research Society (FSRS, www.fsrs.ns.ca/index.html) from eastern Canada, and in association the NSERC-promoted Canadian Fisheries Research Network (www.cfrn-rcrp.ca/Public-Home-EN). The Society was formally established as a nonprofit organization in 1994, after a series of discussions between fishers and a small group of fishery scientists. Its goals included establishing and maintaining a network of personnel within the fishing industry to collect information on the long-term sustainability of the marine fishing industry and to collaborate in fisheries research projects. In New Zealand, individual transferable quotas and a cost-recovery policy have created strong incentives for fishers' participation in assessment, while maintaining the quality standard required by the fisheries authority (NRC, 2004). The industry has collected biological data to be used in assessment and management since the mid 1990s (Harte, 2001; Starr, 2010).

Below we present a collection of selected cases from artisanal and industrial fisheries, mostly from the Americas, to illustrate the engagement of FK in successful collaborative research projects. These cases pertain to collaborative sampling and monitoring, participatory surveys, design of survey methods or gear, gear modifications to avoid bycatch, harvest strategies, evaluation of harvest controls and management strategies, access and tenure systems, and development of management plans. In all the cases there is indication of substantial contribution of FK to the solution of specific management or assessment problems.

Collaborative sampling and monitoring:

- Fishing cooperatives on the Pacific coast of central Baja California, grouped into a federation (FEDECOOP), target lobsters (among other resources) within their territorial concessions. The cooperatives and the fisheries authority collaborate in monitoring the fishery, participation being a formal requisite of the management regime (Ponce-Díaz *et al.,* 2009). Despite the fact that this legal requirement is relatively recent, the cooperatives have collaborated since the 1970s with various institutions (academic, governmental) and nongovernmental organizations (NGOs) to co-produce information relevant for management. Exchange and collaboration has been profuse between fishers and technical personnel of the fisheries authority, from the joint collection of data to discussion of research results. A technical committee organizes annual workshops where results are presented and recommendations for management (including harvest levels) are discussed before they are submitted to the fisheries authority for approval. Workshops are held to define monitoring protocols for the upcoming season. The federation had a leading role in pursuing the certification of the lobster fishery by the Marine Stewardship Council (MSC), achieved in 2004 and renewed in 2011. This was the first artisanal fishery from a developing country to be certified by the MSC.
- The well-organized lobster fishers of Juan Fernández Archipelago (off central Chile) approached scientists within academia to develop their own spatially explicit indicators of stock status and fishery performance, which were then made available to the fisheries authority and used in fostering strategies compatible with the informal but effective traditional tenure system in place in the fishery (Ernst *et al.*, 2010). A collaborative effort led to the design and implementation of a cost-effective logbook-sampling program. Under this bottom-up arrangement, data are shared voluntarily by individual fishers and compiled with assistance from the "sindicato" (a type of fishers' organization). The spatially explicit information collected has been used since 2004 to compute and standardize an index of lobster abundance.

- Culver *et al.* (2010) engaged fishers from a Californian trap fishery in a monitoring program, integrating data collection with fishing activities to provide catch-based indicators of crab populations' status. Their findings substantiated several recommendations: well-defined goals, hands-on training for participants, validation of the collected data, well-defined procedures for handling confidential data, and timely and consistent reviews of the data. The program proved adequate for obtaining comprehensive fishery information in a more cost-effective manner than was then available.

Collaborative surveys:

- 'Sentinel surveys', a special a type of collaborative survey, are conducted on a regular basis on the east coast of Canada through partnerships between the fisheries authority and the fishing industry. They are limited commercial operations designed to maintain a continuous record of fishery-dependent data during temporal closures [http://slgo.ca/bio/index.jsp?source=4&lg=en]. Motivated by the collapse of the cod fishery during the early 1990s, their implementation followed recommendations by the Fisheries Resource Conservation Council (which has participation of managers, scientists and the industry). The fishing industry (ca. 20 organizations) is directly involved in the assessment process. Surveys can reach areas that government trawl surveys cannot access (inshore waters and untrawlable bottom), making use of local knowledge and expertise. An evaluation of the program (NRC, 2004) noticed that "*there is a tension between the rigorous scientific design and adherence to predefined protocols demanded by scientists and the more adaptive 'sizing up' approach used by fishermen to determine resource status. This is an important area of discussion and mutual compromise between the partners. Achieving a workable balance between fishermen's expertise and a defensible statistical design is essential for the effective implementation of cooperative surveys. The discussions leading to this compromise are most effectively achieved through a process of coeducation. Changes in the design, implementation, and analysis of cooperative survey data are continually proposed by both partners and are indicative of a healthy debate and an open dialogue*".
- Because Atlantic halibut is not well estimated with the otter-trawl surveys conducted by the Canadian fisheries authority, collaborative surveys were initiated in 1998 to develop an index of abundance (Zwanenburg and Wilson, 2000). Participating fishers contributed in the development of an annual standardized estimate of commercial CPUE (one of the components of the program). Each year, following the completion of the survey, results are presented in meetings attended by all participants. Results consist of maps showing CPUE for Atlantic halibut and other species of interest, and estimates of fixed station and commercial CPUE. Extensive feedback includes detailed accounts of anomalous observations and ancillary information not formally included in the data collection protocols. Surveys have been successful in increasing the knowledge base for this species and in fostering an effective working relationship between halibut fishers and fishery scientists. Keys to success were (among others) the degree of responsibility assumed by the industry participants, agreement on survey design and protocols, feedback of results to participants on an ongoing basis, and willingness by both partners to commit to a relatively long-term project (NRC, 2004). The high value of halibut was a major incentive.
- The San Diego Watermen's Association (California), which includes commercial sea urchin divers, initiated a data collection program in collaboration with independent scientists and biologists from the fisheries authority (Prince, 2003b). Schroeter *et al.* (2009) explain how both fishery-dependent and fishery-independent data on the local red sea urchin fishery are gathered, organized and

analyzed. Data are collected to support periodical stock assessments needed for management of red sea urchins and the kelp forest ecosystem on which this and other fisheries depend.

