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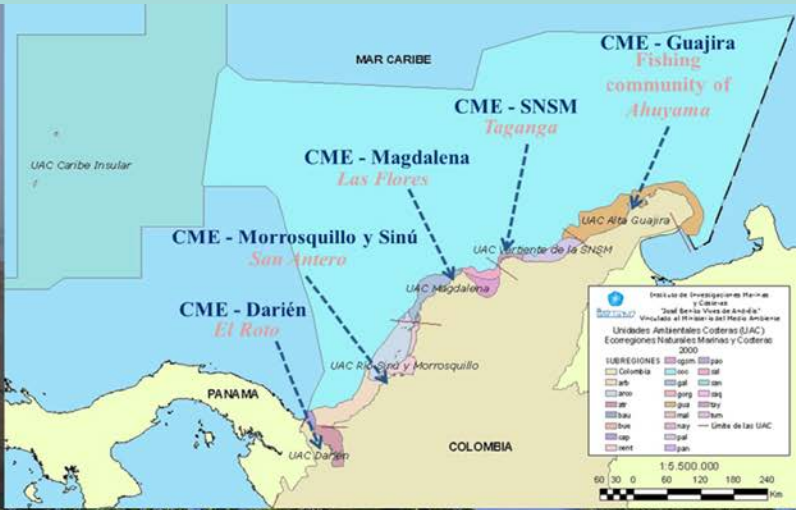
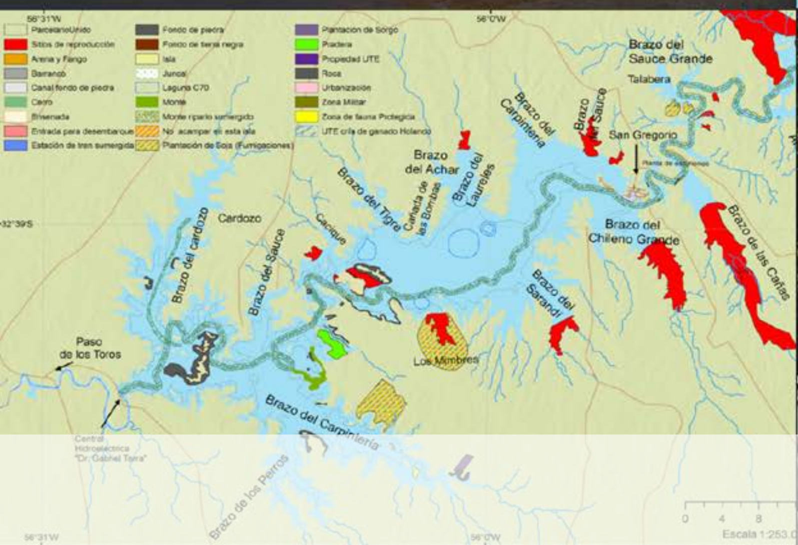
Fishers' knowledge and the ecosystem approach to fisheries

Applications, experiences and lessons in Latin America





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Preparation of this document

This technical paper comprises a series of reviews and case studies from Latin American countries regarding fishers' knowledge (FK) and its application to fisheries management under the ecosystem approach to fisheries (EAF). These papers were compiled by an interdisciplinary group of experts to convey the types of knowledge that fishers possess, the context in which that knowledge is created and used, where and how FK can contribute to data requirements within the EAF, and potential methods and institutional approaches to integrate FK into fisheries science and management.

This publication responds to the pressing need for theoretical frameworks, practical examples and guidance on what FK encompasses and how this knowledge and experience can be integrated into management of fisheries resources under the EAF. The papers highlight underlying principles for working with FK, good practices and lessons learned in knowledge exchange with fishers, and the role of government and legal frameworks in the context of both marine and inland fisheries.

The papers were reviewed internally by two authors, whereby one reviewer was of the same area of expertise and the second reviewer of a different area of expertise to provide an external perspective. Papers have been reproduced as submitted.

Abstract

The ecosystem approach to fisheries (EAF) is a general approach to fisheries management that essentially balances the aims for human and ecological well-being under the broad concept of sustainable development in a fisheries context. The broad data and information base required for implementing the EAF incorporates scientific, traditional and local knowledge of fisheries resources, the ecosystem, and the socio-economic context.

Fishers have a wealth of knowledge and experience that is extremely valuable for research and management of fisheries, particularly in the case of small-scale fisheries in developing countries, where scientific data are often scarce. A major impediment to the integration of fishers' knowledge (FK) in the EAF is the lack of formal guidance on this topic.

This technical paper provides a series of reviews and case studies from nine Latin American countries on how to integrate FK knowledge into fisheries management under the EAF. The cases cover a broad range of topics including the expertise of fishers and its application to the EAF, as well as methods and legal instruments to use FK in fisheries assessment and management.

In general, the papers emphasize FK in the context of small-scale fisheries in both marine and inland systems in Latin America and the role of fishers as active participants in research and management processes.

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Contents

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On behalf of the editor and authors, many thanks are due to Johanne Fischer (former FAO Fisheries Technical Officer) for generating the original idea for this technical paper and for supervising the compilation of contributions, as well as to Helga Josepuit (FAO Senior Fisheries Officer, Rome) for executing its final publication. Thanks are also due to John Valbo-Jorgensen (FAO Fishery and Aquaculture Officer, Panama City) and Daniela Kalikoski (FAO Fishery Industry Officer, Rome) for overseeing and participating in the compilation of these works. The authors thanks the editor Christine Lucas, for translating some of the documents herein.

Finally, the authors wish to thank the small-scale fishers (and their families) who have collaborated with them throughout the years, for their generosity of time, friendship and intellect, which provided the foundation for much of the research presented herein.

Dedication

The authors dedicate this work to Dr José M. (Lobo) Orensanz, friend and colleague who passed away prior to the publication of this work. Lobo Orensanz was a senior scientist at the National Patagonian Center CENPAT - CONICET, the Argentine Council for Science & Technology. His work in conservation and management with Patagonian benthic shellfish fisheries in the 1970s established him as a pioneer in artisanal and data-poor fisheries management. Over decades of work throughout the Americas, he became a leader and mentor in the development of collaborative and ecosystem-based approaches to small-scale fisheries management. His emphasis on knowledge exchange and participation of communities for sustainable management of small-scale fisheries is elaborated herein in his contribution with his co-authors, "Methods to Use Fisher's Knowledge for Fisheries Assessment and Management".

The authors remember Lobo, not only as a scientist dedicated to resource management, conservation, and action-oriented research, but also as a kind, generous, and warm person, who brought talent, initiative and great dedication to addressing major challenges in fisheries management. Some met him for the first time as chair of the workshop on Fishers' Knowledge and the Ecosystem Approach to Fisheries in Central and South America held in Panama in October 2013 where he graciously accepted the task of overseeing the five-day workshop with over 15 invited experts from Latin America. The authors are grateful for this time spent with Lobo and will remember him as an exemplary scientist and human being.

Abbreviations and acronyms

ANCAP	National Administration of fuel, alcohol and Portland cement (Uruguay)
BRD	bycatch reduction device
CBD	Convention on Biological Diversity
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico (National Council for Scientific and Technological Development)
COFI	FAO Committee on Fisheries
CRES	coral reef ecosystem study
DINAMA	National Directorate of the Environment (Uruguay)
DINARA	National Directorate of Aquatic Resources (Uruguay)
EAF	ecosystem approach to fisheries
EBM	ecosystem-based management
EBFM	ecosystem-based fisheries management
EKF	ecological knowledge of fishers
FAPESP	Fundação de Amparo à Pesquisa do Estado de São Paulo (Foundation for Research Support of the State of São Paulo)
FEK	fishers' ecological knowledge
FIFO	Fisheries and Food Institute
FK	fishers' knowledge
GEF	Global Environment Facility
ICMBIO	Instituto Chico Mendes de Conservação da Biodiversidade
IEK	indigenous ecological knowledge
IK	indigenous knowledge
IUCN	International Union for Conservation of Nature
LEK	local ecological knowledge
MA	management agency
MER	marine extractive reserve
MGAP	Ministry of Livestock, Agriculture and Fisheries (Uruguay)
MIDES	Ministry of Social Development (Uruguay)
MPA	marine protected area
PM&E	participatory monitoring and evaluation
SK	scientific knowledge
SNAP	National System of Protected Areas (Uruguay)
SNUC	Brazilian National System for Protected Areas
TED	turtle excluder devices
TEK	traditional ecological knowledge
TL	total length
UDELAR	University of the Republic of Uruguay
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNICAMP	Universidade de Campinas
UTE	National Administration of Power Plants and Electrical Transmissions (Uruguay)
WSEK	western scientific ecological knowledge
UFPR	Federal University of Paraná

PART 1

OVERVIEW OF FISHER'S KNOWLEDGE AND ITS USE IN EAF MANAGEMENT IN LATIN AMERICA

General considerations

ECOSYSTEM APPROACH TO FISHERIES

The ecosystem approach to fisheries (EAF) is a general approach to fisheries management that aims to balance human and ecological well-being under the broad concept of sustainable development in a fisheries context. The EAF incorporates a risk-based management planning process that covers the principles of sustainable development and thus includes the human and social elements of sustainability in addition to ecological and environmental components. The EAF, and other related concepts (e.g. ecosystem-based management [EBM]), were developed in response to the need to implement, in a practical manner, the principles of sustainable development (WCED, 1987), the Convention on Biological Diversity (CBD, 1992) and the Code of Conduct for Responsible Fisheries (FAO, 1995).

The EAF has been adopted by the FAO Committee on Fisheries (COFI) in 2003. It must be stressed that the EAF is not a replacement for current fisheries management approaches, but rather aims at enhancing and complementing existing fisheries management. While information on the biology, ecology and socio-economics of a fisheries is important, the precautionary principle requires that action needs to be taken even where knowledge is lacking. Consequently, the risk management principles adopted by the EAF are based on the assumption that complete knowledge is never available and is not essential to start the process. Instead, the EAF strives to identify and assess relevant issues and priorities through a participatory process which includes all stakeholders. The process combines a precautionary (to reflect the risk) and an adaptive approach (to improve knowledge and adjust decisions) and allows a resource management at conservative (i.e. low) exploitation levels in the absence of sufficient knowledge. This does not mean that fishery data are no longer necessary; on the contrary, to achieve the maximum sustainable yield, high quality data and good knowledge are essential, also in the context of an EAF.

Normally, fisheries managers rely heavily on scientifically derived information. However, while typically of high quality, scientific assessments are costly and normally will not cover all resources or fishing areas of interest. Therefore, it is important to develop management approaches that allow the incorporation of alternative information sources, in particular resource users, into assessment models and decision-making processes, in particular in developing countries where scientific data are often lacking. It Fishers have a wealth of knowledge and experience that is extremely valuable for research and management of fisheries. The long-term empirical data obtained by fishers are often invaluable when examining trends in resource abundance, catch size, fish size, fish movements, spawning habits and habitat quality, and allow information to be nested at spatial and temporal scales. In addition, fishers' knowledge (FK) and experience are often critical in the establishment of a participatory process that integrates stakeholders into multiple stages of the management process.

The participation of fishers as key players in the management process is required by the EAF. However,, the incorporation of fishers' knowledge and expertise for fisheries management has not yet been conceptualised and encouraged at a global level. This document intends to support fisheries managers in this regard by providing relevant perspectives from Latin America on the role of fishers as active participants in this process, reaching from practical examples to theoretical frameworks, methods and guidance. We expect that this contribution will be of value also to fisheries managers of other regions as the main concepts should have a more general application to all areas that face similar challenges and limitations in implementing sustainable fisheries management.

FISHERS' KNOWLEDGE

Fishers' knowledge (FK) comprises the body of experiential knowledge including ecological, resource-based, ecosystem, fishing practices, fishing communities and livelihoods, governance and markets, and their dynamic relationships. This knowledge is developed in a social-cultural and geographical context.

The working definition of FK is broader in scope than traditional, local or indigenous ecological knowledge (TEK/LEK/IEK), but includes these types of knowledge, which are described herein by the authors. The main distinguishing characteristic of FK is that it is experience-based.

THE CONTEXT OF SMALL-SCALE FISHERIES IN LATIN AMERICA

Small-scale fisheries in Latin America feed and provide income for millions of people. These fisheries operate in highly diverse and complex systems, and they are highly diffuse with spatial and temporal dynamics that are challenging to understand and predict owing to multiple ecological, socio-economic and policy interactions. Given the changes that small-scale fisheries face with climate change and regional development and the lack of scientific information in many regions, there is a growing urgency for generating and applying local ecological and fisheries-related knowledge and data for assessment and management under the EAF.

Many Latin American countries are interested in adapting the EAF principles to manage small-scale coastal and freshwater fisheries in data-poor regions. Despite the growing interest in using TEK in this context, its integration into fisheries management has encountered many challenges, which are discussed in these case studies. With examples from nine countries (Figure 1), the authors discuss not only the achievements and benefits of integrating FK into management and collaborating with fishers to collectively manage fisheries, but also the challenges that each has confronted and the lessons learned from overcoming (or not) those challenges. Case studies from South and Central America as well as the Caribbean are presented to illustrate how fishers knowledge can be integrated in different political, economic and social contexts within Latin America.

While the existing case studies of the use of FK are largely consolidated in coastal and estuarine fisheries in some countries of South America and the Caribbean region, there are few examples to guide users on integration of FK in the management of river and floodplain fisheries. South America is the most fluvial continent in the world, holding two large drainage basins, the Amazon River Basin and the Rio de la Plata River Basin, mostly formed by the Paraná Basin. Small-scale fisheries in these large rivers and floodplains play an important role for local economies, rural subsistence, and food security. Fishers manage spatially and temporally dynamic ecological information on habitat, flood regime, and behaviour of multiple species as well as cultural and socio-economic information related to the fishery itself. This knowledge could help fill the gap in scientific knowledge on freshwater fisheries in these regions. Several of the case studies here specifically emphasize the what FK comprises and how FK can be integrated into management through an ecosystem approach to river and floodplain fisheries.

INTEGRATION OF FISHERS' KNOWLEDGE INTO ASSESSING AND MANAGING FISHERIES UNDER THE EAF

The reviews and case studies included in this technical paper demonstrate the opportunities, constraints and challenges for incorporating FK into fisheries assessment and management in Latin America. Together, they provide a comprehensive summary of the kinds of knowledge fishers possess, the context in which that knowledge is generated and used, where and how FK can contribute to data requirements within the EAF, and potential methods and institutional approaches to integrate FK into fisheries science and management. The following general topics are presented:

- biological and fisheries-related knowledge: expertise of fishers;
- how FK can fulfil the data requirements of the ecosystem approach to fisheries;
- methods and institutional approaches for integrating FK into fisheries science and management;
- collaborative and participatory assessment and management with fishers;
- legal instruments and barriers for integrating FK into fisheries management in Latin America;
- examples of engaging fishers in the collaborative assessment and monitoring of fisheries.

The following guiding principles emerged from these case studies on how to integrate FK into fisheries and ecosystem management:

- Use informed consent and transparency to appropriately recognize sources of information, and consider all regional, national and international agreements as well as legal frameworks and protocols for knowledge transmission.
- Consider the context of the resource and its users – including community structure (ethnicity, religion, cultural group, gender and kinship) as well as fisheries subsectors and national policies and socio-economic context.
- Take into account the temporal and spatial scale of fisheries, their resources, environment and management as well as fishers' livelihoods;
- Promote an adaptive management approach (measures must be monitored and adapted in response to social and ecological dynamics in a long-term management process).
- Strengthen collective action and stewardship among stakeholders by taking into account expectations among stakeholders and providing understandable and usable feedback to all stakeholders.

The following recommendation from the case studies and lessons learned can be highlighted:

- All fisheries and ecosystem management must involve fishers and their knowledge.
- Fisheries management and decision-making should follow an interdisciplinary approach based on the social, economic and ecological dimensions of the fisheries system as a guiding principle for sustainability.
- Management design and implementation should provide a space for knowledge exchange among stakeholders that enables or encourages active participation, helps to build capacity, and fosters empowerment, while creating a learning platform where knowledge is coproduced and differences in power are minimized by providing everyone with an equal voice.

Non-systematic approaches to integrate FK are prevalent, but there is a need for more systematic approaches that address scientific concerns.

FIGURE 1

The nine countries (blue) in Latin America within which case studies of fishers' knowledge and its integration into fisheries management are included in this technical paper

Local ecological knowledge (LEK): understanding and managing fisheries

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ABSTRACT

Local ecological knowledge (LEK) is composed of diverse branches that are applicable to the understanding and management of fisheries. Those branches are described here, and the concepts and tools that aid in understanding the relationship between local human populations and nature are considered, particularly the usefulness of LEK for improving the management of small-scale fisheries. We explore three main branches of LEK. First of all, LEK as a perception of nature includes theories, frameworks, and examples for understanding how people perceive and categorize nature, as well as the area of "ethnotaxonomy". Questions originating arising from the disciplines of anthropology and biology, such as the universality of species recognition (or classification), the universality of taxonomic categories, and the general patterns of classification of nature used by human populations, are relevant to this branch. The different perceptions that human populations have of nature are also discussed with a focus on the debate between "utilitarianists" and "intellectualists". The second branch of LEK is the use of nature, also referred to as "ethnoecology", which considers how people perceive and use local natural resources, which resources are important for their livelihoods, and what types of management practices are used for resource extraction. For example, in the case of resource-extractors (e.g., fishers), target species such as commercial fishes are important, and knowledge of target species is often more detailed than knowledge of other species. Finally, the third branch, LEK as an applicable tool for management, approaches the importance of LEK as a driver of and contributor to conventional biological knowledge. The example of LEK as a tool for managing fisheries is illustrated with cases from the scientific literature, and a brief outline of how LEK can be applied to management is discussed in the conclusions. The mentioned branches of LEK overlap and the following sections are not necessarily separate branches of knowledge.

LEK AS A PERCEPTION OF NATURE

Local ecological knowledge (LEK) includes the knowledge local people have of nature: their perceptions, classifications, and understanding of ecological dynamics and functions (ethnoecology), as well as their beliefs. In this study, we use the term local ecological knowledge regardless of whether it is considered to be an aspect of traditional knowledge. Other terms, such as indigenous ecological knowledge (IEK) or traditional ecological knowledge (TEK), are also common in the literature referring to more specific forms of LEK. The main focus of this paper is to understand and apply to fisheries management forms of LEK that, while considered to be outside the conventional system, can complement and be useful to scientific knowledge. As Posey

(1992) observed, traditional knowledge is rich with information about the environment, and very applicable to conservation across a variety of environments and dimensions, such as the genetic manipulation of flora and fauna and the modification of landscapes.

A diverse array of researchers has dealt with LEK, particularly anthropologists and ecologists in the fields of cultural ecology and human ecology. LEK has been studied in a variety of systems, including small-scale agriculture, horticulture, and fisheries. Johannes (1981) was one of the first to apply LEK to fisheries, studying and applying it in the Palau Archipelago, Micronesia (Table 1). Ruddle (2000) identified the *corpus* of LEK as being practical, behavior-oriented, structured, dynamic, and based on long-term empirical observation. In the same study, he described local marine knowledge as comprising the major components of marine ecology and conservation, including knowledge of fish behavior, the marine physical environment and fish habitats, and other ecosystem concepts. Other different and complimentary definitions of LEK, some more conceptual and others more methodological, are listed chronologically in Table 1.

In terms of methodology, the *emic* and *etic* distinction has been an especially useful tool for studying LEK. Methods proposed (Headland *et al.,* 1990) and developed by Harris (1976) have been useful for distinguishing between native views (insider, *emic*) and the views of researchers (outsider, *etic*). The importance of separating native interpretations from the interpretations of researchers has been stressed by many authors: Posey (1992) and Begossi (1992) on food taboos, Berkes (2008) on the Cree system, and Begossi (2013a) more conceptually. In more recent years, a preoccupation with method, adding other variables or other dimensions in the analysis and understanding of LEK, can be observed among researchers, such as Huntington (2011) on historical aspects of the native communities, and Silvano and Valbo-Jorgensen (2008) on comparing native and scientific knowledge through hypothetical analyses (Table 1).