- Kay *et al.* (2012) reported the results of a collaborative fisheries research program designed in part to test whether reserves at the Santa Barbara Channel Islands, U.S., led to spillover that influenced trap yield and effort distribution near reserve borders. Industry training of scientists allowed sampling within reserves; data were then analyzed jointly with pre-reserve fishing records, port sampling records, LEK, and other pieces of information. It was concluded that if spillover had an effect, this was too weak to be detected.

Collaborative research on the design of survey methods or gear:

- A program was started in 1998 in the Jarauá area of the Mamirauá Reserve, Brazilian Amazonia, to promote sustainable fisheries (Castello *et al.*, 2009). The area, controlled by four communities, has about 562 km^2 of várzea, a type of floodplain that is subject to marked seasonal flooding. Collaborative research efforts initially focused on developing a method to count pirarucú (*Arapaima* spp.), pulmonate fishes, when they come to the surface to breath. Two experienced fishers, together, counted pirarucú in a few lakes using an improvised method, later standardized over six months of close collaborative work with a graduate student (Castello, 2004). The protocol consisted of counting large pirarucú (longer than 1 m) during a period of 20 min within an area no larger than 2 ha. Fishers were able to count pirarucú by differentiating among surfacing individuals on the basis of subtle visual and acoustical cues, skills developed only by fishers very experienced in harpooning (Castello, 2004). Comparison between counts and mark-recapture estimates in experimental areas were highly encouraging. In 2000 other fishers started to receive training in the protocol, showing that the technique could be passed from one fisher to another. This method used to count the pirarucú has the advantage of being very cost-effective; it is ~ 200 times faster and less expensive than the mark-recapture method. Use of the method expanded, and is currently utilized for the recommendation of catch quotas.
- During the early 1970's there was concern about the collateral ecological effects of scallop dredging in San Jose Gulf, Argentine Patagonia, after a comparable scallop fishery collapsed in a neighboring region. A partnership was established in 1973 between prospective commercial divers, some skippers and biologist from a regional research center to evaluate diving as an alternative to dredging (Orensanz *et al.*, 2006). Equipment was developed by trial and error, and the ecological effects of dredging were documented in the field. The fisheries authority opened the commercial diving fishery in 1976, and dredging has been effectively banned ever since.
- Fishers' cooperatives from western Baja California (México) have a long history of collaboration with academic institutions and fishery authorities. Following collaborative experimentation, escape vents were incorporated to lobster traps by fishers to improve selectivity. Vents were later incorporated by the fisheries authority as a formal regulation (DOM, 2007).
- Annual bottom trawl surveys of the upper continental slope of the west coast of the U.S. provide information on several indicators of groundfish resources. The validity of the slope time series was challenged in 1993 when a representative of the fishing industry, invited to participate on the survey cruise, observed inconsistencies with the design and operation of the survey trawl (Lauth *et al.*, 1998). Scientists, with input from the fishing industry and net manufacturers, reevaluated the design and operation of the survey trawl. It was concluded that steps should be taken to improve the standard survey trawl's performance

and, consequently, the credibility of the survey. Experimental gear research was conducted because of concerns about the performance of the survey trawl, and as a result gear designed used in surveys was improved. These changes had effective implications for the setting of quotas.

Collaborative research on gear modifications to avoid bycatch:

- An apparently effective turtle excluder device (TED) was developed during the 1980s by the U.S. National Marine Fisheries Service (NMFS) to be used in shrimp trawl fisheries (NRC, 2004). Extensive demonstrations with fishers, however, met with opposition as operation of the gear proved to be too cumbersome. Seeking a more acceptable device from within the fishery, agency personnel conferred with industry leaders, who pointed to devices that had been designed for the exclusion of jellyfish that sometimes clogged nets hampering their retrieval. Environmental organizations, commercial fishers, and government personnel participated in the experimental investigation of various modifications of jellyfish excluding devices, and a number of trial TEDs were shown to be highly effective in excluding turtles from trawls. Subsequently, extensive outreach was conducted to demonstrate the prototype TEDs aboard commercial vessels during shrimp operations. A gear design was ultimately accepted by industry, the environmental community, and NMFS, and is still in use today.
- Yellowfin tuna often associate with certain species of dolphins. Tuna purse seine fishers take advantage of that association by locating dolphins visually and then inspecting the herds (primarily by helicopter) to see if a sufficiently abundant tuna school is swimming beneath them (Hall, 1998). Ways to adapt fishing operations to reduce dolphin mortality were explored in the eastern Pacific Ocean and eventually integrated into management regulations. Tuna and dolphins are herded and captured together in the net, but prior to retrieving the net and tuna, fishers release dolphins by the "backdown procedure", in which the vessel puts its engines in reverse, causing submersion of the corkline at the end of the net due to water drag through the fine-meshed net there (the "Medina panel"). Most of the dolphins are released unharmed, although some do die during the fishing operation. The backdown procedure is an invention of tuna fishers, the incentive being avoidance of dolphin bycatch and public concern. Dolphin mortality was reduced by 97% between 1986 and 1995 (NRC, 2004).