The degree to which people are able to perceive and classify nature is a question of debate. Perspectives range from Levi-Strauss, who emphasized that people recognize and classify nature regardless of whether organisms are identified as useful or not (1962:24), to Hunn (1982: 831, 834), who identified folk science as practical and knowledge as useful and adaptive to the "empty" regions in the folk taxonomic space. Berlin (1992:11) provides an overview of this debate, which is termed "intellectualist" versus "utilitarian" (see Hunn, 1982). Roughly speaking, the intellectualist approaches sees nature perception, classification and identification as a random cognitive process, whereas the utilitarian view argues that the more salient[1] or useful organisms are more easily perceived, classified and identified. In small-scale fishing communities, we have observed that "useful fish" are classified in a more detailed way, such as with binomial nomenclature (Begossi and Figueiredo, 1995). "Useful fish" are actually the salient fish[1]. Hunn (1999: 49, 67) illustrated ecological salience by analyzing perceptual salience in response to the size of plants, mammals, birds, and fish, among others; size was recognized as influencing perceptual salience. Boster and Johnson (1989) argued that intracultural variation or differences are important in that regard: actually it depends on who is asked about the simlarity of organisms. Summing up, in our studies among small-scale fisheries in Brazil, we have observed:

- Studies with snappers have shown that target fish species are recognized in more detail and identified using binomials. Fishers also tend to have more LEK about target species compared to other species (Begossi *et al.,* 2011)
- Among riverine and marine small-scale fishers (the Amazon and the Atlantic Forest, respectively), useful fish species have been given a detailed nomenclature

[1] A salient organism is the one that claim attention, is readily perceived. Salient attributes can be beauty, abundance, large, used for consumption or sale, poisonous, culturally important, among other attributes.

in which morphological and ecological attributes are important. In marine environments, where fish show more diverse morphology than in Amazonian rivers, different taxonomic orders are represented and a LESS detailed, folk nomenclature is used, with many generic names (the opposite occurs in the folk nomenclature of riverine Amazonian fishers, rich in binomials) (Begossi and Figueiredo, 2005; Begossi *et al.*, 2008).

- When small-scale fishers classify higher-ranking groups of fish analogously to the scientific taxonomy, those taxonomies are termed "cousins" or as being part of the same "family" (Begossi *et al.,* 2008). These can be considered to be life-forms in folk taxonomy (Brown 1984).
- Compared to the scientific taxonomy, small-scale fishing communities only have knowledge on a subset of fish, so the universe size is considered to be different for both taxonomies (Begossi, 2013).
- Examples of salience (such as through abundance or color pattern), from coastal fisheries in Brazil, have determined the existence of prototypes in taxonomies from small-scale fisheries (Oliveira *et al.,* 2012).
- Despite being based on morphology and with the exception of color, diagnostic variables used in fish identification differ in importance between folk and scientific taxonomies. Body size, eyes, and scales among others, are used in folk taxonomy whereas rays, spines, gill rakers, and other micro features are used in scientific taxonomy (Begossi, 2013).
- Finally, small-scale fishers should be considered to be important potential partners and "parataxonomists" for inventories associated with research projects (Begossi *et al*., 2008).

TABLE 1
Selected definitions of LEK (local ecological knowledge), or relevant examples, including some associated with the management of fisheries, in order of publication

Reference	Definition	Major association
Johannes (1981)	Traditional native fishermen are especially rich sources of unrecorded knowledge… The native fisherman searches with his eyes and ears. In shallow water he stalks fish at close range on foot…He knows the local currents intimately...He is, in short, more in touch with his prey and their surroundings than his modern, mechanized counterpart (p. vii, parts of preface). A culture is defined in part by the specialized knowledge it possesses (p.148).	Perception of the existence of LEK and its importance as a valuable tool for management
Posey (1986)	Here, using the definition from ethnobiology, it is the study of the knowledge and of the concepts developed by any society in respect to biology. In that sense, ethnobiology relates to human ecology, but the first definition emphasizes the cognitive aspects used by the people being studied (p. 15).	Conceptual, applied to conservation
Berkes (1999, 2008)	The study of traditional ecological knowledge begins with the study of species identifications and classification (ethnobiology) and proceeds to considerations of peoples' understandings of ecological processes and their relationships with *the environment (human ecology)* (p. 3). See also Table 10.1 on page 205.	Holistic, crossing scales, conceptual.
Ruddle (2000); Ruddle and Hickey (2008);	"Empirically based and practically oriented". Ruddle (2000) works out design principles, transmission, components, functions, applications and political issues of coastal-marine knowledge systems. Also, see definitions and comments in Davis and Ruddle (2010: 885) IEK/LEK/TEK* might be regarded as that aspect of a culturally- framed belief system most directly arising from and concerned with food production and other material needs. IEK (Indigenous Ecological Knowledge) TEK (Traditional Ecological Knowledge)	Conceptually analytic, applications to management (including its misuse)
Begossi (2008)	Four elements are considered for the process of linking LEK and management: (1) an understanding of the natural environment of the fishery and on the use of natural resources by locals; (2) the knowledge of the marine area used by fishers, i.e., location of fishing spots for each species; (3) the understanding of fisher behavior, e.g., using tools from optimal foraging theory; and (4) the knowledge fishers have of the biology and ecology of species and their LEK, based on studies of the ethnobiology, ethnoecology, and ethnotaxonomy of fish (p. 591).	Operationalizing concepts to record LEK and apply to management

TABLE 1 (CONTINUED)

Reference	Definition	Major association
Huntington (2011)	The concept of scientists using indigenous, or traditional, knowledge in their research has received increasing attention over the past few decades. This is particularly true in the Arctic, where the potential global effects of changes such as permafrost thaw and ice melt have created an urgent need to understand how climate change is affecting the region. Historical physical data about the region are lacking, but indigenous cultures there have retained practices and knowledge acquired over countless generations (p. 182)	Historical contexts, applications, data-sharing and exchange
Silvano and Valbo-Jorgensen (2008)	Our results may contribute to the so-called "data-less" fisheries management and research in the studied regions and other similar places, besides raising the interest of biologists to properly include fishermen's LEK when planning and conducting fisheries surveys (p. 659). As a general rule, we considered unexpected hypotheses, which contradict existing biological data, of low likelihood. Medium likelihood was assigned to novel hypotheses, which could not be properly compared to available scientific knowledge. Hypotheses that closely agree with scientific data were considered as being of high likelihood. However, it should be underlined that this classification does not reject the LEK: likelihood refers to the hypotheses, not to the fishermen's LEK on which they are based (p. 667).	Analytical methods to understand LEK.
Lopes *et al.* (2013)	There is no doubt that even data-less management is better than no management or an open access situation. However, management disregarding the local historical use of resources and associated local rules as well as the social and economic background can result in conflicts. In the situation evaluated here, this was most likely the case (p. 107).	Valuating and applying LEK to management, use of statistical tools, cluster analysis

LEK AS AN APPLICABLE TOOL FOR MANAGEMENT

This section examines how LEK associated with fish biology can help researchers and managers and also addresses methods of research. Fishers have shown a deep knowledge about fish diet and reproduction, the focus of this section, as well as habitat (Silvano and Begossi, 2002).

Knowledge of fish biology

One of the major management problems is obtaining knowledge about the biology of fish species. Fish reproduction can vary from place to place along with diets, which can vary according to local prey availability and other factors. The behavior of fish species is usually a local feature as well, and knowing what a species eats, where it is located, if it aggregates, if it migrates, and when it reproduces is essential for management. This is especially challenging for data-poor, small-scale fisheries, which characterizes most of those in Latin America but especially those on the coast of Brazil. Fish migration and reproduction are two features of fish biology least known to both biologists and fishers (Silvano and Begossi, 2002), so research should be concentrated in these areas to enable successful management. Among species targeted by small-scale fisheries, some are vulnerable probably helped by to the following conditions:

- They are being caught below their length at first maturity. In informal talks, fishers complain that the largest individuals of some species, such as dusky grouper, *Epinephelus marginatus*, are getting difficult to find, and they have to travel further to find it. Similar observations refer also to *E. niveatus*, which is currently hardly seen in local fish markets of small-scale fisheries in the coast of Brazil.
- A record of a sample of species caught along the coast of Brazil by small-scale fishers is listed below and shows the mean length (Total length, mm), the length at first maturity (Lm), and the IUCN RED LIST STATUS for each species (Table 2).
- Nevertheless, as we will illustrate in the next section, LEK is an interesting tool that allows fishers to assist with the management of these vulnerable species as well as aquatic zoning.

Many authors have dealt with the knowledge that local fishers have about species, including Valbo-Jorgensen and Poulsen (2008), who studied the spawning and migration of 50 fishes in the Mekong River through interviews with 355 expert fishermen. Silvano *et al.* (2006) studied the LEK of spatial and temporal patterns of spawning and migration for 13 marine and estuarine fish species in 7 small-scale fishing communities along the Brazilian coast. In an earlier study of riverine small-scale fishers of the Piracicaba River, Silvano and Begossi (2002) observed that the knowledge of fishers about reproduction, followed by migration and diet, was more difficult to obtain (as measured by the number of fishermen with doubts) than information about habitat and fish predators. The following examples illustrate the diet and reproductive periods for some fish species of the Brazilian coast.

LEK IN THE USE OF NATURE

Much has been written about the use of natural resources by fishers and how their livelihoods depend upon the surrounding environment. Among small-scale fishers, plants are used for a variety of purposes, including the more than 200 species cited in interviews with 389 families from 7 small-scale fishing communities located on the coast of Rio de Janeiro and São Paulo, Brazil (Begossi *et al.*, 2002). The diversity of fish should also be mentioned, even if only a subset of them is taken for sale. Local nomenclature (folk) has been found for most of the more than 100 species with which fishers have contact (Begossi and Figueiredo, 1995). Small-scale fishers depend on the resources that have been extracted for their livelihood, so management is also tied to food security. Further consideration is beyond the scope of this paper, but this subject is of overwhelming importance if management is going to be successful. As an example, the study associating management and food security (Begossi *et al.*, 2013b) illustrates such relationships for small-scale fisheries of SE Brazil.

TABLE 2

Comparison of the mean (L_{mean}) and minimum total length (L_{min}); length at first maturity (L_m); and size at first reproduction (Fork Length, L_{reprod}), Mean population doubling time (T_d) of fish in the Lutjanidae and Serranidae families caught by artisanal fisheries at sites in NE Brazil (Maceió and Porto do Saupe) and SE Brazil (Copacabana, Paraty and Bertioga). Vulnerability is listed according IUCN Red List Status and Cheung *et al.*, 2005. See Begossi *et al.*, 2012a for details

Species or Site	N	L_{mean} (mm)	L_{min} (mm)	L_m^{FP} & L_{reprod}^{GO} (mm)	IUCN Vulnerability[FP]	Vulnerability[FP] (Cheung)	Resilience[FP] (K)	T_d	Stock status[LE]
Lutjanidae									
Mutton snapper *L. analis*	36	434	300	520[FP] 400[GO]	Vulnerable	Moderate to high (47%)	Low K=0.13-0.25	4.5-14	overexploited
Lane snapper *L. synagris*	54	379	240	253[FP] 180[GO]	Not evaluated	Moderate (38%)	Medium K=0.13-0.26	1.4-4.4	overexploited
Silk snapper *L. vivanus*	37	328	180	500[FP]	Not evaluated	High to very high (68%)	Low K=0.09-0.32	4.5-14	Near the maximum limit
Yellowtail snapper *O. chrysurus*	66	388	320	237[FP] 250[GO]	Not Evaluated	High (59%)	Low K=0.10-0.16	4.5-14	overexploited
Vermilion snapper *R.aurorubens*	22	336	260	200-230[FP]	Not Evaluated	Moderate to high (50%)	K=0.20	1.4-4.4	-
Sites									
NE Brazil									
Maceió, Alagoas	28	302	180						
Porto Saupe, Bahia	137	373	250						
SE Brazil									
Copacabana, Rio	35	418	300						
Bertioga, São Paulo	44	449	260						
All Sites		385	180						
N_{total} Lutjanidae	244	-	-						

TABLE 2 (CONTINUED)

Species or Site	**N**	**L_{mean} (mm)**	**L_{min} (mm)**	**L_m[FP] & L_{reprod}[GO] (mm)**	**IUCN Vulnerability[FP]**	**Vulnerability[FP] (Cheung)**	**Resilience[FP] (K)**	**T_d**	**Stock status[LE]**
Lutjanidae									
Mutton snapper *L. analis*	36	434	300	520[FP] 400[GO]	Vulnerable	Moderate to high (47%)	Low K=0.13-0.25	4.5-14	overexploited
Lane snapper *L. synagris*	54	379	240	253[FP] 180[GO]	Not evaluated	Moderate (38%)	Medium K=0.13-0.26	1.4-4.4	overexploited
Silk snapper *L. vivanus*	37	328	180	500[FP]	Not evaluated	High to very high (68%)	Low K=0.09-0.32	4.5-14	Near the maximum limit
Yellowtail snapper *O. chrysurus*	66	388	320	237[FP] 250[GO]	Not Evaluated	High (59%)	Low K=0.10-0.16	4.5-14	overexploited
Vermilion snapper *R.aurorubens*	22	336	260	200-230[FP]	Not Evaluated	Moderate to high (50%)	K=0.20	1.4-4.4	-
Sites									
NE Brazil									
Maceió, Alagoas	28	302	180						
Porto Sauípe, Bahia	137	373	250						
SE Brazil									
Copacabana, Rio	35	418	300						
Bertioga, São Paulo	44	449	260						
All Sites		385	180						
N_{total} Lutjanidae	244	-	-						
Species or Site	**N**	**L_{mean} (mm)**	**L_{min} (mm)**	**L_m[FP] & L_{reprod}[GO] (mm)**	**IUCN Vulnerability[FP]**	**Vulnerability[FP] (Cheung)**	**Resilience[FP] (K)**	**T_d**	**Stock status[LE]**
Serranidae									
Coney *Cephalopolis fulva*	170	255	165	160	Least concern	Moderate to high (51%)	Low K=0.14-0.63	4.5-14	-
Dusky grouper *Epinephelus marginatus*[a]	59	409	240	470	Endangered	High to very high (72%)	Low K=0.03-0.09	4.5-14	-
Comb grouper *Mycteroperca acutirostris*	37	404	310	?	Least concern	High (58%)	Low K=?	4.5-14	-
Sites									
Copacabana, Rio	35	418	300	-	-	-	-	-	

[FP] Froese and Pauly, 2010
[GO] Gobert *et al*., 2005
[LE] Lessa, 2006
[a] In another community, Paraty, Rio de Janeiro most groupers were also caught measuring less than 500 mm of TL (Begossi *et al*., 2012b).

Fish diet

In many cases, particularly when fishermen have doubts or when there is discrepancy among their answers, it is especially important to incorporate both *etic* and *emic* approaches. The *etic* approach to determining diet would be the direct observation of fish stomachs (see Begossi, 2008 for methods), and the emic approach would collect LEK from interviews. Figure 1 compares information about the stomach contents of a grouper, *E. marginatus*, obtained in the southeast coast of Brazil with answers given by fishers to questions about the diet of dusky grouper (Bertioga and Copacabana, Begossi and Silvano, 2008). With the exception of crabs, which make up a higher proportion of stomach contents than indicated by fishers´ answers, the stomach content analysis and interview results appear comparable. Crabs were especially represented by *Cronius ruber* in Copacabana, Rio de Janeiro and by *Petrolisthes galatin*us in Bertioga. A similar study conducted at Paraty, another site along the coast of Rio de Janeiro, showed that stomach contents largely included *Cronius ruber* and *Pilumnus quoyi* (crustaceans represented 35% and fish represented 18% of stomach contents, Begossi *et al.*, 2012b).

Overall, fishers demonstrate strong knowledge of the diet of the dusky grouper, but it would be interesting to understand why crabs are underemphasized in LEK.

The diet of snappers was also examined using the same *etic* (stomach contents) and *emic* (LEK) tools (Begossi *et al.*, 2011). In the case of snappers, questionnaires asked the general question of "What do snappers eat?" to 5 different coastal small-scale fishing communities in Brazil, which corresponded to 5 total species as follows: at Copacabana, Rio de Janeiro, *Lutjanus analis* (cióba, mutton snapper), the most abundant in this fishery; *L. synagris* (vermelho-ariocó, lane snapper), the most abundant in Bertioga (São Paulo coast), Paraty (Rio de Janeiro), and at the Maceió coast, Riacho Doce community (Alagoas State). At the Bahia, Porto do Sauípe community where snappers abound, we examined the stomachs of *L. synagris*, *L. vivanus* (vermelho legítimo, silk snapper), *Ocyurus chrusurus* (guaíuba, yellowtail snapper), and *Romboplites aurorubens* (paramirim, vermilion snapper). In the case of snappers, the stomach contents and the LEK information appear very comparable (Figure 2). In both figures, we observe that fish is overemphasized by LEK (it was counted per species, then it is the total mentioned by each interviewee). (See Begossi *et al.,* 2012a).

FIGURE 1

Examples of comparisons of direct observations and local ecological knowledge (source: Begossi and Silvano 2008). The percent of categories in stomach contents of dusky grouper (n=39 stomachs) and percent of answers of fishermen per category of food (n=21 interviews). Fish is marked with a different pattern since it might be over-represented: here the sum of fishers´ answers of different species is shown

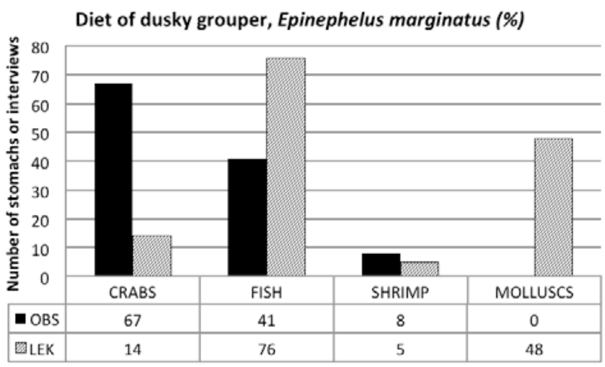
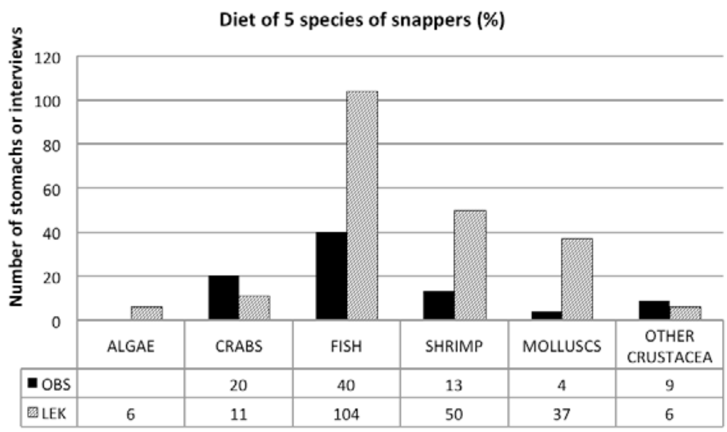


FIGURE 2

Examples of comparisons of direct observations and local ecological knowledge (source: Begossi *et al.*, 2011). The percent of categories in stomach contents of snappers (n=221 stomachs) and percent of answers of fishermen per category of food (n=70 interviews). Fish is marked with a different pattern since it might be over-represented: here the sum of fishers' answers of different species is shown



Fish reproduction: the case of dusky grouper, common snook, and snappers

Knowledge of fish reproduction can be considered to be a "vague niche", and it is currently a priority for investigation in order to effectively manage species. Fishers can help, even if their degree of knowledge is less compared to other categories of biological knowledge, such as fish habitat. A helpful study of methods for analyzing LEK and translating it into useful research and management applications is Silvano and Valbo-Jorgensen (2008).