Harvest controls and strategies:

- The fishing industry and managers collaborate in the sardine fishery from the Gulf of California through an adaptive management system; frequent surveys allow quick reaction to changes in population abundance, e.g. by closing additional areas to fishing or changing the length of the fishing season (Bakun *et al.*, 2010).
- Trawl-closure areas on the Central Coast of California were designed through a collaborative project that involved fishers, NGOs and managers in the evaluation of conservation benefits and costs of alternative options (Gleason *et al.*, 2013). By combining fine-scale information provided by fishers with biodiversity data, a design was identified that protects large areas of the sea bottom from trawling while minimizing economic impacts from closed fishing grounds.

Management strategy evaluation:

- Walters *et al.* (1993) developed a spatial model for the population dynamics and exploitation of the Western Australian rock lobster fishery in order to explore the efficacy of alternative regulatory schemes. Usefulness of the model was tested in workshop sessions attended by scientists, managers and experienced industry representatives who contributed their FK about the fishery. Fishers (commercial and recreational) suggested policy scenarios, which were then evaluated with a gaming approach. Rapid availability of the results stimulated focused and productive debate among participants, with conclusions summarized at the end of each session. Exercises of this nature have been common place in many other fisheries.

Access and tenure systems:

- Lobster fishing has been the main source of income for the people from the Juan Fernández Archipelago (population ca. 770), located more than 700 km off central Chile, for more than a century. The fishery has operated under a traditional territorial tenure system that has put an effective cap on the size of the fishing force, but until recently was virtually invisible to the fisheries authority (Ernst *et al.*, 2010). Resource science-based assessments have recurrently diagnosed overfishing, the basis for prescribing generic "solutions" with no attention to their possible impacts on the users and on traditional tenure arrangements (Ernst *et al.*, 2013). The local fishers' organization ("sindicato") teamed up with scientists from academia, and with support from a conservation-oriented NGO they documented a traditional tenure system based on harvest rights over fishing spots "owned" by individuals, known as "marcas". Between 2004 and 2012 informal access rules were compiled, marcas were mapped and the traditional tenure system was brought to the attention of the fisheries authority to discourage possibly disruptive top-down management interventions (quotas, reserves, complete closures) (Ernst *et al.*, 2013).

Development of management plans:

- Between 2010 and 2011 the fisheries authority from Chubut Province, Argentina, convened a participatory process to develop a management plan for the San José Gulf commercial diving fishery (Orensanz *et al.*, 2006), involving fishers, agency staff and external scientists. The plan was developed over nine meetings during which consensus was reached on governance issues, oversight of fishing operations, access under a limited entry system, harvest regulations (seasons, gear, etc.), indicators (obtained from collaborative surveys), decisions rules, monitoring, enforcement and communication (Cinti *et al.*, 2011). Fishers' knowledge (e.g. on resource distribution, gear performance, behavior of fishers in the face of various regulations, etc.) was instrumental in all aspects of the plan, which was adopted by the authority and incorporated into the current provincial fisheries legislation.

CONTEXTS FOR THE USE OF FK IN MANAGEMENT

If management is defined in a broad sense, i.e. to include both formal and informal institutions, there are four main modes for the use or engagement of FK in fisheries management:

[1] *Informal* - Under this mode, FK is used by fishing communities or fishers' organizations as informal support for self-imposed measures such as seasonal or area closures, gear restrictions (e.g. banning of gaffs in the Quintana Roo lobster fishery, or of diving in the Juan Fernández commercial lobster fishery; Orensanz *et al.*, 2013), etc. TEK as support for traditional management has been reviewed by Berkes *et al.* (2000), who pointed that those systems have some analogies with adaptive management, in that they emphasize feedback learning and attend to the uncertainty and unpredictability intrinsic to all ecosystems. Retrieval and use of FK within fishing communities can be eventually facilitated by "barefoot ecologists" (Prince, 2003a, 2003b) or through Participatory Action Research (PAR; Christie *et al.*, 2000).

[2] *Bottom-up pressure*, when there is a desire for informal (local) FK-supported management practices to be known or endorsed by management agencies or other formal institutions. Pressure for recognition of FK-support can be accompanied by NGO or academic partners, and enhanced by the media. Castello *et al.* (2009) give a detailed and vivid account of the difficult process of obtaining harvest permits for Amazonian pirarucú, and having quotas supported by FK-based assessment accepted by Brazil's management authority (IBAMA). The Association of Producers and the Mamirauá Institute for Sustainable Development worked together to that end.

[3] *Extractive*, when FK is compiled by researchers through interviews, participant observation, participatory mapping, etc., reported, eventually integrated with other sources of information, and used *a posteriori* (typically by scientists and/or managers) as a component of the support for management guidelines or regulations.

[4] *Participatory*, typically in committees or advisory boards with representation of [1] fishing communities or fishers' organizations, [2] government management agencies and/or their providers of scientific support, [3] academia, and [4] environment- or conservation-oriented NGOs. There are many examples in Latin America, e.g. the Participatory Management Board for the Galapagos Marine Reserve (Castrejón, 2011), the Comisión de Manejo de Pesquerías Bentónicas (COMPEB) in the sea urchin fishery of South Chile (Moreno *et al.*, 2006), the Comité Técnico Consultivo de la Pesquería de Langosta del Pacífico in the Baja California (México) lobster fishery (Ponce-Díaz *et al.*, 2009), and the technical advisory board for the management of artisanal fisheries in San José Gulf, Argentine Patagonia (Orensanz *et al.*, 2006).

In most real-life situations there is an actual mixture of these modes, e.g. the same fishers may adhere to FK-guided practices invisible to managers, promote some measures through bottom-up pressure, be interviewed by scientists from academia, and participate in advisory committees together with scientists and managers.

Much of the FK input to management goes undocumented, and in many cases is communicated verbally within the context of community-based or participatory management (e.g. Nenadovic *et al.*, 2012). This contrasts with scientific support to management, which is usually documented in publications, technical reports (published or unpublished) or agency memoranda. In participatory contexts, the significance of FK-based support may be far greater than what is apparent to external observers accessing written materials. The effective integration of FK into fisheries management requires attending to the institutional context within which that knowledge is communicated. This institutional context must open communication channels and facilitate collaboration at multiple scales, from the local scale of the fishing communities to the regional scale at which strategic management issues are addressed. Nonetheless, this aspect has received little attention in the academic literature.

FINAL CONSIDERATIONS

Both extractive and collaborative approaches to the engagement of FK in assessment and management have merit and limitations.

In the case of the extractive approach, an inquiry is generally conducted by the researchers and FK is used (if at all) *a posteriori*, to support fishery's assessment and/or management and usually "integrated" with information from other sources (e.g. see Figure 1 in Mackinson and Nottestad, 1998). This integration is often considered difficult because of the different cultural contexts in which knowledge originates, although institutional factors can play a significant role (Wilson, 2013). On the positive side, one advantage of the extractive approach is that the researcher has control over the study design and selection of the information providers, improving the representativeness of the results. The design of an inquiry is an important consideration for cases in which there is a diverse group of users and issues under scrutiny are sensitive due to political, social or economical reasons. The aspects in which the extractive approach has proved most valuable for assessment and management include [i] the spatial distribution of habitats, resources and effort allocation, particularly in the context of participatory mapping and with the eventual support of GIS tools; [ii] the reconstruction of trends in indicators of abundance (e.g. CPUE). The first is mostly valuable as support for spatial management strategies (zoning, closures, MPA, rotation), and the second to establish baselines and reference points for stock assessment.

The collaborative approach to FK engagement is generally associated with participatory institutional ambits for research, management and governance. Collaborative research usually originates within any stakeholder group to address and seek out solutions to specific problems identified in those ambits. Areas where collaborative research has proved most fruitful include participatory monitoring and surveys, including the design of survey gear, and the modification of gear or fishing operations to reduce bycatch. Impediments to collaboration may arise when one of the partner groups perceives that its contribution is not appreciated (Johnson and McKay, 2013). Collaborative approaches risk not being representative when there is a tendency in the selection of individual partners ("cherry picking", e.g. selection of fisher partners by the scientific partners) or fishers' representatives. The latter is further complicated when leaders representing fishers in participatory committees become politicized and prioritize their own agendas.

Methodological guidelines of how to engage FK in fisheries assessment and management pertain mostly to the nature of the process. Based on experience, regular collaborative partnerships involving fishers, scientists/technicians and managers constitute the most effective way to engage FK in fisheries assessment and management. The cumulative experience from a number of projects suggests that the following guidelines could contribute significantly to the success of collaborative research projects:

- Promote ambits that facilitate interaction and collaboration among fishers, managers, scientists, and eventually other stakeholders (e.g. NGOs)
- Provide for well-established rules of engagement, based on premises of mutual respect and transparency
- Promote collaborative research
- Identify salient research objectives that are reasonable and valuable to one or more of the collaborating stakeholders; articulate projects around such objectives
- Emphasize practical approaches
- Search for reliable financial support
- Contemplate hands-on training of the participants (scientist, fishers, etc)
- Make arrangements for discussion at all stages: design, implementation and follow-up, as well as for eventual feedback and improvements
- Attend to the soundness of standards, protocols and experimental or survey designs
- Incorporate protocols for data validation
- Attend to issues of confidentiality
- Communicate and disseminate project results, particularly within fishing communities

REFERENCES

Ainsworth, C.H. 2011. Quantifying species abundance trends in the northern Gulf of California using Local Ecological Knowledge. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 3: 190–218.

Ainsworth, C.H., Pitcher, T.J. & Rotinsulu, C. 2008. Evidence of fishery depletions and shifting cognitive baselines in Eastern Indonesia. *Biological Conservation*, 141: 848–859.

Arce-Ibarra, A.M. & Charles, A.T. 2008. Inland fisheries of the Mayan Zone in Quintana Roo, Mexico: Using a combined approach to fishery assessment for data-sparse fisheries *Fisheries Research,* 91: 151–159.

Bakun, A., Babcock, E.A., Lluch-Cota, S.E., Santora, C. & Salvadeo, C.J. 2010. Issues of ecosystem-based management of forage fisheries in "open" non-stationary ecosystems: the example of the sardine fishery in the Gulf of California. *Reviews in Fish Biology and Fisheries* 20: 9–29.