One way to address reproductive data analysis is to incorporate both *emic* and *etic* approaches into data collection, such as LEK and macroscopic gonad analysis (see Begossi 2008), respectively. Examples of this approach follow for the dusky grouper, *E. marginatus,* the common snook, *Centropomus undecimalis*, and species of the family Lutjanidae, an important target species of fishers from Bahia (Porto Sauípe).

In general, LEK on reproduction has been shown to be relatively poor compared to other forms of knowledge (Tables 3 & 4). However, in case of the study of dusky grouper, having no gonads for comparison, we could only rely on fishers' information concerning the reproductive behavior of this fish for two periods, June-July and November- December).

In the case of *C. undecimalis*, an estuarine fish, we found that fishers tended to identify the season when eggs were found (Table 4). However, we need to have larger samples of fish and be certain that experienced fishers are selected in order to effectively analyze knowledge about fish reproduction. References to the autumn, but especially the spring-to-autumn, reproduction of *C. undecimalis* come from Lowerre-Barbieri (2003) and Peters *et al.* (1998), and Taylor *et al.* (1998) cites, among others, study sites in Puerto Rico, Mexico, and Venezuela.

LEK for Lutjanidae was especially interesting for Porto Sauípe, where 10 fishers out of 14 answered that snappers have mature eggs in spring (Begossi *et al.*, 2011). In Table 4, it is important to observe that, in Bahia, this is the period where very important and abundant snapper species, such as *L. vivanus* and *O. chrysurus*, have been shown to have mature eggs. However, in general, LEK on reproduction has been shown to be poor, as results obtained from fishers at Fortaleza (Ceará, Brazil) about *Cephalopolis fulva*[2] (coney) (31% out of 13 did not know about it) and about *Mycteroperca acutirostris* (comb grouper)(both Serranidae) at Copacabana, Rio de Janeiro and Bertioga, São Paulo coast (57% out of 21 did not know about it). Figure 3 shows the method of collecting data on reproduction and diet of snappers in the fish market (*etic*). For more information, see Begossi *et al.* (2012).

TABLE 3

Results taken from interviews with fishers. Example of reproductive periods of important target species Begossi and Silvano (2008, Silvano *et al.* (2006) based on LEK. We found just immature individuals of *E. marginatus* from fish landings, in which gonads were not observed macroscopically (Begossi and Silvano 2008, Begossi *et al.*, 2012a)

Month	% 2008[a]	% 2006[b]	Month	% 2008[a]	% 2006[b]
J	12	8	A	16	4
F	12	4	S		6
M	12	4	O	6	10
A	10		N	18	12
M	10		D	18	12
J	20	10	Does not know	49	54
J	16	10	Number of interviews	49	52

[a] Copacabana (Rio de Janeiro city), Bertioga and Vitoria I. (São Paulo coast), Itacimirim (Bahia coast, NE Brazil), Florianopolis (Santa Catarina coast, Southern Brazil).

[b] Arembepe, Valença, Porto Sauípe (Bahia, NE Brazil), Almada, Picinguaba, Puruba, Bertioga (São Paulo coast, SE Brazil).

[2] Data collected by L.S. Silva in the Project FAPESP 2006/50435-0 coord. By Begossi.

TABLE 4

Percent of individuals of *Centropomus undecimalis* with visible eggs or sperm/mean taken from Copacabana, Rio de Janeiro) in 2007; Percent of answers from interviews (source: updated from Begossi, 2008). B = Bertioga, SP; C = Copacabana, Rio, RJ

Month	LEK (%)	EGGS[b] B,C	SPERMA[b] B,C
Autumn	21	33	67
Winter	16	NS	NS
Spring	16	0	100
Summer	16	0	100
Year round	5		
DNK	26		
Total (interviews/individuals)	19	24	24

CONCLUDING REMARKS

In this paper, it is shown the importance of aggregating the knowledge that fishers have about fish into the management of small-scale fisheries. In particular, we have described LEK definitions and how fishers perceive, use, and demonstrate knowledge about fish biology as follows:

- Fishers have more knowledge about target species and show a more detailed ethnotaxonomy (through the use of binomials, for example), for target species than for non-target species.
- Fishers use diverse resources from their surroundings, and management of these resources should be associated with food security. Food security is then a subject that should be associated to conservation issues.
- Fishers' knowledge about fish diet and fish reproduction was described, and we demonstrated the interplay of the *emic* and *etic* procedures in the data collection. More data concerning fish reproduction and migration are urgently needed to manage small-scale fisheries, especially the data-poor fisheries of the Brazilian coast.

Currently, since many species have urgent management needs, and based on the importance and usefulness of LEK, there is no reason to not consider it as a tool towards acquiring knowledge for managing fisheries. There are sometimes discrepancies about information based on data collected by the researcher and the information given by fishers based on their perceptions (see Figure 1). The reason for such discrepancies, when investigated, add information that is important for the understanding of the system fisher-fish. For example, the emphasis by fishers (LEK) in considering fish more important than crabs (OBS) as food preferred or most eaten by groupers might be the fisher use of fish as bait to catch groupers (they also use shrimp to catch them, but a diversity of fish species are used). The importance of mollusk is also conspicuous in the observed LEK: squid also is used as bait. The use of fish and squid as bait denotes that groupers also like such food, since they are caught usually with hook and line. It might sound as a circular reasoning but it is not: the efficiency of fishing depends on the knowledge on fish biology. Therefore, fisher´s knowledge adds information that can be followed for future research. Moreover, in this case, their information also helps in maintaining or conserving other trophic levels, such as the levels cited by them as important food for fish.

Another important point is that considering the knowledge fishers have on target species, it might be important to access differentially the different subgroups within the fishery studied. For example, it can done by accessing differentially kin groups, or groups that have specific targets (and associated technology), among others (Begossi 2013b). In that way, accessing sub-groups or different groups of interest within fishers, more specific information can be obtained (also also intracultural differences would be more easily observed).

Finally, we recommend the studies by Begossi (2008), Silvano and Begossi (2012), and Leite and Gasalla (2013) as useful tools to deal with the integrative and challenging process of LEK , scientific knowledge and management of fisheries.

TABLE 5
Visible eggs and sperm in snappers and groupers collected in the Brazilian coast (macroscopically analysis of gonads in the field). Source for snappers: Begossi *et al.* (2011, 2012a, b), Begossi (2008), Begossi and Silvano (2008). In bold we observe the months in which eggs were mostly visible

Species	Site (number of individuals)	Month with visible egg (%)	Month with sperm (%)
L. analis	Copacabana (n=32)	April (12%)	
L. synagris	Bertioga and Maceió (n=44)	May (50%) June (13%) September (20%) December (100%) January (73%)	May (11%) January (27%)
L. vivanus	Porto Sauípe (n=29)	July (29%) October (73%)	 October (7%)
O. chrysurus	Porto Sauípe (n=66)	July (2%) October (67%)	 October (22%)
R. aurorubens,	Porto Sauípe (n=16)	October (8%)	October (42%)
C. fulva	Mucuripe (n=171)	January (2%)	
M. acutirostris	Bertioga and Copacabana (n=37)	January (5%) March (3%)	

FIGURE 4
Author during research in fish market at Porto do Saupe, Bahia, Brazil

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Ecosystem-based knowledge and reasoning in tropical, multi-species, small-scale fishers' LEK: What can fishers LEK contribute to coastal ecological science and management?

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ABSTRACT

Fishers' Local Ecological Knowledge (LEK) is an important, but largely untapped, source of information about continuity and change in coastal ecosystems. This is due to fishers' continued experience in coastal environments, coupled with the nature of their interaction with the ecosystem and the diachronic depth that their knowledge reaches through their lifetimes, as well as through intergenerational communication. In this paper, we will draw upon original research in the Caribbean to describe the extent and scope of tropical small-scale fishers' knowledge of target species biology and ecosystem processes, emphasizing topics where fishers local ecological knowledge can most contribute to the management of tropical coastal ecosystems. We will argue that fishers manage the information necessary to predictably find fish in an uncertain underwater environment with limited gear by "thinking ecologically", which positions them to contribute to understanding ecosystem-level processes such as habitat connectivity, temporal cycles and patterns, target species responses to environmental (including possible climate) change, dynamics of trophic webs, and indentifying reliable indicators of marine environmental health. We include a discussion of methodological issues pertinent to 1) eliciting and measuring fishers' local ecological knowledge, and 2) translating between local and (Western) scientific ecological knowledge.

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INTRODUCTION

The late tropical marine ecologist Robert E. Johannes' (1936-2002) portrayed a powerful compound message in two of his final works: In "The Case for Data-Less Fishery Management: Examples from Tropical Nearshore Finfisheries", published in the journal *Trends in Ecology and Evolution*, Johannes (1998) argued that the uncertainty and complexity inherent in managing nearshore fisheries, coupled with the time and inherent cost in developing the extensive datasets needed for data-based management, often make implementing scientific management an often unattainable dream. As such, Johannes advocated the adoption of "data-less management", based on sound ecosystem reasoning and application of locally-plausible effort control and habitat protections measures, noting that successful coastal management has been implemented for centuries by many tropical coastal societies, based on their Local Ecological Knowledge, (LEK) without "scientific data" (see Box 1). Having established that fisheries management is an "against-the-clock", information-starved endeavor, Johannes and colleagues (2000) wrote "Ignore Fishers' Knowledge and Miss the Boat", published in *Fish and Fisheries*, arguing that by privileging the information gathered by Western Science to the extent of ignoring fishers knowledge, humanity runs the danger of "missing the boat" on fisheries sustainability.

Johannes had been working for close to 30 years in topics related to fishers' knowledge and related systems of marine tenure. Although a marine ecologist by training he was considered by many (ourselves included) an "honorary anthropologist", since his work with LEK was influenced by -and in turn became a key contribution to- a long tradition of anthropological attention to individual and societal knowledge of their local environments, including that explicitly dealing with fishers and coastal peoples' local ecological knowledge (e.g. Anderson, 1967; 1972, Morrill, 1967; Forman, 1967). The greatest contribution of Johannes' classic study, "Words of the Lagoon" (1981), is that it is among the very first works to explicitly address the potential contribution of fishers' knowledge to the scientific ecological endeavors of classifying, understanding and managing local ecosystems, a modern enterprise dominated by Western Science and its approaches.

BOX 1
Definitions

Local Ecological Knowledge (LEK): Knowledge about local ecosystems or environments held by residents, resource users such as fishers and farmers, and/or other people with continued experience with these environments. LEK is a broad concept that encompasses more specific definitions such as:

Traditional Ecological Knowledge (TEK): Ecological Knowledge that is designated as "traditional" due to being encoded in a society's oral history or cultural practices. A common requirement of TEK is that knowledge is transmitted over multiple generations (e.g. Berkes 1993).

Indigenous Knowledge (IK): Knowledge held by peoples considered to be Indigenous to a place, usually in contrast to Western European colonialism and expansion (e.g. Stevenson 1996).

Western Scientific Ecological Knowledge (WSEK): Ecological Knowledge achieved by the application of "Western" (formal or academic) science, usually performed by scientists working in an academic, governmental, or non-governmental organization context (e.g. García-Quijano 2009).

In the years following the insights of Johannes and colleagues, their case has only been strengthened: As more and more fisheries scientists and managers accept that coastal fisheries need to be managed as whole ecosystems, rather than discrete species' populations (Pikitch *et al.,* 2004; García *et al.,* 2003; Hall and Mainprize, 2004; Link, 2010), it becomes more and more apparent how little is known about coastal fishery ecosystem processes, and how urgent it is to manage them effectively, before the fisheries are gone.

The last few decades have witnessed a proliferation of case studies and synthetic works dealing with the systematic study of local resources users' LEK and TEK, including that of fishers, and considering how to include this knowledge in natural resource management. The study and application of LEK has become an eminently interdisciplinary endeavor, undertaken by ecologists, anthropologists, geographers, political scientists, psychologists and cognitive scientists, planners, and even molecular biologists who are also fishers (e.g. Ames, 2004), both as individuals and as part of interdisciplinary teams. It is contended that LEK can be an important complement to Western scientific ecological knowledge (WSEK) for assessing the state of natural resources and determining optimal patterns of resource use and allocation (e.g. Aswani and Hamilton, 2004; Berkes, 1999; Berkes *et al.,* 2000; Brush, 1993; DeWalt, 1994; Ford and Martinez, 2000; Gadgil *et al.,* 2003; Gragson and Blount, 1999; Hunn *et al.,* 2003; Johannes, 2001; Johannes *et al.,* 2000; Ruddle, 1996b; Silvano *et al.,* 2007; Sillitoe, 1998; Thornton and Maciejewski-Scheer, 2012; Huntington, 2000; 2011). There is an increased awareness of the utility and validity of LEK, in and of itself or as complementary to WSEK, and of the urgency of sharing and synthesizing LEK and WSEK to achieve effective resource management, sustainability, and resiliency.

However, in practice resource managers and state officials often tend to fall back to regarding any knowledge not produced by Western trained scientists as ancillary/subsidiary or unreliable. In our opinion, this stems moreso from a methodological challenge of communication and translation between systems of knowledge than from the quality or lack thereof of any specific source of ecological knowledge. Like Johannes and colleagues, we feel that the urgency of global environmental problems, including fisheries issues, is such that sharing and integrating as much ecological knowledge as possible (as well as creating the social conditions to enable this sharing) is obligatory for everyone involved.

FISHERIES LEK, WITH EMPHASIS ON TROPICAL, SMALL-SCALE FISHERIES

Tropical, small-scale fisheries, which feed and provide income to millions of people around the world (Zeller *et al.,* 2007; Pauly, 2006; McGoodwin, 2001; Berkes *et al.,* 2001), are especially difficult to manage in what could be called the "proper scientific" manner based on "optimum yield". Tropical coastal fisheries are complex, dynamic, and difficult to understand and predict, due to ecological factors such as the biomass distribution in tropical, reef-estuarine ecosystems, in which total fish biomass is high, but spread among multiple species with relatively low biomass for each species (Munro 1984; Polunin and Roberts 1996; Sale 2002), favoring multiple species and multi-gear fisheries (Johannes 1981; 2001; Ruddle 1996a; Roberts and Polunin 1996; Suarez Caabro 1979). For example, 100+ fish, crustaceans, and finfish species are harvested routinely by small-scale fishers in the Caribbean island of Puerto Rico (García-Quijano, 2009; Griffith *et al.,* 2007; Suarez Caabro, 1979), using a variety of gears and techniques from small, multipurpose crafts.

Many tropical fishers have adapted to this by using a wide variety of gear types and by engaging in multiple and complementary forms of fishing, targeting multiple species over space and time (Johannes, 1981; Ruddle, 1994; 1996a; 1996b; McGoodwin, 2001). In tropical fisheries, specializing in a few fish species using one or two types of gear and expensive and specialized fishing vessels comes at the expense of the flexibility in harvesting strategies, which allows fishers to take advantage of the specific conditions they encounter when they go out to sea. Specialization also tends to increase fishers' and their families' vulnerability to environmental and market fluctuations (Jacob *et al.*, 2001). Moreover, tropical fisheries are also often located in developing countries, with underfunded management agencies and far from the large marine science centers of the world (e.g. Pauly, 2006).

The characteristics of tropical fisheries mentioned above certainly magnify the problems with the availability and application of ecological knowledge and data for tropical fisheries and highlight the urgency of synthesizing WSEK-based knowledge with that of fishers and other resource users. However, many non-tropical fisheries and coastal systems are also being managed under data-poor circumstances and could greatly benefit from including the knowledge of fishers in the management toolkit. As we discuss below, the widespread international adoption of ecosystem-based fisheries management (EBFM) as the state-of-the-art in fisheries and coastal management has introduced novel ecological data and knowledge gaps that could be considerably fulfilled by collaboration between WSEK and fishers' TEK/LEK.

Over the last ten years we have participated in a variety of initiatives and research projects studying Caribbean (mostly Puerto Rican) fishers' TEK/LEK, its development, cultural transmission, importance for coastal livelihoods, and potential for enhancing the toolkit available for fisheries management (e.g. Valdés-Pizzini *et al.*, 1996; García-Quijano, 2006; 2007; 2009; Valdés-Pizzini and García-Quijano, 2009). Some of these research projects originated from an anthropological/human ecology interest, while others were part of interdisciplinary collaborations with biological/ecological scientists.

In this article we present areas and topics of convergence and potential synergy of collaboration between LEK and WSEK and address some conceptual and methodological issues that we have encountered from our vantage points as human ecologists and anthropologists working with small-scale fisheries. We also comment on methodological issues regarding 1) eliciting and measuring fishers' local ecological knowledge, and 2) translating between local and (Western) scientific ecological knowledge. Finally, we share examples from our own work bridging LEK and WSEK in Caribbean fisheries.

THINKING ECOLOGICALLY AS COMMON GROUND

Fishers obviously tend to have very good knowledge of local current conditions and the state of resources in the areas in which they fish at any given time, because of their repeated and extensive experience with these specific locales in which they fish. In our experience, this descriptive, place-based, natural history dimension of fishers' knowledge and experience is usually what many Western scientists (biological and social alike) first seem to think about when fishers' TEK/LEK is mentioned; one which recent studies applying GIS-based TEK/LEK elicitation methodologies have emphasized (e.g. Aswani and Lauer, 2004; Lauer and Aswani, 2010). We consider this dimension of LEK, albeit important, as being more environmental or natural history than truly ecological.

While it is true that an important and unique value of fishers' knowledge is related to their intimate, time-deep knowledge of specific locales, too much emphasizing of this natural history, locally-specific, descriptive dimension can risk portraying fishers as mere reporters -albeit knowledgeable ones- of local environmental conditions. This is problematic for at least two reasons: one, it reinforces views of Western scientists as directing the knowledge gathering process and thus upholds power and prestige differentials (which probably explains why scientists are comfortable with the notion), and two, most importantly, it misses an important dimension of fishers' knowledge which constitutes in our opinion the most promising common ground between resource users and scientists. This important dimension is related to *thinking ecologically*. Ecological information and ecological thinking *sensu stricto* (i.e., dealing with species, populations, and communities in relationship to each other and the aquatic environment) is often a key component of fishers' cognition of the seascape. It guides their activities as well as their folk taxonomies (e.g. Valdés-Pizzini and García-Quijano, 2009; Ross-Casiano and Banuchi, 2007).

Fishers, ecosystem scientists and fishery managers face similar cognitive challenges when dealing with ecosystems. They need to be able to decipher discernable patterns to adequately predict the state and location of fishery resources among considerable complexity and rapid change. They are neither omniscient nor can they observe and understand all of the processes at work in local coastal ecosystems. Therefore, they have to rely on proxies, correlations, and inferences made based upon discontinuous and limited data that is not always representative of the larger scale ecosystem (Acheson and Wilson, 1996; Holling, 2001; Berkes *et al.,* 2001; Berkes, Colding and Folke, 2003). The more and better ecological knowledge fishers, resource managers, and scientists have, the more likely that they will be able to make accurate predictions about the status and location of fishery resources. In that sense, WSEK and TEK/LEK share similar constrains and goals.

Particular to aquatic ecosystems is that both fishers and fishery scientists, as non-aquatic obligate air breathers, have constraints in experiencing and observing the underwater environment which unifies their common experience (see García-Quijano and Pitchon, 2008). Western scientists and fishers alike pursue resources that are often mobile, and exist in a medium in which the targeted resources cannot be easily seen. Therefore, they must constantly make inferences about the location, abundance, quality, and distribution of resources as derived from indirect observation and sampling. Moreover, both groups are limited to similar tools and means of 'data gathering', capturing, observation, and sampling: nets of different kinds, traps, hook and line, and sometimes a diving mask. In fact, many of the data-capturing devices used by Western aquatic scientists were originally fabricated as fishing devices, and often the scientists themselves hire fishers to operate the boats and capture technologies they use to gather their research data. Just like a marine biologist or fishery scientist, each a fisher sets out a net, hook, or trap. He/she is sampling the water for the resource, which can then be related to environmental parameters such as water conditions, underwater environments and topography, weather, and catch characteristics.