Barahona, N.T., Young, Z., Galvez, P., Orensanz, J.M., Cornejo, S., Mejias, P., Miranda, H., Jerez, G. & Carrasco, J. 2005. Monitoreo biológico pesquero del recurso erizo en la XII Región (Fase I). Project FIP 2003-16, Final Report. Valparaiso (Chile), 328 pp. (available at www.fip.cl)

Basurto, X. 2005. How locally designed access and use controls can prevent the tragedy of the commons in a Mexican small-scale fishing community. *Society and Natural Resources*, 18: 643–659.

Begossi, A., Salivonchyk, S.V., Araujo, L.G., Andreoli, T.B., Clauzet, M., Martinelli, C.M., Ferreira, A.G.L., Oliveira, L.E.C. & Silvano, R.A.M. 2011. Ethnobiology of snappers (Lutjanidae): target species and suggestions for management. *Journal of Ethnobiology and Ethnomedicine*, 7: 11, 22 pp.

Bender, M.G., Floeter, S.R. & Hanazaki, N. 2013. Do traditional fishers recognise reef fish species declines? Shifting environmental baselines in Eastern Brazil. *Fisheries Management and Ecology,* 20: 58–67.

Berkes, F., Colding, J. & Folke, K. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications,* 10 (5): 1251–1262.

Berkes, F. Mahon, R. McConney, P. & Pomeroy, R.S. 2001. *Managing small-scale fisheries: alternative directions and methods.* IDRC, Ottawa, Canada: 320 pp. (available at www.idrc.ca/booktique).

Boudreau, S.A. & Worm, B. 2010. Top-down control of lobster in the Gulf of Maine: insights from local ecological knowledge and research surveys. *Marine Ecology Progress Series*, 403: 181–191.

Bradburn, N.M., Rips, L.J. & Shevell, S.K. 1987. Answering autobiographical questions: the impact of memory and inference on surveys. *Science*, 236, 157–161.

Bunce, M., Rodwell, L.D., Gibb, R. & Mee, L. 2008. Shifting baselines in fishers' perceptions of island reef fishery degradation. *Ocean & Coastal Management*, 51: 285–302.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jager, J. & Mitchell, R.B. 2003. Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences,* 100: 8086–8091.

Castello, L. 2004. A method to count pirarucu *Arapaima gigas*: Fishers, assessment, and management. *North American Journal of Fisheries Management*, 24: 379–389.

Castello, L., Viana, J.P., Watkins, G., Pinedo-Vasquez, M. & Luzadis, V.A. 2009. Lessons from integrating fishers of arapaima in small-scale fisheries management at the Mamirauá Reserve, *Amazon. Environmental Management*, 43:197–209.

Castrejón, M. 2011. *Co-manejo pesquero en la Reserva Marina de Galápagos: tendencias, retos y perspectivas de cambio*. México, Charles Darwin Foundation and Fundación Kanankil. 422 pp.

Chinquihue Foundation. 2010. Investigación y recuperación de recursos bentónicos. Fondo Nacional de Desarrollo Regional, Gobierno Regional de Los Lagos, Chile, 312 pp.

Christie, P., Bradford, D., Garth, R., Gonzalez, B., Hostetler, M., Morales, O., Rigby, R., Simmons, B., Tmkam, E., Vega, G., Vemooy, R. & White, N. 2000. Taking care of what you have- Participatory natural resource management on the Caribbean coast of Nicaragua. Centre for Research and Documentation of the Atlantic Coast (Nicaragua) and International Development Research Centre (IDRC, Canada), 181 pp.

Cinti, A. 2006. The management and exploitation areas for benthic resources from the IVth Region small scale fishermen's perspective (in Spanish). Universidad Católica del Norte, Coquimbo, Chile, 151 pp. (M.Sc. thesis)

Cinti, A., Orensanz, J.M. & Parma, A.M., compilers. 2011. Plan de Manejo para la Pesca Comercial de Mariscos Mediante Buceo en el Golfo San José. Secretary of Fisheries, Chubut Province, Argentina. Puerto Madryn, 73 pp.

Cinti, A., Shaw, W. & Torre, J. 2010. Insights from the users to improve fisheries performance: Fishers' knowledge and attitudes on fisheries policies in Bahía de Kino, Gulf of California, Mexico. *Marine Policy,* 34: 1322–1334.

Cuello, F. & Duarte, L.O. 2009. El pescador artesanal, fuente de información ecológica para la ordenación pesquera en el Mar Caribe de Colombia. Proceedings of the 62nd Gulf and Caribbean Fisheries Institute, Cumana, Venezuela, pp. 463–470.

Culver, C.S., Schroeter, S.C., Page, H.M. & Dugan, J.E. 2010. Essential fishery information for trap-based fisheries: development of a framework for collaborative data collection. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science,* 2: 98–114.

Davis, A., Hanson, J.M., Watts, H. & MacPherson, H. 2004. Local ecological knowledge and marine fisheries research: The case of St. Georges Bay fish harvesters' ecological knowledge of White Hake (*Urophycis tenuis*) predation on juvenile American lobster (*Homarus americanus*). *Canadian Journal of Fisheries and Aquatic Sciences*, 61: 1191–1201.

Davis, A. & Ruddle, K. 2010. Constructing confidence: rational skepticism and systematic enquiry in local ecological research. *Ecological Applications,* 20(3): 880–894.

Daw, T. 2008. How fishers count. Engaging with fishers' knowledge in fisheries science and management. Newcastle University, Newcastle upon Tyne. UK (Ph.D. thesis)

Daw, T. 2010. Shifting baselines and memory illusions –what should we worry about when inferring trends from resource user interviews? *Animal Conservation*, 13: 534–535.

Daw, T.M., Robinson, J. & Graham, N.A.J. 2011. Perceptions of trends in Seychelles artisanal trap fisheries: comparing catch monitoring, underwater visual census and fishers' knowledge. *Environmental Conservation*, 38: 75–88.

Densen, W.L.T. van. 2001. On the perception of time trends in resource outcome. Its importance in fisheries co-management, agriculture and whaling. Ph.D. Dissertation. Twente University, Enschede, The Netherlands, 299 pp.

DOM (Diario Oficial, México). 2007. Modificación a la Norma Oficial Mexicana NOM-006-PESC-1993, para regular el aprovechamiento de todas las especies de langosta en las aguas de jurisdicción federal del Golfo de México y Mar Caribe, así como del Océano Pacífico incluyendo el Golfo de California. Publised on 31 December 1993. 10 pp.

Ernst, B., Chamorro, J., Manríquez, P., Orensanz, J.M., Parma, A.M., Porobic, J. & Román, C. 2013. Sustainability of the Juan Fernández lobster fishery (Chile) and the perils of generic science-based prescriptions. *Global Environmental Change* , 23: 1381–1392.

Ernst, B., Manríquez, P., Orensanz, J.M., Roa R., Chamorro, J. & Parada, C. 2010. Strengthening of a traditional territorial tenure system through protagonism in monitoring activities by lobster fishermen from Juan Fernández Islands (Chile). *Bulletin of Marine Science,* 86: 315–338.

FAO. 2003. The ecosystem approach to fisheries. *FAO Technical Guidelines for Responsible Fisheries*. No. 4, Suppl. 2. Rome, 112 pp.

Fernández-Boán, M., Freire, J., Parma, A.M., Fernández, L. & Orensanz., J.M. 2013. Monitoring the fishing process in the sea urchin diving fishery of Galicia. *ICES Journal of Marine Science* 70: 604–617.

Festinger, L. 1985. *A theory of cognitive dissonance*. Standord, USA, Stanford University Press.

Foster, S.J. & Vincent, A.C.J. 2010. Tropical shrimp trawl fisheries: Fishers' knowledge of and attitudes about a doomed fishery. *Marine Policy,* 34: 437–446.

Garcia, S.M., Allison, E., Andrew, N., Bene, C., Bianchi, G., de Graaf, G., Kalikoski, D., Mahon, B. & Orensanz, J.M. 2008. Towards integrated assessment and advice in small-scale fisheries: principles and processes. *FAO Fisheries and Aquaculture Technical Paper,* No. 515. Rome.

Gendron, L., Camirand, R. & Archambault, J. 2000. Knowledge sharing between fishers and scientists: towards a better understanding of the status of lobster stocks in the Magdalen Islands. *In* B. Neis & L. Felt, eds. *Finding our sea legs*. ISER Books- Faculty of Arts Publications, St. John's, NL, p 6–71.

Gleason, M., Feller, E.M., Merrifield, M., Copps, S., Fujita, R., Bell, M., Rienecke, S. & Cook, C. 2013. A transactional and collaborative approach to reducing effects of bottom trawling. *Conservation Biology*, 27: 470–479.

González, J., Stotz, W., Garrido, J., Orensanz, J.M., Parma, A.M., Tapia, C. & Zuleta, A. 2006. The Chilean TURF system- How is it performing in the case of the loco fishery? *Bulletin of Marine Science* 78: 499–527.

Govender, Y. 2007. A multidisciplinary approach towards understanding the distribution, abundance, and size of the land crab, *Cardisoma guanhumi*, in Puerto Rico. Ph.D. Dissertation, University of Puerto Rico.

Hall, M.A. 1998. An ecological view of the tuna-dolphin problem: Impacts and trade-offs. *Reviews in Fish Biology and Fisheries,* 8:1–34.

Hall-Arber, M. & Pedersen, J. 1999. Habitat observed from the decks of fishing vessels. *Fisheries*, 24 (6): 6–13.

Hallwass, G., Lopes, P.F., Juras, A.A. & Silvano, R.A.M. 2013. Fishers' knowledge identifies environmental changes and fish abundance trends in impounded tropical rivers. *Ecological Applications*, 23: 392–407.

Hanazaki, N., Berkes, F, Seixas, C.S. & Peroni, N. 2013. Livelihood diversity, food security and resilience among the Caiçara of coastal Brazil. *Human Ecology,* 41: 153–164.

Harte, M. 2001. Opportunities and barriers for industry-led fisheries research. *Marine Policy,* 25: 159–167.

Heyman, W.D. & Granados-Dieseldorff, P. 2012. The voice of the fishermen of the Gulf of Honduras: Improving regional fisheries management through fisher participation. *Fisheries Research,* 125-126: 129–148.

Johannes, R. E., Freeman, M.M.R. & Hamilton, R.J. 2000. Ignore fishers' knowledge and miss the boat. ***Fish and Fisheries*** 1: 257–271.