ECOLOGICAL THINKING IN PUERTO RICAN FISHERIES

More than a decade of research in Puerto Rico (García-Quijano (2006; 2007; 2009; Ross-Casiano and Banuchi, 2007; Valdés-Pizzini and García-Quijano, 2009) has found that fishers clearly engage in ecological thinking as their main way of directing their fishing and resource management activities. Ethnoecological studies of fishers' classifications of marine species using cultural domain analysis gathered independently in different locations around the Puerto Rican Coast over more than a decade (Valdés-Pizzini *et al.*, 1996; Ross-Casiano and Banuchi, 2007; García-Quijano, 2007; Valdés-Pizzini and García-Quijano forthcoming) all found that ecological, rather than economic or morphological, criteria guide their culturally-shared categorization of coastal organisms and habitats. Like ecosystem scientists, fishers think about a species of interest as part of a system of biophysical relationships and correlations.

For example, García-Quijano (2006; 2009) documented that Southeastern Puerto Rican fishers, defined their "fishing areas", not as bounded geographical units, but rather by the their ecological parameters (Johnson *et al.,* 1968) (e.g. bottom/substrate composition, depth, salinity, water turbidity, sediment input, currents, prey species populations, and the species assemblages found) as they relate to the species pursued by fishers and their population status (García-Quijano, 2009). The "fishing area" is an ecosystem-like concept (Berkes *et al.*, 1998) that guides cognition and behavior for the fishers.

> *"The sea is immense, but it has areas, fishing areas, where you can fish… "You have to ask yourself: Where are the fish? Where food is abundant. Where there are reefs, or seagrasses, or mangroves, places where there is protection for fish and food that the fish can eat. This is the most important knowledge. To know the kinds of places that are good fishing areas."*
> – Interview with Puerto Rican fisher, November 2003.

In the statement above, the ecological parameters that define a fishing area are: 1) the type of habitat, defined by the type of bottom substrate, and 2) availability of food for the pursued species. A fishing area may only be considered as such during certain times of the year. Fishers report and realize that many species are predictably seasonal in their movements between habitats and/or geographic locations and they move their fishing effort between habitat patches as productivity and the species assemblages found vary through the seasons (e.g. Aswani and Lauer, 2006). Thus, ecological thinking constitutes a key feature of the adaptive value of fishers' LEK as fishers make a living in an uncertain and highly dynamic environment.

Don Aquiles[*], an elderly Puerto Rican fisher, spoke in 2004 about how fishers make sense of habitat changes through observed species assemblages. He is exclusively a trap fisher and has not dived for more than two decades. His observations of environmental change happened via proxies, by observing the assemblages of species he has caught at specific sites over the years:

> *"Aquiles: I am going to tell you something. Many of the reefs around here have become clogged! Now I am catching fish in what should be reefs that are not reef fish! I lift a trap, in areas that are supposed to be reefs, and it comes back full or plumas (pluma porgy). And that kind of fish is not a reef fish!*
>
> *CGQ: Are the porgies sand fish, then?*
>
> *Aquiles: Yes, sand! Also the trunkfish. You put your fishpot in the banks and it comes back with trunkfish. And you think 'look at this, this fishpot is here near the reefs and catching trunkfish and lane snappers. Those are sand fish, not reef fish! Because, I can tell you from the kinds of fish that you bring if you were in the reefs, in the sand, or in deep waters. I would tell you: "you went to the reefs today, didn't you? But now, it's harder because many reefs are clogged with sand. I cannot tell you: in this area, I am going to catch this and this fish. You should write this down, this is important data for your study! This is how the sea is, always changing."*

Establishing that fishers' LEK can be, and often is, ecological, rather than just environmentally descriptive and place-contingent, is very important to push LEK/WSEK collaborations forward. Like Don Aquiles recognized in the previous quote, the marine environment is always changing and will change a lot more rapidly with climate change. Fishers, especially small-scale fishers who rely less on heavy technology, are experts at using their ecological knowledge to adapt to change and dynamism: thus their insights and knowledge actually become more relevant under conditions of heightened change. In fact, climate change might make the LEK of fishers from a particular location relevant to new locations as marine species assemblages move to new locations in response to climate change.

In an example from more temperate fisheries (Garcia-Quijano, personal experience), in the last few years at the University of Rhode Island (URI) local lobstermen have come to URI fisheries experts with ideas to stay ahead of the impacts of climate change to local fisheries: one of them stems from their observations that blue crab numbers (*Callinectes sapidus*) are increasing locally as a result of warming ocean waters (a change that they predict, based on their LEK, might push less heat-tolerant lobster populations to the North). The local lobstermen wanted to be prepared to start fishing blue crabs along with lobsters. As they experimented with blue crab traps, they asked URI fisheries extension agents to help assess the market for blue crabs and to help find efficient and by-catch-safe blue crab trapping devices. One of the ideas floated around has involved establishing knowledge sharing with crab fishers from further South in the U.S. East Coast where there are established blue crab fisheries.

CONVERGENCE BETWEEN WSEK AND LEK IN ECOSYSTEM-BASED ECOLOGY AND MANAGEMENT

In a recent American Anthropological Association meeting in Philadelphia, we were having dinner with a group of colleagues, including David Griffith and Benjamin Blount, who all worked with fisheries management and small-scale fishers' LEK. Talking about LEK and Ecosystem-Based management approaches, we realized that many of the basic insights that Ecosystem-Based Fisheries Management (EBFM) is based upon are closely matched to some of the accounts about the workings of coastal ecosystems and their proper management that small-scale fishers had been relating to us for decades. Convergence between WSEK and LEK brought about by ecosystem-based approaches to fisheries and coastal management has resulted in WSEK-based findings and/or advances in knowledge that are actually converging what fishers have been telling us all along.

Consider a comparison between a passage in one of the seminal publications (in the journal *Science*) calling for EBFM approaches (Pikitch *et al.*, 2004) and what an elderly fisher told us in an interview performed the same year the article was published.

> *"Fisheries management to date has often been ineffective: it focuses on maximizing the catch of a single target species and often ignores habitat, predators and prey of the target species and other ecosystem components and interactions."* – Pikitch *et al.* (2004, p. 346).

> *"What we see out there, in fishing, is that they (the Government) are only looking at fishing effort for this or that species, using outside models, and they ignore the habitat, and the food that sustain the species. Meanwhile the marinas, the power plants, the hotels, the rich folk urbanizations are killing the baitfish nurseries, polluting the bays and baitfish areas, filling up the coral reefs with sediments: destroying the quality of the environment and the very capacity of this coast to harbor life. This is not good management"* – 2004 interview with elder fisher in Aguirre, Puerto Rico.

The fisher and the scientists in the passages above clearly agree on what should be purpose of effective fisheries management: "to protect healthy marine ecosystems at the fisheries they support" (Pikitch *et al.*, 2004). The emphasis on the ECOSYSTEM brought by EBFM has brought WSEK and resource users' LEK together.

WHAT CAN FISHERS' LEK CONTRIBUTE TO COASTAL ECOSYSTEM SCIENCE?

First of all, "**sample sizes**". As discussed above, managing coastal fisheries ecosystems entails information about ecosystem and landscape-level processes that take substantial time and effort to observe and document, as many ecosystem processes are clustered unevenly in time and space. For example, just assessing the connectivity in fish species assemblages between habitats (for example, between reefs, backreef lagoons, sandflats, and seagrass prairies) requires extensive observation and sampling over large expanses of coast, at different times of day and night, and over the seasons and years. Below we will detail an example of engaging fishers' LEK to obtain information about fish species' connectivity between different habitats.

Fishers' spend vast amounts of time in direct contact with local ecosystems, observing macroscopic ecosystem processes, "sampling" fish populations with their gear and/or observing them from their small boats or underwater by diving, all the while noting the correlation of their observations and catch with observed environmental parameters (García-Quijano, 2006; 2009). In one of our recent studies in Southeastern Puerto Rico, we found that an average small-scale fisher from a randomly chosen sample had spent 37.5 years going out to fish ten hours at a time, four times a week, 30 weeks out of the year, for a total of 45 000 hours fishing in direct contact with local ecosystems. This is the equivalent of 21.6 years working 40-hour weeks without vacation. Furthermore, because fishers are also coastal residents, they spend a lot of time, beyond the time spent fishing, observing coastal ecosystems and species movements and discussing them, often within their own homes (Figure 1). Fishers (and, most notably, in Caribbean fishing families, women and youth as well, who often clean and process fish) also observe firsthand the stomach contents and physical health of a great number of captured fish.

FIGURE 1
Fisher's home facing the water in Aguirre, Puerto Rico. Fishers spent vast amounts of time fishing and observing coastal ecosystems during their daily lives

This puts fishers in a privileged position for observing phenomena that require large, chronologically-deep and geographically comprehensive observations as well as sample sizes. Many of these are precisely the novel kinds of data required by ecosystem approaches to management (e.g. Pikitch *et al.,* 2004; García and Cochrane, 2005), which must include ecosystem-level, broad process data together with the species-specific, highly focused data that WSEK fisheries science has been collecting and analyzing for so long. Some key areas of knowledge for ecosystem-based management where fishers LEK can contribute include: 1) the movement patterns of key species or species assemblages such as reef fishes (García-Quijano 2009; Aswani and Lauer, 2006) and bowhead whales (Huntington, 2000; 2011); 2) identifying critical habitat and habitat connectivity (García-Quijano, 2007; Koenig *et al.,* 2007); 3) spawning aggregations of reef fishes (Valdés-Pizzini *et al.,* 2012; Johannes 1981); 4) trophic chains and food webs (Valdés and García-Quijano, 2009; Ruddle, 1994; Whiting *et al.,* 2013), and 5) identifying indicator species for ecosystem health (García-Quijano, 2006). Some important topics of convergence between fishers' LEK and EBFM are mentioned below:

CONNECTIVITY: MANGROVES AND OFFSHORE REEF FISHERIES

For example, based on their longtime observations of mangrove habitat utilization and ontogeny of important species in the reef fishery fishers in Puerto Rico have told us for almost a decade that managing coastal reef fisheries without protecting mangroves and other estuarine ecosystems is futile (Griffith *et al.,* 2007; Valdés and García-Quijano *forthcoming*; García-Quijano, 2006; 2007). Fishers have long recognized that mangroves are critical habitats for many reef species, serving as spawning grounds, nurseries, refuge and food reservoirs. Thus they have resisted and criticized fishery management plans that focus on reducing fishing effort while allowing coastal development of various kinds to degrade and often destroy precious mangrove habitat. Over the last decade, we have witnessed firsthand how fishers have drawn upon their LEK to resist (sometimes quite successfully, other times less so) coastal development projects that threaten estuarine areas that fishers know are important nurseries for their fishery (Valdés-Pizzini 1990; Griffith *et al.,* 2007).

High-profile WSEK-based studies over the last decade or so have increasingly confirmed the fishers' long-time LEK-based insight: that the presence and health of mangrove habitat directly affects the quantity, health, and composition of reef fish assemblages offshore (Nagelkerken *et al., 2*008; Koenig *et al.*, 2007; Mumby *et al.*, 2004). Mumby *et al.* (2004), for example, found that the presence/absence or health/ degradation status of coastal mangroves in Belize had a significant effect on the biomass and species composition of spatially associated offshore reefs, which for us raises the question of how often the effects of estuarine habitat destruction on reefs might have been wrongly attributed to overfishing. Likewise, Koenig *et al.* (2007) found that the best predictor of the number and size of individuals in recovering populations of Goliath groupers (*Epinephelus itajara*) in Florida was their association with healthy mangrove habitats, which they found are "essential nursery habitat" for this species. The arguments and findings of these ecological scientists about the importance of mangroves for offshore fisheries very closely mirror the LEK-based arguments of fishers over the years. In fact, Koenig *et al.* (2007) specifically acknowledge that their research question was based in part on insights from conversations with fishers.

During recent fieldwork in southeastern Puerto Rico fishers have expressed to García-Quijano that lately they have been quite pleased by seeing renewed efforts by government biologists to protect mangroves from development *("if only they would have listened to us sooner, a lot of nurseries could have been saved"* a fisher from Salinas, PR said in an interview). Fishers see the emphasis on protection of mangrove habitat as common ground upon which fishers and managers, often at odds with each other, can collaborate.

THE SOMETIMES-PERVERSE EFFECTS OF FISHERIES REGULATIONS

Some management techniques end up harming rather than helping the fishery species populations and/or their ecosystems: this phenomenon is known as a "perverse effect". Fishers in the Caribbean have long noticed that approaches to a management that are designed to narrow the fish species and sizes that can be caught ("selective fisheries management"; García *et al.,* 2012) often result in imbalances that harm the fished species' populations and also impact the fishers' economic options and resilience. For example, Puerto Rican fishers have noted that blanket measures that regulated minimum fish trap mesh sizes increased fishing pressure on key vulnerable species like the red hind (*Epinephelus guttatus*), the very species that the management measure was aimed to protect, by preventing the traps from catching species like the spotted goatfish (*Pseudupeneus maculatus*), whose adult size and shape allowed to escape increased mesh sizes (Griffith *et al.,* 2013). When we compared the fishers' story with WSEK studies of trap selectivity by adult fish species (Rosario and Sadovy, 1991), the fishers' accounts were confirmed. Fishers have also been reporting the minimum size regulations in deep water grouper-snapper fisheries actually increase mortality by forcing fishers to kill more fish while dramatically increasing discards of dead catch. Similar accounts related to other species and selectivity measures have been told to us by fishers over the years elsewhere in the Caribbean and in temperate fisheries like the Mid-Atlantic and New England.

A recent paper in the journal *Science* by S. García of the IUCN and colleagues, which caps and summarizes a multi-study workshop by the IUCN in Nagoya, Japan, again converges with fishers' reservations about selective fishery management strategies by pointing out the harmful and perverse effects of overly selective harvesting on ecosystem structure and fish assemblage composition (García *et al.,* 2012). Like fishers, García *et al.* (2012) advocate an overall "balanced harvesting" strategy which "distributes a moderate mortality from fishing across the widest possible range of species, stocks and sizes in the ecosystem". A similar view in another prestigious scientific journal, the *Proceedings of the National Academy of Science* (PNAS), is presented by Zhou *et al.* (2013).

In summary, we view the advent and implementation of EBFM as a very promising point of convergence and platform for collaboration between fishers' LEK and WSEK. It is urgent and crucial to capitalize on this convergence to achieve more sophisticated, effective, and socially just fisheries management.

THE SYSTEMATIC STUDY OF FISHERS' LEK: TWO EXAMPLES OF METHODS AND APPLICATIONS FROM PUERTO RICAN FISHERIES

An often-mentioned obstacle to include LEK in resource management is the supposed "incommensurability" between LEK and WSEK. We do not agree with that view and instead view this as a methodological issue, and a challenge (and opportunity) in translation of cultural knowledge. LEK (and WSEK for that matter) is part of **culture,** the corpus of learned, shared, and patterned information and accompanying behavior that humans in any social group share to a greater or lesser degree, and which is the main object of study in Cultural Anthropology.

LEK can be collected and analyzed in a variety of ways, from textual and discourse-based approaches, including oral histories and conversations as well as formal classification exercises and structured surveys. All of these formats can yield information that is useful for collaboration with WSEK and management, as long as there are processes of systematic collection, analysis, and quality control in place.

SAMPLING

Idiosyncratic knowledge can be important, but in general data gathered from a group or population of fishers is more reliable and provides broader applicability. Insights and knowledge where multiple fishers agree are generally more reliable than idiosyncratic insights. However, the sampling strategy used to identify these fishers is very important as expertise about any given topic varies in human populations according to individual characteristics such as experience, aptitude, location in social networks, and opportunities to learn (e.g. Boster, 1991; Ross, 2004; Davis, 2003). Knowledge in human societies is part of a distributed and patterned "Information Economy" (Boster, 1991).

For example, random or randomized sampling is very useful to look for overall patterns in knowledge held by a population of fishers. However, if researchers are interested in expert knowledge of fisheries or coastal ecosystems (which is often the topic of interest), then a random sample would be inappropriate because experts tend to be, by definition, rare and thus many experts would likely be missed by a random sampling approach. Alternative sampling approaches such as "snowball" or chain referral sampling (e.g. Johnson, 1990) are useful technique for finding informants who meet specific criteria, such as being recognized experts or highly experienced fishers, and who can be found by following social networks from one or more starting points (e.g. by asking fellow fishers or fish sellers in a community). Geographic-based sampling techniques can also be used to find fishers or coastal residents in particular areas who might have access to spatially-specific ecosystem information (Aswani and Lauer, 2004; García-Quijano *et al.,* 2013). Often, the best strategies include a mix of random and purposive sampling that synergically combine expert or targeted knowledge with an overall view of knowledge distribution in a population (e.g. Johnson 1990; 1998; Boster and Johnson, 1989; Davis, 2013; Medin *et al.,* 2006; Cooley, 2002; García-Quijano, 2006; 2009; García-Quijano *et al.,* 2013).

ELICITING LEK

A comprehensive survey of methods for elicitation and analysis of LEK is beyond the scope of this contribution, but useful sources on LEK methodology can be found in the cognitive sciences, ethnobiological, and anthropological literature (e.g. Berlin, 1992; Pollnac and Johnson, 1995; Johnson, 2000; Ross, 2004; D'Andrade, 1995; Johnson and Griffith, 1998; Stepp, 2005; Bernard 2011). LEK-based data can be gathered in a variety of formats: the elicitation technique used should correspond and be appropriate to the research question and kinds of data being sought. Discourse-based responses (open-ended interviews and conversations) usually contain the more detailed information. They are amenable to a variety of qualitative text analysis techniques (e.g. Bernard and Ryan, 1998) and are crucial for the process of discovery of the content, topical breadth, and extent of LEK. However, discourse data can be harder to quantify, and might not be appropriate for specific questions about the distribution, content, and organization of LEK. Formal or structured data elicitation techniques (for example cultural domain analysis techniques such as freelists, pile-sorts, similarity judgments, and triad tests (Conklin, 1962; D'Andrade, 1995; Boster and Johnson, 1989; Roos, 1998; Harman 1998)) are well-suited for this endeavor as they go beyond the very limited usefulness of mere species identification exercises and can help reveal patterns in the way fishers think about their resources and their environment.

Most often, methodological creativity, as well as rigor, will come into play as combinations of interviews, conversations, and formal elicitation exercises often yield the best results. Thus high quality LEK-elicitation work will often consist of mixed-methods approaches (e.g. Johnson, 1998) that balance the context-richness and attention to detail achievable with open-ended methods with the predictive power and comparability of results acquired by exposing respondents to comparable stimuli (Kempton *et al.,* 1995, Johnson, 2000; Johnson and Griffith, 1998; Medin *et al.,* 2007; Ross, 2004). The process of including LEK in resource management is inherently interdisciplinary, and thus mixed methods approaches should be the norm. Two examples of our own work with LEK in Puerto Rican fisheries using such mixed methods approaches are illustrated below.

Example 1. Tropical Coastal Habitat Connectivity

We studied the LEK of reef fishers in the southern coast of Puerto Rico as part of a large, multi-year and multidisciplinary National Oceanic and Atmospheric Administration-funded Coral Reef Ecosystem Study (CRES) led by the Caribbean Coral Reef Institute, University of Puerto Rico-Mayagüez. One of the unifying concepts of interest of the CRES was the connectivity of tropical coastal ecosystems and their species assemblages (Appeldoorn *et al.,* 2009). We gathered fishers' LEK around this topic.

Extensive interviews and conversations with South Puerto Rican fishers revealed that the fishers' paid much attention to and had extensive knowledge of species connectivity and movements between different habitats and followed the movements of species in and out of ecosystem-type units (Berkes *et al.,* 1998) that they called "fishing areas". As fishers discussed resource species and their habitats, they also shared information about the species they considered to be representative of the overall health of those habitats, what WSEK ecological scientists call indicator species (Carignan and Villard, 2002; Dufrêne and Legendre 1997). Two species frequently mentioned by fishers in this context were the liza (*Mugil liza*) as an indicator of estuarine ecosystem health and the rainbow parrotfish (*Scarus guacamaia*) as an indicator of the health of coral reef ecosystems. Other species mentioned as indicators of ecosystem health were the queen conch (seagrasses), Atlantic barracuda (all ecosystems), white mullet (estuaries), land crabs (terrestrial sections of mangroves) and the long-spine sea urchin (coral reefs). Identifying indicator species for overall ecosystem health is an important focus of research for EBFM, specially as it relates to evaluation and monitoring (Carignan and Villard, 2002; Pikitch *et al.,* 2004).

Based on our open-ended interviews with the fishers about species and their habitats, we designed a formal exercise using freelists, a simple and widely-used cultural domain analysis technique in which a group of respondents are asked to exhaustively list items belonging to a domain that the respondents know about (e.g. reef fishes). The exercise; "habitat-centered freelists" (García-Quijano, 2007) consisted of asking fishers (55 fishers in this case) to list all of the fish and shellfish species they associated with 8 habitat types: coral reefs, bays, mangroves, seagrasses, sandy bottoms, deep waters, and pelagic waters.

TABLE 1
Species mentioned by SE Puerto Rican fishers as indicators of ecosystem health

Species		Habitat	Role
liza	*Mugil liza*	Estuaries/mangrove channels	Detritivore/prey species
rainbow parrotfish	*Scarus guacamaia*	Coral reefs	Grazer/algal control
queen conch	*Strombus giga*	Seagrasses	Grazer
Atlantic barracuda	*Sphyrraena barracuda*	All Ecosystems	Apex predator
white mullet	*Mugil curema*	Estuaries/bays	Detritivore/prey species
land crab	*Cardisoma guanhumi*	Mangroves/terrestrial	herbivore, plant disperser
snook	*Centropomus undecimalis*	Estuaries	Predator
long-spine sea urchin	*Diadema antillarum*	coral reefs	Grazer/algal control

We analyzed the resulting dataset (55 sets of eight habitat-centered freelists) for species frequency and salience using ANTHROPAC X (Borgatti, 2001). To assess the degree of overlap between the species assemblages mentioned by fishers as representative for each habitat type, we chose the 10 most salient species for each habitat type and calculated Bray-Curtis (BC) dissimilarity coefficients were between habitat types (Gauch, 1982; Krebs, 1999) and presented them as a distance cluster graph (García-Quijano, 2007). The scientists in the CRES study were highly enthusiastic about these results, as they were presented in a familiar format and showed valuable information, for example, the relative distance in species connectivity between habitats, comparable by some studies done by ecologists as part of the CRES project. The results of the exercises are shown below in Table 2 and Figure 1.

TABLE 2
Ten most salient species mentioned by fishers in habitat-centered freelists for 8 habitat types

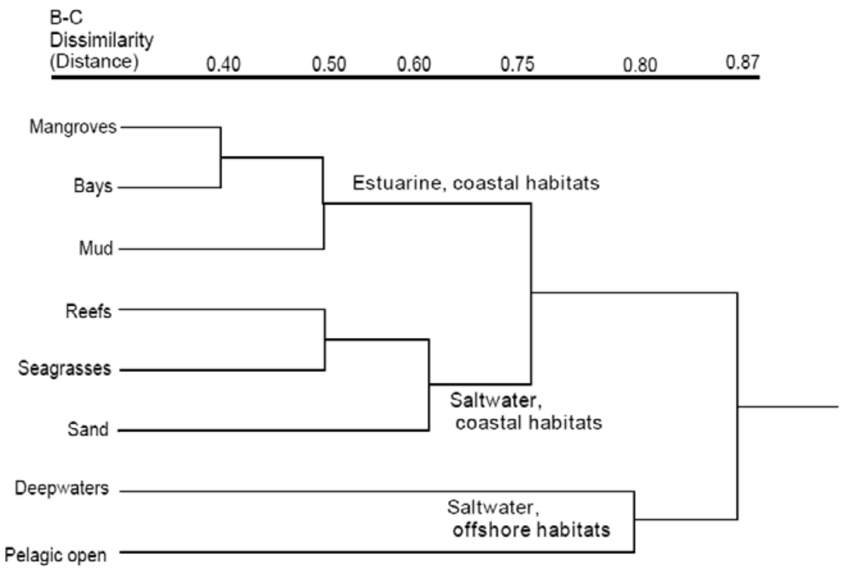
Mangroves (75 species)			Bays (71 species)		
Spanish	**English**	**Scientific**	**Spanish**	**English**	**Scientific**
jarea	*white mullet*	Mugil curema	Jarea	white mullet	Mugil curema
róbalo	*Snook*	Centropomus undecimalis	Róbalo	snook	Centropomus undecimalis
pargo	*schoolmaster snapper*	Lutjanus apodus	Sama	mutton snapper	Lutjanus analis
lisa	*Liza*	Mugil liza	Sábalo	tarpon	Megalops atlanticus
picuílla	*southern sennet*	Sphyraena picudilla	Pargo	schoolmaster snapper	Lutjanus apodus
sábalo	*Tarpon*	Megalops atlanticus	Picuílla	southern sennet	Sphyraena picudilla
mojarra	*yellowfin mojarra*	gerres cinereus	Arrayao	lane snapper	Lutjanus synagris
crianza	*juvenile fish*	N/A	Manatí	manatee	Trichechus manatus
congre	*green moray*	Gymnothorax funebris	Sierra	spanish mackerel	Scomberomorus maculatus
picúa	*atlantic barracuda*	Sphyraena barracuda	Picúa	atlantic barracuda	Sphyraena barracuda
Mud (70 species)			**Deepwaters (67 species)**		
Spanish	**English**	**Scientific**	**Spanish**	**English**	**Scientific**
arrayao	*lane snapper*	Lutjanus synagris	Chillo	silk snapper	Lutjanus vivanus
jarea	*white mullet*	Mugil curema	Cartucho	queen snapper	Etelis oculatus
róbalo	*Snook*	Centropomus undecimalis	Mero	red grouper	Epinephelus morio
burro	*whitemouth croaker*	Micropogonias furnieri	Negra	blackfin snapper	Lutjanus bucanella
cachupín	*Irish mojarra*	Diapterus auratus	Cabrilla	red hind	Epinephelus guttatus
sama	*mutton snapper*	Lutjanus analis	Colirrubia	yellowtail snapper	Ocyurus chrysurus
pargo	*schoolmaster snapper*	Lutjanus apodus	Moniama	cardinal snapper	Pristipomoides macropthtalmus
chopa	*Bermuda sea chub*	Kyphosus sectator	Sama	mutton snapper	Lutjanus analis
mojarra	*yelowfin mojarra*	Gerres cinereus	mero guasa	misty grouper	Epinephelus mystacinus
lisa	*Liza*	Mugil liza	sierra canalera	king mackerel	Scomberomorus cavalla
Reefs (84 species)			**Sand (71 species)**		
Spanish	**English**	**Scientific**	**Spanish**	**English**	**Scientific**
pargo	*schoolmaster snapper*	Lutjanus apodus	pluma	pluma porgy	Calamus pennatula
loro	*Parrotfish*	Sparidae	arraya'o	lane snapper	Lutjanus synagris
colirrubia	*yellowtail snapper*	Ocyurus chrysurus	carrucho	Queen conch	Strombus giga
mero	*red grouper*	Epinephelus morio	sama	mutton snapper	Lutjanus analis
boquicolora'o	*striped grunt*	Haemulon plumierii	chapín	trunkfish	Lactophrys trigonus
sama	*mutton snapper*	Lutjanus analis	mantarraya	spotted eagle ray	Aetobatus narinari
langosta	*spiny lobster*	Panulirus argus	cojinúa	bar jack	Carangoides ruber
gallo	*Squirrelfish*	Holocentrus adscensionis	colirrubia	yelowtail snapper	Ocyurus chrysurus
pulpo	*Octopus*	Octopus vulgaris	jurel	Crevalle jack	Caranx hippos
arraya'o	*lane snapper*	Lutjanus synagris	picuílla	southern sennet	Sphyraena picudilla

TABLE 2 (CONTINUED)

Open waters (56 species)			Seagrasses (68 species)		
Spanish	**English**	**Scientific**	**Spanish**	**English**	**Scientific**
dorado	*Dolphinfish*	Coryphaena hippurus	arrayao	lane snapper	Lutjanus synagris
marlin	*blue marlin*	Makaira nigricans	sama	mutton snapper	Lutjanus analis
sierra canalera	*Cero*	Scomberomorus regalis	salmonete	spotted goatfish	Pseudupeneus maculatus
peto	*Wahoo*	Acanthocybium solandri	colirrubia	yellowtail snapper	Ocyurus chrysurus
atunes	*Tunas*	Thunnus sp.	carrucho	queen conch	Strombus giga
tiburón	*Sharks*	Carcharinidae	boquicolora'o	striped grunt	Haemulon plumierii
picúa	*Atlantic barracuda*	Sphyraena barracuda	manatí	manatee	Trichechus manatus
sama	*mutton snapper*	Lutjanus analis	langosta	spiny lobster	Panulirus argus
bonito	*little tunny*	Euthynnus alletteratus	balajú	ballyhoo	Hemyramphus brasiliensis
aguja blanca	*white marlin*	Tetrapturus albidus	cojinúa	bar jack	Carangoides ruber

Source: from García-Quijano 2007.

FIGURE 2
Hierarchical cluster analysis dendrogram showing relative distances between habitat types based on Bray-Curtis dissimilarities in species assemblages according to fishers



Source: from García-Quijano 2007.

Example 2. Patterns of agreement in LEK

Patterns of agreement (or consensus) between fishers or other LEK holders are important to identify patterns of knowledge distribution among a population of fishers that might point to differences in experience or vantage points about local ecosystems. Differentiating between idiosyncratic and widely agreed-upon knowledge is crucial for indentifying local collaborators and topics of collaboration (Boster, 1991; Davis and Wagner, 2003). Also, under certain circumstances such as the case of small-scale fisheries where the effect of technology is small, looking at agreement patterns can serve as data quality control. Fishers use their LEK to predict location and health and composition of captured species assemblages and thus performance in catching fish will reinforce "correct" LEK insights. Under those conditions consensus can be used as a proxy for the reliability of that knowledge (Romney *et al.*, 1986; Weller, 2007).

In a study in southeastern Puerto Rico, García-Quijano (2006; 2009) used Cultural Consensus Analysis (Romney *et al.*, 1986, Weller, 2007), an analytical technique developed by social scientists to measure and describe clustering of cultural knowledge patterns, to measure patterns of agreement among fishers about various fishery species ecology. This study found that there were high levels of agreement about aspects of the ecology of important fishery species, and that fishers' knowledge significantly correlated with their success in fishing. Fishers reported that the most important knowledge they need to have about resource species was related to: 1) Species-habitat matching: in what kinds of habitats are the species most commonly caught, 2) Seasonality: at what times of the year are the species most commonly caught, 3) gear types used to capture the species and 4) whether the species are usually found alone (solitary), in mono-specific groups, or together with other species. Three of these knowledge domains are ecological in nature. Fishers highly agreed on both the importance of these domains as well as, in a probability sample of fishers, on the particular ecological characteristics of important resource species (García-Quijano, 2006; 2009). This kind of ecological information, about the habitat requirements and environmental parameters associated with important resource species, can be used directly for EBFM management based on essential habitats and associated species assemblages (See Tables 3,4, and Box 2).

TABLE 3
Consensus analysis showed that randomly chosen SE Puerto Rican fishers exhibit high agreement in responses regarding important resource species' ecological parameters. Ratios of the first to the second eigenvalues are larger than 3:1, suggesting high levels of agreement between fishers and an adequate fit to the cultural consensus model (Romney, *et al.*, 1986)

Ecological knowledge assessment question	Variable	1st Eigenvalue	2nd Eigenvalue	1st:2nd Eigenvalue ratio
Where species are found	WHERE**	15.880	1.986	7.994
Season when species are found	SEASON**	13.022	2.426	5.367
Species' aggregation habits	AGGREG**	13.320	4.253	3.132
Gear used to capture species	CAPGEAR**	11.348	2.896	3.919
Depth at which species are found	DEPTHFIND*	10.433	2.995	3.483

Source: Modified from García-Quijano (2006).

TABLE 4
Consensus-weighted answers to LEK questions asked for 16 important/salient fishery species

Fishery species	Habitat	Season	Aggregation	Capture gear
mutton snapper	reefs	summer	groups same species	bottom lines
Spanish mackerel	deepwater	winter	groups same species	troll line
cero	deepwater	winter	groups same species	troll line
yellowtail snapper	reefs	all year	groups same species	bottom lines
lane snapper	mud bottoms	all year	groups same species	bottom nets, bottom lines
red hind	reefs	winter	groups same species	bottom lines
red grouper	reefs	all year	groups same species	bottom lines
queen conch	grass	all year	groups same species	diving
white mullet	bays	all year	groups same species	surface nets
Striped grunt	reefs	all year	groups same species	bottom nets
spiny lobster	reefs	all year	groups same species	fishpots
queen triggerfish	reefs	all year	groups other species	fishpots, bottom lines
silk snapper	deepwater	all year	groups same species	bottom lines
spotted goatfish	grass	fall	groups same species	fishpots
octopus	reefs	all year	solitary	diving
rainbow parrotfish	reefs	all year	groups other species	fishpots

BOX 2

Consensus weighted answers to LEK questions about ciguatera toxicity, preferred depth for deep water species, and preferred salinity ranges for estuarine species

Species	Toxicity (ciguatera)	Species	Preferred depth	Species	Salinity range
Crevalle jack	always toxic	Yellowtail snapper	less than 20 *brazas**	white mullet	fresh and brackish water
amberjack *	always toxic	mutton snapper	less than 20 *brazas*	liza	fresh and brackish water
Atlantic barracuda	always toxic	lane snapper	less than 20 *brazas*	snook	fresh and brackish water
bar jack	never toxic	cardinal snapper	less than 20 *brazas*	Atlantic tarpon	brackish water only
blue runner	always toxic	blackfin snapper	more than 50 *brazas*	sardine**	brackish water only
black jack	always toxic	silk snapper	more than 50 *brazas*	sardine**	brackish water only
yellow jack	never toxic	queen snapper	more than 100 *brazas*	herring**	brackish water only
horse-eye jack	always toxic	misty grouper	more than 20 *brazas*	half-beak	brackish water only
schoolmaster snapper	frequently toxic	yellowfin grouper	more than 20 *brazas*	White ballyhoo	saltwater only
silk snapper	never toxic	red hind	less than 20 *brazas*	thread herring	brackish water only
spanish hogfish	sometimes toxic	Jewfish	less than 20 *brazas*	sardine**	brackish water only
octopus	never toxic	Nassau grouper	less than 20 *brazas*	yellowfin mojarra	brackish water only
red grouper	never toxic			land crab	brackish water only
yellowfin grouper	never toxic			peneid shrimp	brackish water only
misty grouper	never toxic			oysters**	brackish water only
jewfish	never toxic			largehead hairtail	brackish water only
mutton snapper	never toxic			whitemouth croaker	brackish water only
spanish mackerel	never toxic			southern sennet	brackish water only
cero	never toxic				

Source: Modified from García-Quijano (2006) *Braza*= app. 1.7 m

* 3 species, *Seriola* sp. genus

** Local name at generic level. exact species unknown

FINAL THOUGHTS: KNOWLEDGE SHARING IS A TWO-WAY STREET

A necessary precondition for LEK-WSEK translation and integration is to genuinely realize that no person or group of persons can know everything about something as complex as a fishery ecosystem, and that to have any hope of increasing the quantity and quality of useful environmental knowledge we need to be open to combining knowledge sources and vantage points. Just like scientists, fishers are positioned to know more about certain topics and less about other topics, and in our experience fishers are greatly interested in having access to WSEK-based knowledge about biological and ecological processes. A good example of this would be knowledge about ecosystem and biological processes occurring at very small or microscopic scales, which are difficult to observe and visualize without specialized scientific equipment.

For example, in a research project in which the author García-Quijano participates, studying fishers' knowledge of the West Indian Top Shell, *Cittarium pica*, fishers have shown detailed and nuanced knowledge of the biology and ecology of large juvenile or adult snails but admittedly little knowledge about small juvenile or larval stages and about the reproductive cycle, that require assessing gonad maturity (Forrester *et al. In progress*). The shell fishers reported that they would really like for the scientists to share this kind of information with fishers in an accessible format, so that they could take this information into account as they planned their fishing activities. Likewise, in a study with land crab (*Cardisoma guanhumi*) fishers (crabbers) in Puerto Rico (García-Quijano *et al.,* 2013), crabbers shared extensive knowledge of critical habitat and ecology of adult land crabs, as well as conditions that lead to crab spawning aggregations. Meanwhile, they told us that they would really like to scientists to teach them about the movement and recruitment patterns of crab larval stages, which is largely unknown to them.

For real two-way knowledge sharing, the forums and spaces for developing fishery knowledge should be democratized. Fishers will share more knowledge and participate more in the application of ecological knowledge for management if they have more confidence that their accounts will be listened to and valued. This might require a commitment to cooperative formats and venues of knowledge sharing that veer away from the usual conference presentation or public hearing formats, which fishers feel favors and empowers formally-educated WSEK holders and those who command technological tools such as computers, statistical-graphing software, and slide presenters.

Our main goal for this article has been to present areas and topics of convergence and potential synergy of collaboration between LEK and WSEK and to address some conceptual and methodological issues that we have encountered from our vantage points as human ecologists and anthropologists. We thus fully expect that our accounts are incomplete, precisely because integrating LEK and WSEK is a complex endeavor that requires group-based interdisciplinary collaboration. We feel that Ecosystem-Based approaches to management present the greatest potential yet for LEK-WSEK collaboration. This is evidenced by the remarkable convergence between ecosystem-based WSEK and fishers' LEK. There has never been a better time to act than "right now" to avoid the disaster that would be "missing the boat" (Johannes *et al.,* 2000) on fisheries sustainability.

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Methods to use fishers' knowledge for fisheries assessment and management

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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

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

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- 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

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Guidelines for use of fishers' ecological knowledge in the context of the fisheries ecosystem approach applied to small-scale fisheries in neotropical South America

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ABSTRACT

Although the ecosystem approach to Fisheries (EAF) requires and encourages the participation of fishers as key players in the management process, it is still necessary to strengthen the effort to spread this approach as a management concept and determine how to leverage and incorporate the ecological knowledge of fishermen (EKF). This is important for managers and resource administrators to be able to recognize the desirability of considering the EAF as a valid instrument for stimulating the integration of knowledge possessed by fishermen with scientific knowledge in order to improve the diagnosis, evaluation and sustainable use of fisheries as well as to maintain the ecological integrity of aquatic ecosystems. This emerges as a top priority, particularly in the area of inland waters of Latin America where there is an evident lack of experience and information on the use of this approach. In this context, this paper explores the potential of the EKF, including both its limitations and advantages, within the EAF framework and also analyzes how cultural, biological, fisheries, ecological and environmental information are relevant components of the information matrix required to implement resource management under this approach at appropriate spatial scales. In accordance, we outline general guidelines and strategies aimed at integrating and applying the EKF at different stages of management planning within the proposed guidelines of EAF with the objective of improving conservation and management of fishery resources.

Lineamientos para el uso del conocimiento ecologico de los pescadores en el marco de un enfoque ecosistemico pesquero aplicado a pesquerias de pequeña escala en america del sur

Aun cuando el Enfoque Ecosistémico Pesquero (EEP) requiere y estimula la participación de los pescadores como actores principales en el proceso de ordenación, es aún necesario profundizar el esfuerzo dirigido a difundir este enfoque como concepto de manejo y determinar cómo aprovechar e incorporar al mismo el conocimiento ecológico de los pescadores (CEP). Ello resulta importante con el fin que los manejadores y administradores de recursos reconozcan la conveniencia de considerar el EEP como instrumento válido para estimular la integración del conocimiento que poseen los pescadores con el conocimiento científico con el fin de mejorar la diagnosis, evaluación y favorecer un uso sostenible de las pesquerías, así como el mantenimiento de la integridad ecológica de los ecosistemas acuáticos. Esto emerge como una importante prioridad, particularmente dentro del ámbito de las aguas continentales de América Latina donde se advierte una evidente ausencia de experiencia e información sobre el uso de este enfoque. En este contexto, este trabajo explora cual es el potencial que posee el CEP, incluyendo sus limitaciones y ventajas, en el marco del EEP y analiza que información cultural, biológica, pesquera, ecológica y ambiental resulta relevante adoptar como parte de la matriz de información que se requiere para implementar el manejo de los recursos bajo dicho enfoque y en que escala espacial ello resulta apropiado. Acorde a ello, se presentan directrices y estrategias generales dirigidas a integrar y aplicar el CEP en las diferentes etapas de los planes de manejo que se desarrollen siguiendo los lineamientos propuestos en un EEP y con el objetivo de mejorar la conservación y manejo de los recursos pesqueros.