Johnson, T.R. & McCay, B.J. 2013. Trading expertise: The rise and demise of an industry/government committee on survey trawl design. *Maritime Studies*, 11:14.

Kahneman, D., Slovic, P. & Tversky, A. 1982. *Judgment under uncertainty: heuristics and biases*. Cambridge, Cambridge University Press.

Kalikoski, D. & Vasconcellos, M. 2003. The role of fishers' knowledge in co-management of artisanal fisheries in the estuary of Patos Lagoon, southern Brazil. *In* N. Haggan, C. Brignall & L. Wood, eds. *Putting Fishers' Knowledge to Work*, pp. 445-455. Fisheries Centre, University of British Columbia, Vancouver, Canada.

Kay, M.C., Lenihan, H., Guenther, C.M., Wilson, J.R., Miller, C.J. & Shrout, S.W. 2012. Collaborative assessment of California spiny lobster population and fishery responses to a marine reserve network. *Ecological Applications,* 22(1): 322–335.

Lambert, G.I., Hiddink, J.G., Hintzen, N.T., Hinz, H., Kaiser, M.J., Murray, L.G. & Jennings, S. 2012. Implications of using alternative methods of vessel monitoring system (VMS) data analysis to describe fishing activities and impacts. *ICES Journal of Marine Science,* 69: 682–693.

Lauth, R.R., Syrjala, S.E. & McEntire, S.W. 1998. Effects of gear modifications on the trawl performance and catching efficiency of the West Coast upper continental slope groundfish survey trawl. *Marine Fisheries Review,* 60(1): 1–26.

Leite, M.C.F. & Gasalla, M.A. 2013. A method for assessing fishers' ecological knowledge as a practical tool for ecosystem-based fisheries management: Seeking consensus in Southeastern Brazil. *Fisheries Research,* 145: 43–53.

Lopes, P.F.M., Rosa, E.M., Salyvonchyk, S., Nora, V. & Begossi, A. 2013. Suggestions for fixing top-down coastal fisheries management through participatory approaches. *Marine Policy,* 40: 100–110.

Lordan, C., Ó Cuaig, M., Graham, N. & Rihan, D. 2011. The ups and downs of working with industry to collect fishery-dependent data: the Irish experience. *ICES Journal of Marine Science,* 68: 1670–1678.

Mackinson, S. & Nøttestad, L. 1998. Combining local and scientific knowledge. *Reviews in Fish Biology and Fisheries,* 8(4):481– 490.

Marín, A. & Berkes, F. 2010. Network approach for understanding small-scale fisheries governance: The case of the Chilean coastal co-management system. *Marine Policy,* 34: 851–858.

McKenna, J., Quinn, R.J., Donnelly, D.J.& Cooper, J.A.G. 2008. Accurate mental maps as an aspect of local ecological knowledge (LEK): a case study from Lough Neagh, Northern Ireland. *Ecology & Society,* 13(1): 13.

Moreau, M.A. & Coomes, O.T. 2008. Structure and organization of small-scale freshwater fisheries: Aquarium fish collection in western Amazonia. *Human Ecology*, 36: 309–323.

Moreno, C., Barahona, N., Molinet, C., Orensanz, J.M., Parma A.M. & Zuleta, A. 2006. Chapter 3: From crisis to institutional sustainability in the Chilean sea urchin fishery. *In* T.R. McClanahan & J.C. Castilla, eds. *Fisheries Management: Progress towards Sustainability*, pp. 43-65. Blackwell Publ.

Moreno-Baez, M., Orr, B.J., Cudney-Bueno, R. & Shaw, W.W. 2010. Using fishers' local knowledge to aid management at regional scales: spatial distribution of small-scale fisheries in the northern Gulf of California, Mexico. *Bulletin of Marine Science,* 86: 339–353.

Murray, G., Neis, B., Palmer, C.T. & Schneider, D.C. 2008. Mapping Cod: Fisheries science, Fish Harvesters' Ecological knowledge and Cod Migration in the Northern Gulf of St.Lawrence. *Human Ecology*, 36: 581–598.

Nenadovic, M., Johnson, T. & Wilson, J. 2012. Implementing the western gulf of Maine area closure: The role and perception of fishers' ecological knowledge. *Ecology & Society,* 17.

NRC (National Research Council). 2004. *Cooperative research in the National Marine Fisheries Service*. Washington, D.C., National Academies Press,

O'Donnell ,K.P., Molloy, P.P. & Vincent, A.C.J. 2012. Comparing fisher interviews, logbooks, and catch landings estimates **O'Donnell ,K.P., Molloy, P.P. & Vincent, A.C.J.** of extraction rates in a small-scale fishery. *Coastal Management*, 40: 594–611.

O'Donnell, K.P., Pajaro, M.G. & Vincent, A.C.J. 2010a. How does the accuracy of fisher knowledge affect seahorse conservation status? *Animal Conservation*, 13: 526–533.

O'Donnell, K.P., Pajaro, M.G. & Vincent, A.C.J. 2010b. Improving conservation and fishery assessments with local knowledge: future directions. *Animal Conservation*, 13: 539–540.

Orensanz, J.M., Cinti, A., Parma, A.M., Burotto, L., Espinosa-Guerrero, S., Sosa-Cordero, E., Sepúlveda, C. & Toral-Granda, V. 2013. Latin-American rights-based fisheries targeting sedentary resources. *FAO Fisheries and Aquaculture Technical Paper* No. 582 (in press).