1. INTRODUCTION

Over the past two decades the Ecosystem Approach to Fisheries (EAF) has received growing attention as an alternative approach to fisheries management (e.g. Link, 2002; FAO, 2003). The EAF emphasizes the need to plan, develop and manage fisheries in a manner that balances social needs while preserving the goods and services provided by marine ecosystems (FAO, 2003). Overall, the EAF aims to integrate the social, economic and environmental aspects of fisheries in a balanced way, highlighting the social value of fishing, the central role of the human component (De Young *et al.*, 2008), the need to maintain structural biodiversity and genetic resources, and the ecological integrity of aquatic ecosystems Ward *et al.* (2002), Mace (2004), Hall and Mainprize (2004). The EAF can be regarded as an extension of conventional management, noticing, however, that fisheries cannot be managed without the participation of fishers in decision-making processes. In this context, FAO (1997a, b) stresses in the Code of Conduct for Responsible Fisheries that conservation and management decisions for fisheries should also take into account traditional knowledge about resources and their habitat, and that states should investigate and document the knowledge and technologies of small-scale fisheries in order to assess their application to the conservation, management and development of fisheries.

In South America, the knowledge base and methodology developed for the use of fishers' ecological knowledge (FEK) appear to have been consolidated mainly in Brazil (Faulkner and Sylvain, 2002), demonstrating the usefulness of this type of knowledge with respect to coastal fisheries (e.g. Reis and D' Incao, 2000; Silvano *et al.*, 2005, 2006; Begossi, 2006; Begossi *et al.*, 2011; Silvano and Begossi, 2012; Begossi *et al.*, 2012) and estuarine fisheries (Kalikoski and Vasconcellos, 2003, 2007, Shafer and Reis, 2008; Vasconcellos*et al.*, 2009), but much less so in riparian systems (Calheiros *et al.*, 2000; Silvano and Begossi, 2002; Seixas and Berkes, 2003, Duke *et al.*, 2008). Nonetheless, a comprehensive review on the use of FEK in Latin America by Chuenpagdee *et al.* (2009) demonstrated that most countries to date have been reluctant to apply this type of approach.

Despite the growing interest in using traditional ecological knowledge (Brooks and McLachlan, 2008), its integration into fisheries management has encountered many apparent difficulties. On one hand, traditional fishery assessments based primarily on obtaining catch and effort data have not taken into account the relevance, need and importance of considering information from fishers as complementary to scientific information (Berkes, 2001). This gap is related in part to the lack of inclusion that the EAF still has as part of a comprehensive framework for the management of coastal and river fisheries in South America, and also to the limited understanding and appreciation by resource managers of the contribution that FEK can make to improve baseline information and decision criteria for fisheries management.

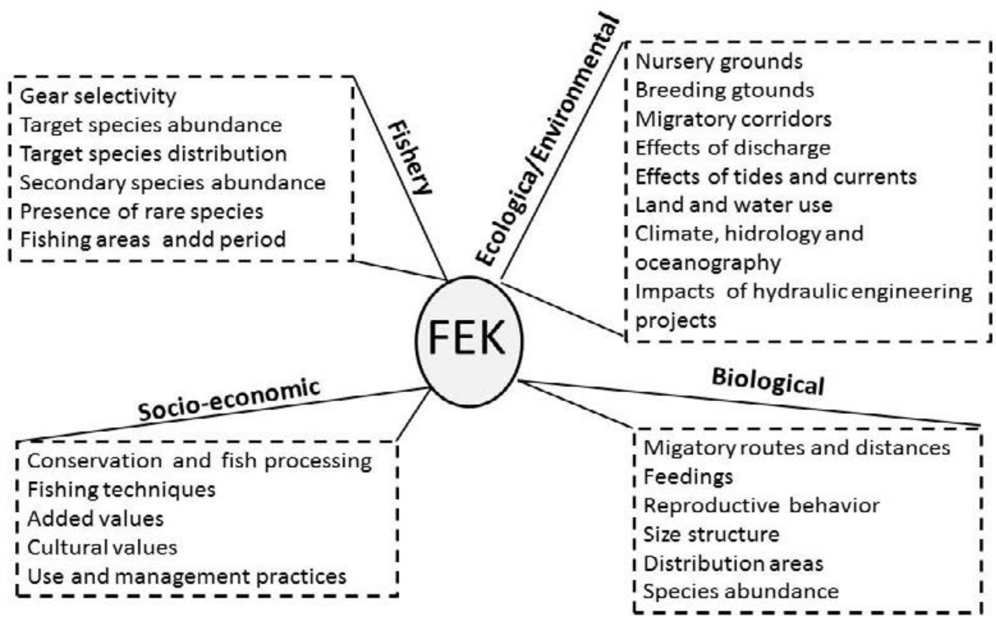
In this context, the aim of this paper is to consider what information and alternatives exist to ensure that fishers' ecological knowledge can be incorporated into the management process of small-scale fisheries in the neotropical South American areas under an ecosystem approach. Specifically, this study emphasizes fisheries from large river basins, where this type of approach has been rarely applied or need to be developed.

2. INFORMATION PROVIDED BY FISHERS' ECOLOGICAL KNOWLEDGE FOR ECOSYSTEM-BASED APPROACH TOWARDS MANAGEMENT OF SMALL-SCALE FISHERIES

Traditional ecological knowledge is defined as the accumulation of knowledge, practices and experiences that have evolved through an adaptive process and are culturally transmitted across generations (Berkes, 1999). This type of knowledge is differentiated from local knowledge, based on more recent experiences and shared by people of a common geographical area (Berkes, 2001). Here, the concept of fishers' ecological knowledge (FEK) is considered as a source of information that is based on both cultural and local experiences, and thus representative of knowledge of fishing communities. This knowledge is considered substantially factual, founded in empirical observations of biological species traits and long-term experience with the use of resources and their relationship to the environment, as well as validation through social interaction among fishers (Usher, 2000; Houde, 2007). The FEK definition is appropriate for large rivers, since these systems exhibit a large environmental variability at different spatial and temporal scales.

Certainly, the use of FEK in South American fisheries has not been widely considered as a management tool due to the lack of acceptance among resource managers, and the fact that its meaning, application and implementation are not properly understood due to bureaucratic, cultural, scientific and social barriers (Soto, 2006). Although management agencies may have frequent contact with fishers, they have been reluctant to incorporate FEK into management processes; no organized or systematic strategy has been developed with the aim of harnessing the traditional ecological information of fishers. The use of FEK, nonetheless, can provide information on various aspects of fish biodiversity, species ecology and biology, and on how resource dynamics are related to the use of the environment (Figure 1). Begossi (2008) points out that fishers' knowledge based on the use of fisheries resources and

FIGURE 1
Dimensions of fishers' ecological knowledge (FEK) in coastal marine and river fisheries



the biology and ecology of fish, represent aspects that, together with fishers' behavior, must be integrated into management, particularly in cases where scientific information is scant (Silvano and Begossi, 2010). Whereas in marine environments this fishers' knowledge has accumulated over continuous observation of fish behavior and its interaction with oceanographic factors such as currents, temperature, type of substrate, etc. (Berkes and Folke, 2002), in large rivers catch trends have been associated with flood pulses, changes in turbidity, temperature, etc. Combined knowledge from both scenarios contributes not only to enhance the understanding of change in the presence and abundance of species in relation to multiple bio-ecological factors in marine or fluvial ecosystems, but also allows for the assessment of the potential effects of fishing on fish communities and about which periods of the year and areas may require regulation to protect fish life cycles. The value of the many components that comprise ecological knowledge is that they are not based on specific or occasional observations but develop from accumulated experience over extended periods of time. Moreover, this ecological knowledge remains often adaptive, responding to the need for wise use of fisheries resources as a livelihood component, consistent with the concept that ecological systems are not static or immutable but, rather, dynamic and changing as is characteristic in river basins.

The value and diversity of the aspects that comprise FEK, however, differ in significance depending upon the characteristics of the ecosystem, particularly with respect to marine vs. continental ecosystems (Table 1). Marine systems are more stable and more complex across a vertical dimension which lends itself to acquiring

TABLE 1
Aspects of fishers' ecological knowledge in relation to the different components of ecosystem-based management of marine-coastal and river fisheries, rated in terms of more (+); less (-) and equal (=) importance - for management

		Importance	
Aspects of management	**Fisher's ecological knowledge**	**Marine-coastal**	**River watersheds**
Temporal scope of resources	Temporal distribution of concentration of most relevant species	(=)	(=)
Spatial distribution of resources	Fishing areas of most relevant species	(+)	(-)
Fishing methods	Fishing strategies associates with tide cycles, currents/flood pulse	(=)	(=)
Gear use	Gear use efficiency on species	(-)	(+)
Species captured	Target species, secondary species, incidental species	(=)	(=)
Present and past state of fisheries	Perception of changes in species abundance and size of fish	(=)	(=)
Factors regulating the fishery and species abundance	Water quality	(-)	(+)
	Substrate	(+)	(-)
	Depth	(+)	(-)
	Oceanography/Hydrology	(=)	(=)
Biodiversity	Detection/Identification of frequent, rare and exotic species	(=)	(=)
Bionomic characteristics	Breeding period and area	(=)	(=)
	Feeding behavior	(+)	(-)
	Migratory behavior	(-)	(+)
Habitats with ecological value	Identification of breeding and nursery grounds	(=)	(=)
Management guidelines	Spatial and temporal regulations	(=)	(=)
Socio-cultural factors	Religious, symbolic, mythic and sentimental values related to species	(-)	(+)
Anthropogenic and natural factors	Changes in behavior, distribution and species abundance	(-)	(+)

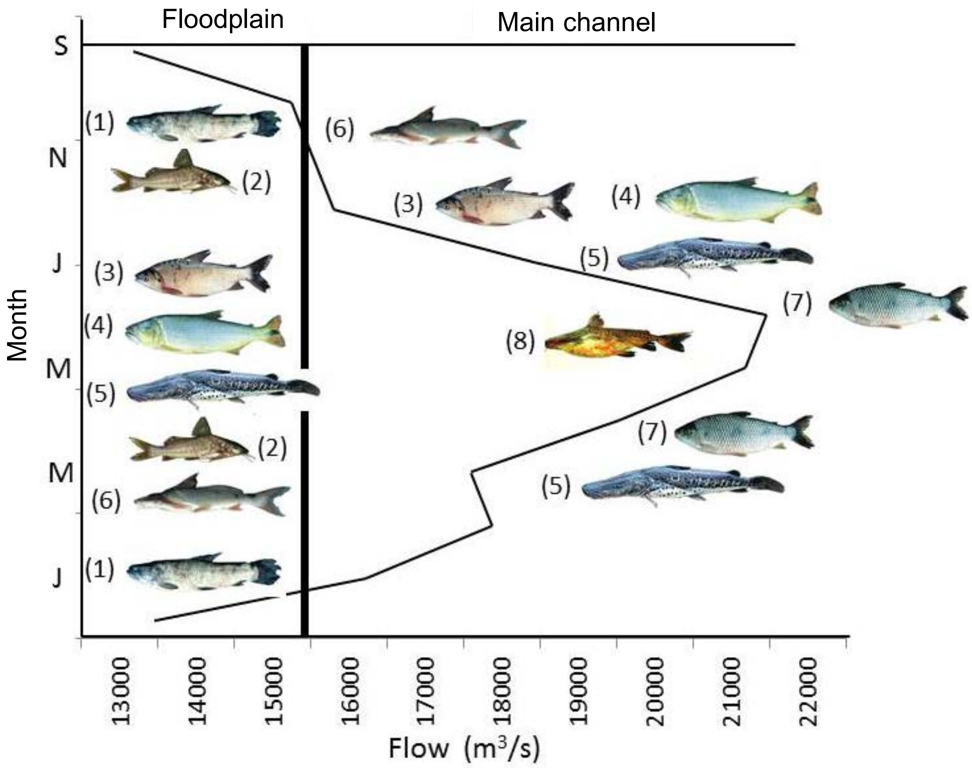
an extensive knowledge of available habitats and resources. However, due to the continuous nature of river systems, with contrasting limnophase (low water period) and potamophase (high water period) and a great potential for lateral expansion when associated with vast flood plains (Neiff, 1999), fishers have knowledge specific to those species migrating along longitudinal and lateral floodplain river axes. As such, the temporal and spatial variability of fisheries in large rivers, in sync with the rising and falling of flood waters that define the lotic and lentic environments, is undoubtedly the most distinctive feature that differentiates these fisheries from their marine counterparts.

Two of the components of principal concern in fisheries management are the time at which resources are most abundant, and the areas of the ocean or the watershed where they are concentrated. The experience of fishers, given their almost daily contact with fish, provides valuable information about temporal changes in abundance (Johannes *et al.*, 2000; Camacho, 2013) whereas their fishing strategies are clearly synchronized with the spatio-temporal distribution of resources due to the need to optimize the benefits of fishing. In the coastal lagoons of Brazil, for example, fishers were able to predict species patterns of abundance and distribution according to lunar phases, tides, winds, etc. (Seixas, 2002; Seixas and Berkes, 2003), while fishers in coastal marine fisheries have substantial knowledge of species diversity, breeding habitats, reproductive periods, and trophic relationships among species (Peace and Begossi, 1996; Silvano *et al.*, 2006, 2008, Silvano and Begossi, 2005, 2002, 2012; Begossi *et al.*, 2011, 2012).

In river fisheries there are fewer studies derived from FEK, but in cases such as the Upper Amazon (Colombia) and the Tietê Basin (Brazil) information has been gathered on fish habitat use, breeding season, diet, abundance, migration patterns, spatial distribution, etc. (Silvano and Begossi, 2002; Damaso, 2006, Duke *et al.*, 2008). As expected, most information is related to migratory species which provide the principal resource base for inland artisanal fisheries in South America (Barletta *et al.*, 2010). In large river systems, species reproductive cycles are usually coupled with the hydrological cycle (Welcomme, 1992), but the period and direction of migration may differ between rivers even for the same species (Lucas and Baras, 2001).

Moreover, fishers develop strategies for fishing based on distribution and abundance changes in relation to variation in discharge, a behavior manifested in large river floodplains where fish move laterally and longitudinally in synchrony with the flood pulse (Junk, 1989), and where migrations represent adaptive responses of species to environmental fluctuations (Arrington *et al.*, 2004). For example, in the middle Paraná River (Argentina) fishers have adapted to capture different species of economic importance according to seasonal flow variation. Species such as *Prochilodus lineatus* (sábalo), *Salminus brasiliensi* (dorado), *Pseudoplatystoma corruscans* (surubí), *Luciopimelodus pati* (patí) *and Leporinum obstusidens* (boga) among others, are often caught in the main channel during flooding with gill nets, while *Oxydoras kneri* (armado chancho), *Rhinodoras d´orbigny* (armado)and other siluriformes are caught using longlines. When floodwaters recede from the floodplain, fisher´s target *P. corruscans* and *L. obtusidens*. In the floodplain, the flooded period offers the opportunity to capture the same species that seek floodplains for feeding grounds, as well as the sedentary (non-migratory) species *Hoplias malabaricus* (tararira) The latter remains during the dry season in the floodplain as being tolerant to low oxygen concentrations and is one of the species of interest for fisheries (Figure 2).

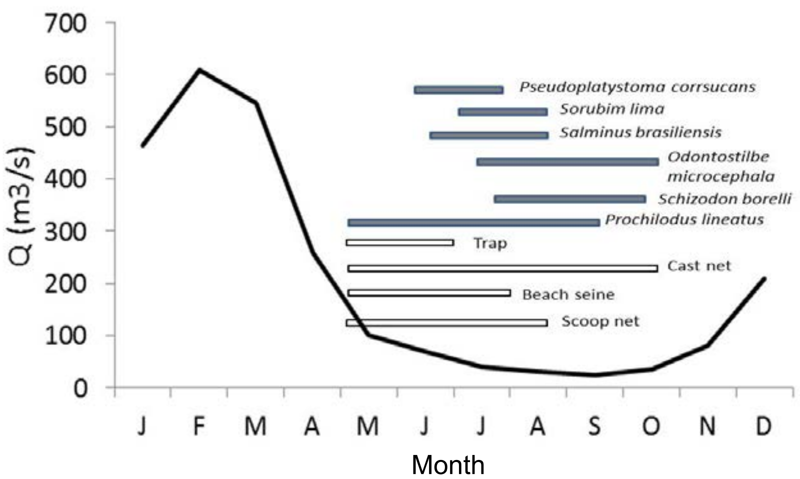
FIGURE 2
Capture of economically important species for artisanal fishing in floodplain and main channel habitats of the middle stretch (sector) of the Lower Parana River
(1) *H. malabaricus*; (2) *P. maculatus*; (3) *P. lineatus*; (4) *S. brasiliensis*; (5) *P. corruscans*; (6) *L. pati*; (7) *L. obtusidens;* (8) *O. kneri, R. dorbignyi*



Source: Unpublished data, Baigún.

In the Pilcomayo River (Bolivia), beyond a focused interest in capturing *P. lineatus* during its migration period, fishers have acquired empirical knowledge regarding the seasonality of migrations of other fish species relative to changes in flow. The result is a true fishing calendar, adapting their gears in hydrological conditions changes (Figure 3). Meanwhile, in the Upper Amazon, Duke *et al.* (2008) found an association between

FIGURE 3
Migration periods for different species as identified by fishers and type of fishing gear used in relation to discharge rates in the Pilcomayo River (Bolivia)



Source: Unpublished data, Baigún.

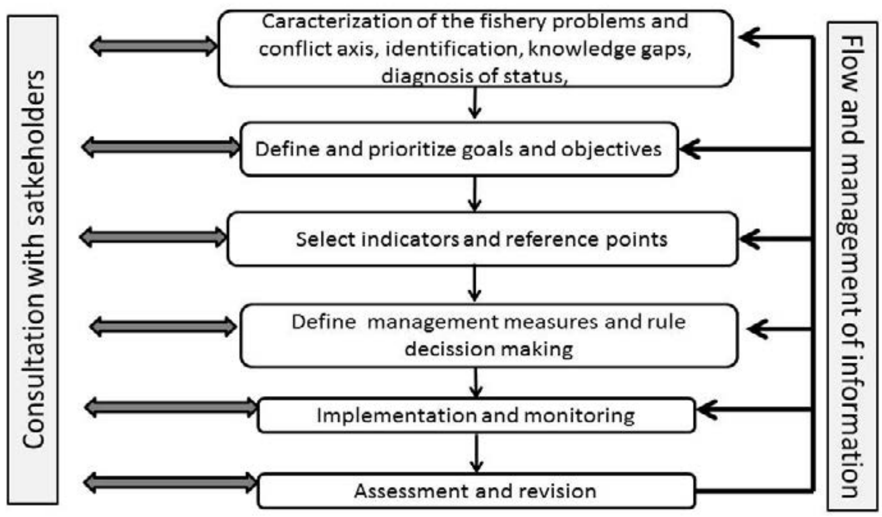
the movement of species between the river and flooded forest and how this condition promotes the selection of gear. Also, in Caqueta River, Camacho (2013) demonstrated how fishers regulate the dynamics of seasonal catches of *Pseudoplatystoma fasciatum* in response to hydrological factors and reproductive behavior.

Moreover, the knowledge of fishers is an element of great importance when they are able to detect changes in the abundance of migratory species associated with the construction of dams (Garavello *et al.*, 2010). This topic may be of particular interest for several river basins of South America, where the accelerated development of hydroelectric dams poses a potential threat to the sustainability of artisanal fisheries, and where long-term monitoring programs are not feasible (Agostinho *et al.*, 2007; Baigún *et al.*, 2011). For example, after closing Yacyreta Dam (Paraná River, Argentina) artisanal fishers belonging to upstream communities stated that over a period of 3-5 years overall fishing quality strongly decreased whereas the *Pseudoplatystoma* fishery collapsed due to its virtual disappearance (Baigún, pers. obs.). This event coincided with the poor performance of the fishways (fish elevators) of this dam (Oldani and Baigún, 2002; Oldani *et al.*, 2007). In addition, the knowledge that fishers possess on nursery and breeding grounds can contribute to the delineation of areas within large rivers where scientific knowledge is limited.

3. HOW TO INCORPORATE FEK INTO THE ECOSYSTEM APPROACH

While many artisanal fisheries remain without a management regime the increasing environmental damage suffered by watersheds and commercial fishing pressure require attention to the need to expand management objectives that consider fishing as an ecosystem service strongly conditioned by land and water use (Baigún *et al.*, 2008; Kandus *et al.*,2009; Minotti *et al.*, 2009). These new scenarios demand the development and implementation of management plans under an ecosystem approach that incorporates the importance of the relationship and permanent interaction among different stakeholders, particularly with fishing communities (FAO, 2003). Given that the development of management plans is a continuous and sequential process where the flow of information among actors emerges as a central aspect, such plans facilitate the incorporation of the vision and perspective of fishers at different stages of the management process. Figure 4 summarizes this process and highlights the points at which the intervention of local stakeholders is critical, thus necessitating information about the fishery, not only from a scientific point of view but also taking into account

FIGURE 4
Flow diagram of the management plan process under an ecosystem-based approach



Source: modified from García and Cochrane, 2005.

the ecological knowledge of fishers. When that is not the case, fishers lose confidence and trust in the plans as they feel marginalized and are less willing to collaborate, which puts at risk the success of management.

Main aspects pertaining to management plans in the context of ecosystem-based approach are considered below, together with discussion of how FEK participates in each phase of the management process.

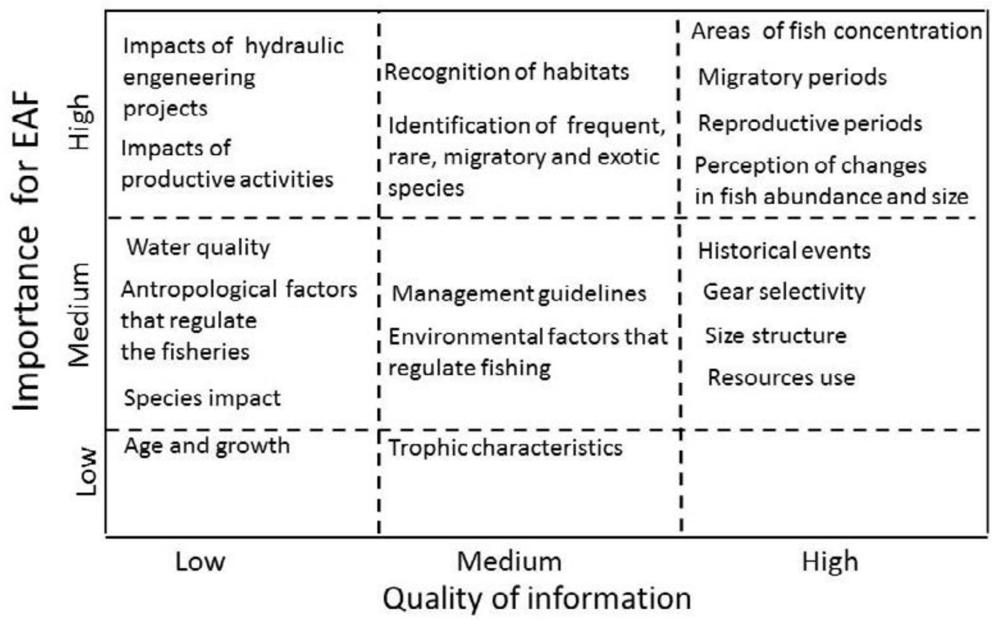
3.1 Diagnosis of resource status and identification of problems and conflicts in the fishery

A critical step in developing successful management plans for small-scale fisheries is achieving an adequate perspective on the situation and status of a fishery, including social, economic, cultural, and environmental dimensions (Charles, 2001). Actors with different needs, points of view and expectations, different from each other in how these aspects contribute to their quality of life, usually coexists in these fisheries – both in marine coastal and river systems (Gasalla and Tutui, 2006). In order to achieve a holistic vision of the fishery it is necessary to incorporate fisher's views and perceptions regarding the status and historical development of fisheries as a means of accurately recognizing possible axes of conflict. These axes differ between cases, but usually cover aspects related to the state of resources, environmental conservation, management criteria, fishing regulations, monitoring and enforcement of management measures and problems between sectors. Thus, for example, in large river fisheries fishers are likely to show concern about the impact of large dams or other infrastructure designs such as waterways, weirs, roads, etc., given their possible effect on reducing populations of migratory fish (Oldani *et al.*, 2007; Baigún *et al.*, 2007, 2011; Agostinho *et al.*, 2007). In marine environments, by contrast, the more visible conflicts focus on the lack of enforcement of fishing regulations and the problems associated with open-access fisheries (Cinti *et al.*, 2010). In order to collect the information held by fishers, managers and fisheries administrators follow various strategies aimed at promoting the involvement of different groups in workshops and meetings, or in consultation with expert fishers (Castello *et al.*, 2009) or qualified informants (Valdez-Pizzini and Garcia-Quijano, 2009). The latter, with extensive and proven experience in fishing, are recognized by their peers, know the history of the fishery, tend to come from families with a history in fishing, and rely on fishing for their livelihoods. These informants can be contacted by using open questionnaires that provide a broad overview of those issues of greatest concern to fishers (Silvano *et al.*, 2006). Through semi-structured interviews, groups of fishers are guided also to report freely on predetermined topics (Huntington, 1998), or techniques associated with the Delphi method may be applied (Leite and Gasalla, 2013). These strategies should be complemented by participatory mapping exercises to identify migration routes, fishing areas, spawning grounds, rearing habitats, etc. at a very fine scale (Begossi, 2000; Shafer and Reis, 2008; Valbo-Jorgenssen and Poulsen, 2000; Camacho, 2012), as well as anticipate how development projects may impact fishery resources (Gilmore and Young, 2012). This method is arguably one of the most useful for integrating FEK in the context of ecosystem management, facilitating spatial and temporal representation of environmental and biological scenarios based on the integration of knowledge from different fishers.

Nonetheless, the information provided by fishers varies in value with respect to quality and reliability (Figure 5). Certain aspects of FEK, particularly those relating to the various sources of impacts that can affect fisheries, can be difficult for fishers to recognize and/or separate, or not necessarily reflect direct causation. In large river floodplains, for example, where biotic and abiotic processes occur at different spatial (e.g., longitudinally and laterally) and temporal scales, fishers' capacity of observation and perception may not be sensitive enough to explain certain events or changes in fisheries. Brasil et al (2013),for example, found that fisher knowledge were unable to detected negative impacts of Nile Tilapia introduction in the Gargalheiras reservoir on native species ignoring that such impact occurred at the juveniles planktivorous stage.

FIGURE 5

Diverse types of information that can make up fishers' ecological knowledge according to its quality and importance for management within an ecosystem-based approach to fisheries (EAF) in large rivers



3.2 Definition and prioritization of goals and objectives

Management plans based on an ecosystem-based approach require identification of social, economic and environmental goals (Cochrane, 2005), each of which is associated with a number of objectives. Based on their knowledge and perspectives on the changes and state of the fishery, fishers at this phase should contribute in the identification of which aspects of the fishery require conservation, modification, or recuperation to maintain sustainable use. In this way, goals as well as objectives should respond to the social values within the fishery.

3.3 Selection of indicators and reference points

The use of indicators and associated reference values has an increasingly dominant role in the management of fisheries resources as one of the key points in the development of management plans. In general terms, the purpose of indicators is to assist in the evaluation of the effectiveness of fisheries management policies; thus, serving as a tool to describe the status and trends of resources (FAO, 1999). These indicators become instruments for monitoring, providing early warning signals, identifying potential risks for the fishery and anticipating future conditions and trends (Boyd & Charles, 2006). Reference points, in turn, enhance the meaning and value of indicators by providing a tool to measure the extent to which progress has been made in meeting previously determined objectives. Similarly, reference points facilitate the recognition of the directional effect of management actions by monitoring the trajectory of change in the fishery and providing warning if the situation is approaching or straying from an optimal state (target reference point) or critical state (limit reference point) (Caddy and Mahon, 1995). In this context, FEK can make a substantial contribution to the construction of sustainability indicators such as capture size, presence of memorable or trophy catch sizes, catch volumes, hydrological conditions, etc., as well as to the determination of which reference values are acceptable vs. unacceptable.

3.4 Management measurements and decision-making rules

Management measures and the application of decision-making rules are elements of strategies for achieving predetermined objectives. Measures, which are grouped into technical measures, input and output controls (Hoggarth *et al.*, 2006), can hardly become effective in artisanal fisheries if not accompanied by broad social consensus (McClanahan *et al.*, 2008). This implies the opening of opportunities for fishers to contribute their views on the efficiency of specific measures, based on their knowledge of biological cycles and their relation to regulatory environmental factors, as well as fishing methods used and possible conflicts with other actors (e.g., foreign fishers, users of prohibited gear, land owners). More importantly, it is at this stage that fishers need to be recognized and valued as active participants in management decisions as a means of validating and verifying that their contributions materialize into actions that provide benefits and relate to the knowledge they possess. A typical case includes the application of different types of spatial and temporal closures, whose design should take into consideration breeding and reproductive habitats, migrations and spawning periods, information that is often known in sufficient detail by fishers. Similarly, the regulations that respond to detected change in certain key indicators of the state of fisheries need to be associated with reference points based on fisher's ecological knowledge.

3.5 Evaluation and Revision

This phase is key for observing the achievements of the management plan, the extent to which objectives have been achieved and the required adjustments necessary to meet original goals. This stage requires the comparison of different indicator values with proposed reference points. Given that fishers are the principal target group of management, their participation and support is critical to perceive and assess the effectiveness of measures that have been applied.

4. DISCUSSION

The use of FEK applied to resource management undoubtedly represents one of the mechanisms to generate resilience within artisanal fisheries (Berkes and Seixas, 2005) and contributes to improved governance mechanisms that promote trust, transparency hen fishers are incorporated into the decision process (Folke *et al.*, 2005; Berkes and Turner, 2009). As a result, fisheries are empowered as improve their visibility, influence and importance with respect to the management of fisheries and acquire a sense of ownership over resources. This represents an important input for advancing in the implementation of an ecosystem-based management approach in which basic information about the dynamics of the environment and major biological and ecological aspects of the species are required but that in several cases cannot be timely gather by scientific knowledge or management agencies. Resource managers should design appropriate strategies to include FEK as a component of data collection programs, identifying what aspects may be informed by fishers and specifying their value to resource management. In the particular case of the large river ecosystems of Latin America, where scientific information remains scarce and many fisheries depend on migratory species, it is necessary to involve the knowledge of fishers in order to improve management of these critical resources (Fabre and Barthem, 2005).

Fisher´s Ecological Knowledge Use and Implementation

The use of FEK in an ecosystem-based approach differs from other approaches by emphasizing aspects and information related to the function and conservation of fluvial ecosystems, rather than exclusive collection of fisheries data. In other words, FEK as concept involves the possibility of gathering an array of ecological and fishery information in a related way. This is an aspect that resource managers should take into account, while observing several premises, if they intend to incorporate FEK as a wise strategy. In the case of South America freshwater and marine fisheries, it is necessary to ensure that the application of the ecosystem approach to artisanal fisheries management be adopted as part of planning and management agendas. For this to occur, it is important to have a full understanding of this approach and how to implement it for the conservation of ecological integrity of river and marine systems, including their abiotic, biotic and human components. Such knowledge should be expanded across stakeholders involved not only in fisheries management but also in other environmental issues related to watersheds conservation and resource uses. In South America, particularly in large river fisheries, there is a substantial lack of examples of implementation of the EAF, and those that exist are poorly developed, having only recently been recommended as an appropriate management approach for river basins (Valbo-Jørgensen *et al.*, 2008). It is therefore critical to begin laying the conceptual and empirical foundations with which to promote and disseminate the EAF as a means to capitalize and apply FEK to management processes in inland waters.

The implementation of FEK, however, has several important implications that must be recognized by the different actors involved. First, resource managers should acknowledge that artisanal fishing needs to be considered an ecosystem service and not a mere "commodity", being valued as a food resource, a source of jobs, a regulatory effect on the abundance of species and food webs and a relevant component related to the functioning of river systems, etc. (FAO, 2012; Baigún, 2013). This implies recognizing that the welfare of many fishers depends on the exploitation and subsistence of these services for which it is essential to conserve the health of marine and freshwater ecosystems. This principle is one of the essential foundations of the EAF management whereby artisanal fishers of small-scale fisheries do not necessarily seek to maximize economic gains, as do large scale fisheries, but seek to ensure long-term sustainable resource use (Johannes, 2002). Examples of such include Amazon fisheries managed via fishing agreements (Almeida *et al.*, 2004; McGrath *et al.*, 2008; MacCord *et al.*, 2007), where the objective is not economic-extractivist but social-conservationist, and through which economic benefits are feasible to preserve fishing as a steady livelihood component for local communities. The fishers know that these fisheries are regulated in the face of profound hydrological changes across the year, caused by drought and flood pulses, which clearly reinforces the ecosystem framework on which their management should be based.

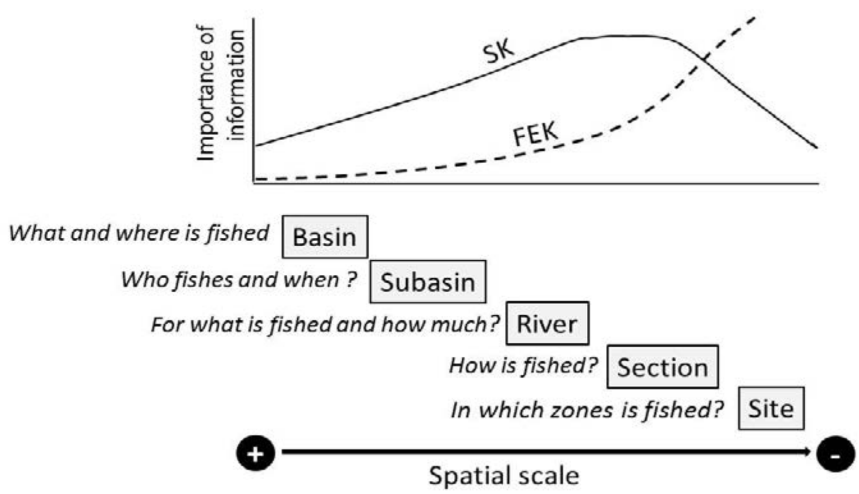
Secondly, FEK should be considered an inseparable part of the socio-cultural context of the fisher communities and therefore its incorporation should not be conducted as a formal act isolated from those who generate this knowledge, avoiding considering them mere low-cost data collectors (Stanley and Rice, 2003). On the contrary, those who are the owners of the knowledge and information of interest should be involved in a participatory manner, preferentially of the iterative type when possible (Geilfus, 2009). This implies that locally organized groups should participate in the design, implementation and evaluation of projects, being involved in a teaching-learning cycle and allowing them to take progressively some control of the fishery management process.

Such situations are facilitated when fishers have their own local knowledge that resource managers and scientists often lack. These skills are inseparable traits of each person "and go with them", making it essential that they partake in decisions about when, where and how their knowledge is used (Johannes, Freeman and Hamilton, 2000; Johannes and Neis, 2007). This mandates that FEK be conceived as part of the social, human and natural capital that fishing communities own and utilize. In this sense, this knowledge is a cultural resource oriented towards the creation of management systems, adapting to each culture as occurs in fishing and in the maintenance of the diversity of local human practices and relevant knowledge (Camacho, 2013).

Scaling Fisher´s Ecological Knowledge

In many cases scientific information, when available, is limited to a few sites within a watershed over limited timespans, and often focuses on a small number of species. In contrast, FEK, based on an enhanced spatial extent of experience in diverse environments and over prolonged time periods, allows improved understanding fishing events at larger time scale (Figure 5).In this context, FEK has the ability to integrate common and extraordinary episodes and extract knowledge and lessons that can be materialized into adapted behaviors among fishers. Not surprisingly, most fishers have the ability to optimize fishing strategies as result of continuous learning processes. The different scales at which fishers acquire their knowledge is of great relevance as they have the capacity of recognizing specific habitats that play a key role in supporting fish life cycles, therefore having great ecological relevance. For example, fishers have the capacity to detect changes on a small spatial scale such reduction or increase of floodplain lakes, disappearance of species in river sectors or small tributaries, increase of catch and effort, etc. This small scale perspective is in agreement with the noticeable environmental complexity showed by the fluvial landscape in floodplain rivers (Nestler *et al.,* 2012). It cannot be always captured by scientific assessment, and often is of not of interest to management agencies. Also, it is given low priority for scientific research, which tends to be oriented towards the understanding of larger-scale processes and phenomena, thus requiring different questions and assessment objectives (Figure 6). In fluvial systems, however, a broad perspective can be also achieved by integrating small scale and patchy information provided by as fishers. For example, while scientific research is appropriate and more relevant for describing characteristics of the fishery at the scale of the basin, sub-basin or of the entire river from a management perspective, FEK highly increase its relevance at the scale of particular section or specific sites of the river, filling also a valuable knowledge niche. In this context, scientific knowledge and FEK and can both been applied in a complementary way to provide fisheries information at multiple scales.

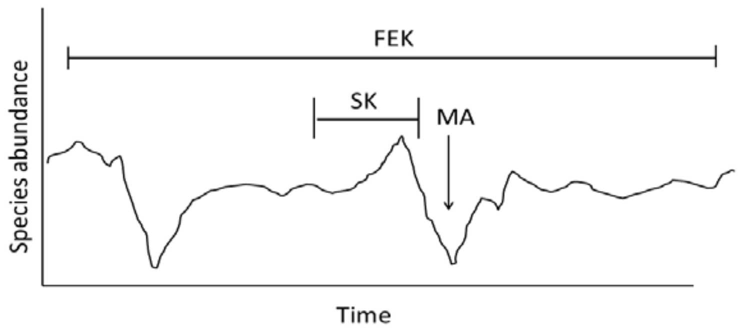
FIGURE 6
Importance level of information derived from scientific knowledge (SK) and fishers' ecological knowledge (FEK) according to questions and information acquisition that may be appropriate at each scale



Certainly, one of the most prominent aspects of FEK is that it usually applies at different spatial and temporal scales than scientific knowledge, allowing the detection of phenomena over the long-term (diachronic information) or at fine spatial scales often unrecognized by short-term data (synchronous data) obtained by management agencies and scientific assessments. Therefore, FEK can provide records of extreme events and unusual patterns reflected by memories and collective experiences (Moller *et al.*, 2004). Whereas some events can be considered as rare or "surprises" by a short term perspective, FEK can report them as not new or unusual (Figure 7). Such changes ultimately respond to natural phenomena integrated into the multi-scale character of ecosystems (Wilson, 2006) and small scale fishery systems, and cannot be necessarily accounted for within a conventional approach that aims to record changes only in species abundance with no regard to the environmental and socio-economic context. It is for this reason that, under an ecosystem approach, where information linking the behavior of the fishery with changes in processes occurring at different scales is desired, FEK holds considerable value. FEK is even more important in the case of species that are migratory or that use transboundary rivers for which local fishers provide detailed information on biology and habitat use in certain zones of rivers, thus providing valuable information that can be integrated at the river scale.