Orensanz, J.M., Parma, A.M., Ciocco, N. & Cinti, A. 2006 Chapter 4: Achievements and setbacks in the commercial diving fishery of San José Gulf, Argentine Patagonia. *In* T.R. McClanahan & J.C. Castilla, eds. *Fisheries Management: Progress towards Sustainability*, pp. 68–87. Blackwell Publ.

Orensanz, J.M., Parma, A.M., Turk, T. & Valero, J. 2005. Population dynamics, assessment and management. *In* S. Shumway, ed., *Scallops: biology, ecology and aquaculture*, 2nd Ed., Chapter 14, pp. 765–868. Elsevier Publ.

Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the National* **Ostrom, E.** *Academy of Sciences*, 104: 15181–15187.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science*, 325: 419–422.

Papworth, S.K., Rist, J., Coad, L. & Milner-Gulland, E.J. 2009. Evidence for shifting baseline syndrome in conservation. *Conservation Letters*, 2: 93–100.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution*, 10: 430.

Ponce-Díaz, G., Weisman, W. & McCay, B. 2009. Co-responsibility and participation in fisheries management in Mexico: lessons from Baja California Sur. *Pesca Conserv.*, 1: 14–22.

Prince, J.D. 2003a. The barefoot ecologist goes fishing. *Fish and Fisheries*, 4: 359–371.

Prince, J.D. 2003b. The development of industry based sustainability surveys for the California sea urchin fishery advisory committee. MS, 54 pp.

Rossiter, T. & Stead, S. 2003. Days at sea: from the fishers' mouths. *Marine Policy,* 27: 281–288.

Ruddle, K. 2000. Systems of knowledge: dialogue, relationships and process. *Environment, Development and Sustainability*, 2: 277–304.

Sáenz-Arroyo, A., Roberts, C.M., Torre, J. & Cariño-Olvera, M. 2005a. Using fishers' anecdotes, naturalists' observations and grey literature to reassess marine species at risk: the case of the Gulf grouper in the Gulf of California, Mexico. *Fish and Fisheries*, 6: 121–133.

Saenz-Arroyo, A., Roberts, C.M., Torre, J., Carino-Olvera, M. & Enriquez-Andrade, R.R. 2005b. Rapidly shifting environmental baselines among fishers of the Gulf of California. *Proceedings of the Royal Society B: Biological Sciences*, 272: 1957–1962.

Salomon, A.L., Tanape, N.M.Sr. & Huntington, H.P. 2007. Serial depletion of marine invertebrates leads to the decline of a strongly interacting grazer. *Ecological Applications*, 17: 1752–1770.

San Martín, G., Parma, A.M. & Orensanz, J.M. 2009. The Chilean experience with territorial use rights in fisheries. *In* R. Q. Grafton , R. Hilborn, D. Squires, M. Tait & M. Williams, eds. *Handbook of marine fisheries conservation and management*, pp. 324-337. Oxford University Press.

Schafer A.G. & Reis, **E.** 2008. Artisanal fishing areas and traditional ecological knowledge: The case study of the artisanal fisheries of the Patos Lagoon estuary (Brazil). *Marine Policy,* 32: 283–292.

Schroeter, S., Gutiérrez, N., Robinson, M., Hilborn, R. & Halmay, P. 2009. Moving from data poor to data rich: A case study of community-based data collection for the San Diego red sea urchin fishery. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 1: 230–243.

Schumann, S. 2010. A tenuous triumvirate:The role of independent biologists in Chile's co-management regime for shellfish. *Marine Policy,* 34: 133–138.

Silvano, R.A.M. & Begossi, A. 2010. What can be learned from fishers? An integrated survey of fishers ecological knowledge and bluefish (*Pomatomus saltatrix*) biology on the Brazilian coast. *Hydrobiologia*, 637: 3–18.

Starr, P. 2010. Fisher-collected sampling data: lessons from the New Zealand experience. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 2:47–59.

Thornton, T. F. & Maciejewski Scheer, A. 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: a review. *Ecology & Society*, 17: 8.

Turk, T. 2000. Distribution, abundance and spatial management of the weathervane scallop (Patinopecten caurinus) fishery in Alaska. University of Washington, Seattle, USA. (M.Sc.,thesis)

Tversky, A. & Kahneman, D. 1973. Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, 5: 207–232.

Walters, C. J., Hall, N., Brown, R. & Chubb, C. 1993. Spatial model for the population dynamics and exploitation of the Western Australian rock lobster, *Panulirus cygnus*. *Canadian Journal of Fisheries and Aquatic Sciences,* 50: 1650–1662.

Wilson, D.C. 2013. Examining the two cultures theory of fisheries knowledge: The case of bluefish management. *Society & Natural Resources*, 16: 491–508.

Wendt, D.E. & Starr, R.M. 2009. Collaborative research: An effective way to collect data for stock assessments and evaluate marine protected areas in California. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*., 1: 315–324.

Wroblewski, J., Neis, B. & Gosse, K. 2005. Inshore stocks of Atlantic cod are important for rebuilding the East Coast fishery. ***Coastal Management***, 33: 411–432.

Zwanenburg, K.C.T. & Wilson, S. 2000. The Scotian Shelf and Southern Grand Banks Halibut (*Hippoglossus hippoglossus*) survey—collaboration between the fishing and fisheries science communities. International Council for Exploration of the Sea CM 2000/W:20, 26 pp.