FIGURE 7

Comparative capacity to obtain information on a resource variation according to temporal scales (horizontal lines) and spatial scales (vertical lines) based on fishers ecological knowledge (FEF) and scientific knowledge (SK). The arrow indicates the moment at which information is obtained based on a considered unusual event (surprise) from the management agency perspective (MA), but that has been detected in the past by the FEK and could not been documented by SK



Fisher´s Ecological Knowledge and Scientific Ecological Knowledge in a Management Context

One of the most obvious difficulties in incorporating FEK into fisheries resource management is that usually FEK is not equated with, or recognized as, complementing scientific knowledge (Moller *et al.*, 2004; Lertzman, 2010), even when the advantages of its use are demonstrated in the management of natural resources (Huntington, 2000). In the Amazon Basin, however, the participation of the fishers was decisive in reversing the state of the population of *Arapaima gigas* (Castello *et al.*, 2009) based on their capacity for counting individuals and therefore define catch quotas. Similarly, fishers of Brazil's coastal fisheries exhibit detailed knowledge of fish behavior and ecological factors that facilitated complementation of scientific information (Silvano and Valbo - Jørgenssen, 2008). Although there are obvious differences and approaches between traditional community-based knowledge and scientific knowledge (Johnson, 1992), this should not be considered an obstacle. Rather, it is necessary to eliminate the preconceived notions so ingrained in many resource managers such that FEK cannot be formally applied in fisheries management given a lack of support by scientific evidence. Certainly, FEK does not always require scientific validation in order to be accepted or used (Mackinson and Nottestad, 1998), and scientific knowledge needs not be the baseline against which FEK is compared. While quantitative data regularly support scientific research, qualitative information provided by fishers regarding changes in environmental factors, relative abundances of target species or catch size have an intrinsic value and therefore not should be dismissed or underestimated. Similarly, FEK may not necessarily be systematized according to classic scientific paradigms to make a valuable contribution. Rather, there is often substantial and complementary agreement between FEK and scientific information (Begossi and Silvano, 2002; 2008; Silvano *et al.*, 2008; Silvano and Begossi, 2012). In some cases, FEK may be the only source of information available, thereby being in agreement with the precautionary principle that claims to use the best information available to conserve resources (FAO, 1995). Such principle applies well in large rivers where most of knowledge is "embedded" within fisher´s communities and scientific knowledge is limited and open new visions for assessing fishery status and detect trends.

FEK, on the other hand, provides a direct link with different approaches or strategies that make up fisheries management, such as user rights, the code of conduct for responsible fisheries, the precautionary approach and co-management. The latter is of particular interest given its strong association with the application of FEK (Begossi *et al.*, 2011). This strategy has provided promising results in various coastal fisheries of Central America (Fannning *et al.*, 2011) and Uruguay, in the Amazon Basin (Ruffino, 2005, McGrath *et al.*, 2006; Ruffino, 2008), as well as in other major rivers worldwide (Baird, 2003), particularly when accompanied by the implementation of land use rights, or to organize resource use and prevent the potential effects of overfishing. Shared resource management overcomes the various barriers that still exist between management agencies, scientists and fishers by means of improving communication between sectors, generating mutual trust and enabling a fluid exchange of information and knowledge that facilitates the use of ecological knowledge of fishers and its integration in an ecosystem framework. As mentioned by Begossi (2008), local knowledge on resource use and on the biology and ecology of fishes is essential for enhancing the understanding of ecosystem function and the fisheries they sustain. In this context, FEK must be incorporated together with scientific knowledge in order to reduce uncertainty and the risk associated with management decisions (FAO, 2010).

5. CONCLUSIONS

The perspective presented here shows that in South America the use of FEK remains rudimentary or at an early stage and - with the exception of some cases from coastal areas and few sites in the Amazon basin –is still rarely used for the management of artisanal fisheries. These fisheries contribute to livelihoods in many coastal and riverine communities that rely heavily on fishing and, thus, for which there is a considerable wealth of information and knowledge that is not harnessed or used appropriately. The formal incorporation of this knowledge into management faces limitations related to several factors, such as lack of appreciation of its importance by governing agencies and academia, a shortage of experts in the field, cultural barriers, and changing political and institutional scenarios. To overcome these challenges, management agencies should begin to design strategies that include FEK their databases, and use as a framework to address fishery-related, biological, ecological, social and economic factors that shape the structure of fishery systems. Nonetheless, given that the ecological knowledge possessed by fishers is almost always inextricably linked to them as part of their cultural heritage, it is imperative to interact with, and integrate, fishing communities into policy-making decisions. This means, on one side, supporting decentralized management agencies to achieve or reinforce a stronger relationship with local communities, as usually the fishers knowledge is rather disperse more than concentrated in the large riverine systems. On the other side, it is necessary to guide management plans towards an adaptive ecosystem-based approach, which comprises the appropriate tools and offer reliable opportunities for the use of FEK and achieving the necessary interaction among different actors. This approach thus incorporates guidelines and good fishing practices that many fishers are already developing in fisheries characterized by traditional management or even unmanaged, which prioritizes the conservation of resources to guarantee fishing as a livelihood source.

However, particularly in the case of inland water fisheries, there remains a challenge to achieve a sufficiently developed theoretical framework and to gain experience as to how to make the ecosystem approach to fisheries management operational and effective. At present, this represents a true bottleneck which affects also taking advantage of FEK for large river fisheries management. While there are many examples in South America, basically in marine environments, of the use and value of FEK, it has been primarily used as a means to capture biological information on species rather than to diagnose fisheries. These cases generally respond to needs or concerns arising from the academia, rather than from the needs of management agencies, highlighting the need of a change in the paradigms of use and data collection for artisanal fisheries and the perspective these agencies have.

These examples, while still limited, have rescued the positive responses and interests shown by fishers to contribute their knowledge when they are incorporated into the process of diagnosis, evaluation and monitoring. Furthermore, they have demonstrated how management agencies could benefit from obtaining fishing and reliable biological information at a local scale, which would be directly applicable to define or modify management guidelines for specific resources. Clearly, fisheries ordination processes, including management plans, should start expanding their scope encompassing the integration of FEK as a main avenue to support healthy fisheries within an ecosystem framework.

The application of FEK, however, will requires expanding the competency of fisheries administrations to include the collection of ethnobiological information, the application of new methodological tools, and training of human resources in new aspects related to fishing sociology and economics. This should be accompanied by the development or adjustment of the legal and administrative instruments that promote and facilitate interaction between sectors, and allow the active involvement of fishing communities in the politics of resources management and administration. In this context, FEK relevance will be notably empowered as fisheries management in South American fisheries start shifting from a conventional management perspective, based on solely fisheries issues, to a co-management and ecosystem approach where also ecological and social dimensions are strongly taken into account.

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PART 2

CASE STUDIES ON INTEGRATING FISHERS' KNOWLEDGE IN LATIN AMERICA

2.1
Biological and fisheries-related knowledge: expertise of fishers

Why Colombian marine fishers' knowledge is a fundamental tool for marine resource management and assessment

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ABSTRACT

The troubling condition of many global fisheries has prompted Colombian scientists and administrators to examine fisheries within Colombia and explore how this situation might be managed in order to address resource sustainability, preserve fisheries, and maintain livelihoods that rely on fishing activities. However, lack of scientific knowledge at the national level and recognition of the importance of including Fishers in management has made Local Ecological Knowledge (LEK) necessary for understanding the past and present conditions of Colombia's small-scale marine fisheries. Fishing communities have compiled LEK through decades of experience gained by fishing in local marine environments. Fishers, who have experienced firsthand the deteriorating conditions that threaten their livelihoods, are increasingly sharing valuable knowledge with the scientific community. Recently, the behavior of Fisher has been recognized as key to improving fisheries management via Ecosystem Based Management, as well as essential to sustaining small-scale marine fisheries and fishing communities. Here, core research on Colombian Fishers' knowledge, obtained from a three-level survey (communal, group and individual) conducted in five communities on the Caribbean and four communities on the Pacific coasts, informs a vision that combines four pillars: 1. Historical changes; 2. Actual fishery situation; 3. Fishery problems; and 4. Fishery solutions. Fisher experts revealed sixteen categories of LEK as part of each pillar. This paper shows examples of the type of information collected on each pillar, including description of possible uses and conflicts when the methods are applied. LEK has become a powerful tool in the development of baseline plans, a first approach to small-scale fisheries management in Colombia. It also adds legitimacy and builds trust among scientists, managers, Fishers, fishing communities and the public.

INTRODUCTION

Colombia has a high diversity of natural environments (sea grass beds, coral reefs, river mouth, rivers, mangrove swamps, estuarine, wetlands, open sea, deep-sea floor, among others), ethnic variability (indigenous, afro-Colombians, whites, mixed), political/jurisdictional institutions (municipalities, townships, villages and unincorporated neighborhoods), categories of Fishers within communities (part-time on an annual or daily basis, full-time, seasonal, migratory), fishing methods and gears. This diversity makes it difficult to find one methodology that is appropriate for monitoring, enforcing and managing fisheries and coastal resources in the country. The deteriorating condition of these resources (Gómez-Canchong *et al.,* 2004, CCI 2009, Díaz *et al.,* 2011) has prompted Colombian scientists and administrators to examine fisheries within Colombia and explore how this situation might be managed in order to address resource sustainability, preserve fisheries, and maintain livelihoods that rely on fishing activities. However, lack of scientific data and information at the national and local levels has made this task difficult.

Local Ecological Knowledge (LEK) has proven to be an important source of information for developing sustainable fisheries management strategies and tactics that, at the same time, empower Fishers and advance human rights (FAO, 1995; COFI 2007). Fishery communities have compiled LEK through decades of experience on fishing and interacting with local marine environments. This knowledge, transmitted from Fisher´s generation to generation, pertains to where, when and what to fish (Bergmann *et al.,* 2003, St. Martin *et al.,* 2007). Although ecological knowledge is stressed, LEK also involves the social and cultural context of fishing activities in those communities (Murray *et al.* 2006). Therefore, LEK is important for understanding the past and present conditions of Colombia's small-scale marine fisheries. Fishing communities have compiled LEK on their local marine environments through decades of experience, and have experienced firsthand the deteriorating conditions that threaten their livelihoods. Fishers are increasingly sharing their valuable knowledge with the scientific community worldwide as a result of the growing recognition of the value of LEK for fisheries management (Macnab, 1998; Haque, 2001, Power and Mercer, 2001; Wilson *et al.,* 2003, Schumann 2007) and locally (Vieira 2001, Sánchez-Páez *et al.* 2005, Zapata 2005, Lopez *et al.,* 2006, Zapata 2006; Duarte, 2007; Garcia, 2010; Navia, *et al.,* 2010; Saavedra-Díaz, 2012).

More recently, Fishers knowledge has been recognized as a key element for the improvement of fisheries management via an ecosystem approach to fisheries management (EAFM) (Leite and Gasalla, 2013), as well as essential for the sustenance of small-scale marine fisheries and fishing communities. The EAFM involves a deep understanding of the socio-ecological systems used by Fishers, connecting the goods and services provided by the ecosystems with the direct importance for Fishers' wellbeing and livelihoods. Consequently, the EAFM is used to manage and improve not only human well-being (such as food security or job security), but also ecological well-being (such as sustainable fisheries harvesting, habitat protection, or pollution reduction) (Pomeroy *et al.,* 2013). This relationship enhances the power of Fishers LEK since it integrates human and ecological knowledge and becomes the basis for adaptive EAFM.

Colombian Caribbean fishing communities are not as isolated as are most communities on the Pacific coast, but on both coasts there are many examples of fishing communities located in remote areas where the presence of government or of the fisheries administration is minimal or weak. For these reasons, the decisions made by Fishers on a daily basis (concerning resources and ecosystems) drive the fishery and can lead towards or away from sustainability. Integration of LEK can lead to better management of marine ecosystems.

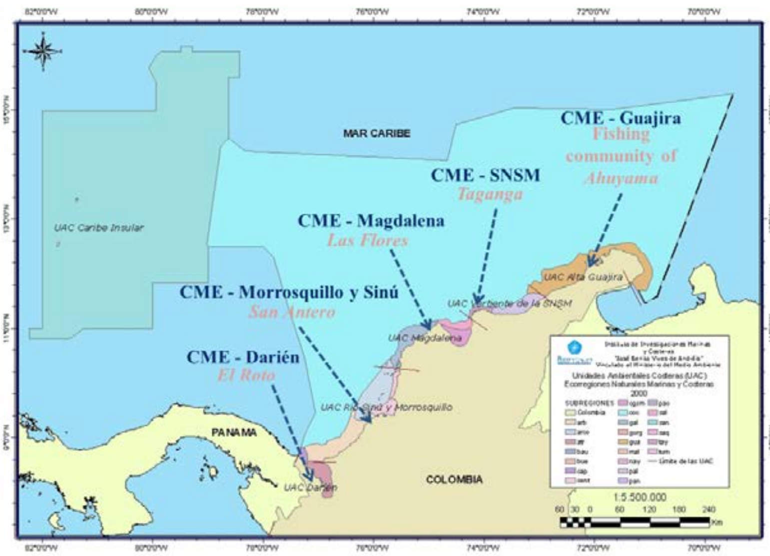
This paper seeks to capture this knowledge in order to reveal key features of artisanal fisheries in Colombia, the challenges artisanal fishing communities are facing and possible solutions to address those challenges. The paper presents results from a three-level survey (communal, group and individual) conducted on the Caribbean (five communities) and Pacific (four communities) coasts, which provided information about four pillars of the fishery: 1. Historical changes; 2. Actual fishery situation; 3. Fishery problems; and 4. Fishery solutions.

METHODS

The Colombian Caribbean coastline stretches for 1 642 km (see Figure 1), the Pacific coastline for 2 188 km (see Figure 2), and island coastlines for a total of 52 km. The total population of the Caribbean coastal states is 1 406 466, while 5 952 871 people live in the Pacific states. Meanwhile, the Caribbean coast supports 2 919 348 inhabitants, while the Pacific coast supports only 543 594 (Posada y Rozo 2005). Although the Pacific coastline is 1.3 times longer than the Caribbean, the Caribbean population is 1.7 times greater, and this difference in population shapes both fisheries and management.

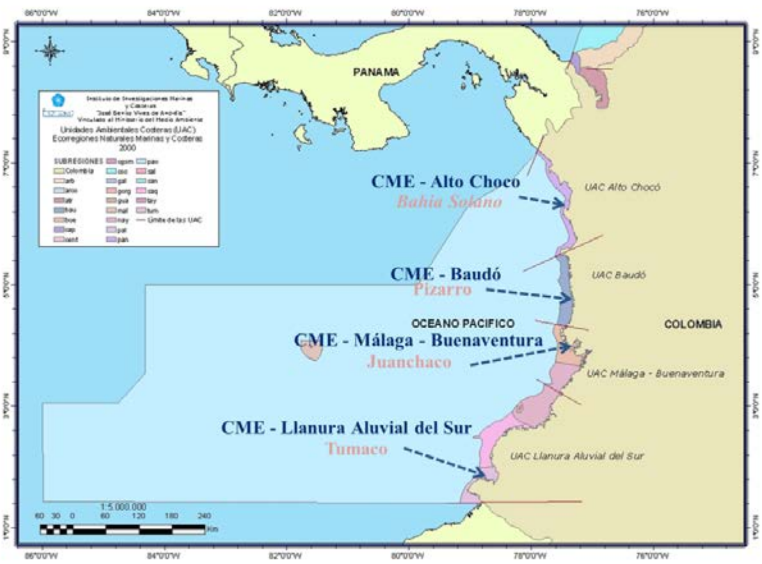
The Colombian coast is divided into six Coastal and Marine Ecoregions (CMEs) on the Caribbean coast (see Figure 1) and four CMEs on the Pacific coast (Figure 2). CMEs are distinguished by environmental characteristics such as geo-morphology,

FIGURE 1
Selected fishing communities corresponding to each Coastal and Marine Ecoregions (CME) from the Colombian Caribbean coast



Source: modified from MMA 2000.

FIGURE 2
Selected fishing communities corresponding to each Coastal and Marine Ecoregions (CME) from the Colombian Pacific coast



Source: modified from MMA 2000.

hydrography, sedimentology and coastal and marine ecosystems (MMA, 2000). Jurisdictional (states) and CME boundaries are relatively similar, in some cases nearly overlapping. Given its focus, this study does not include the insular eco-regions since they are Marine Protected Areas. Data were collected in nine communities (one per CME) selected as representative of inshore artisanal fisheries communities (AFC), four on the Pacific and five on the Caribbean coast.

Selected Caribbean coast fishing communities included:
- *Ahuyama* in the Guajira CME.
- *Taganga* in the Sierra Nevada de Santa Marta CME.
- *Las Flores* in the Magdalena CME.
- *San Antero* in the Morrosquillo and Sinú CME.
- *El Roto* in the Darién CME.

Pacific coast fishing communities are:
- *Bahía Solano* in the Alto Chocó CME.
- *Pizarro* in the Baudó CME.
- *Juanchaco* in the Málaga-Buenaventura CME.
- *Tumaco* in the Llanura Aluvial del Sur CME.

Data Collection and Analysis of LEK

Fieldwork took place from August 2008 to August 2009. On the Caribbean coast, work was conducted from August 2008 to March 2009, and on the Pacific coast from March 2009 to August 2009. Selection of the nine AFC was based on advices from environmental and academic institutions fishery experts. All AFC selected had voluntarily decided to participate in the study. Once the nine AFC were identified, first author conducted the fieldwork within each community for approximately four to six weeks. Fieldwork time varied depending on the participation of Fishers and community Leaders in planned activities, the variety of fishing methods, as well as Fisher's availability. The study included communal, group and individual approaches:
- The **communal approach** consisted of two main hearings: one to discuss and identify threats to the fishery in the community, and the other focused on co-management and fisheries regulations.
- The **group approach** was based on a focus group with "experienced Fishers" in order to reconstruct historical fishery changes based on traditional knowledge.
- The **individual approach** was based on semi-structured interviews with Fishers (two or three Fishers were selected per fishery method, including at least an old and a young Fishers per method) and local leaders. The selected Fishers were referred by other interviewed Fisher or local leader.

The number of community members involved in each implemented method varied per community due to low community participation or high community engagement. In order to minimize these variations, some extra hearings and group were held to complete this activity (Table 1).

TABLE 1
Number of participants by applied method on the nine fishing communities in the Caribbean and Pacific coasts

	Caribbean					Pacific				
METHODS	**Ahuyama**	**Taganga**	**Las Flores**	**San Antero**	**El Roto**	**Bahía Solano**	**Pizarro**	**Juanchaco**	**Tumaco**	**Total number of participants by method**
Fishery Threats Hearings	16	14 and 8	30	40	20	35	19	20	40 and 15	257
Co-management Hearings	17	10 and 18	20	27 and 28	20	35	13	13 and 17	17	235
Focus Groups	7	7	15	6	10	13	4	10	10	82
Semi-structured interviews	18	23	31	36	17	14	15	18	23	195

TABLE 2

Subset of data obtained through interviews about historical changes in the nine fishing communities (five on the Caribbean coast and four on the Pacific coast). Information presented as presence-absence for traditionally caught species which are depleted now (four out of 103 species)

INTERVIEWS	Fishery small-scale fishery communities								
	Caribbean					Pacific			
Fish common name	Ahuyama	Taganga	Las Flores	San Antero	El Roto	Bahía Solano	Pizarro	Juanchaco	Tumaco
"Mero"Groupers	X	X	X	X	X	X	X	X	X
"Pargos"Snapper	X	X	X	X	X	X	X	X	X
Sábalo-Tarpon		X	X	X	X				
Dorado						X	X	X	

All primary information collected (interviews, hearings and focus group discussions) was transcribed from audio to text files. Information collected during hearings and in historical analysis group meetings was organized in diagrams that synthesize for the reader the drawings done by Fishers during the meetings. All information was crosschecked with videos of the meetings, photos of the drawings, and audio recording in order to ensure accuracy of the information.

The information from interviews and fieldwork activities was organized and analyzed using computer-assisted qualitative data analysis software (CAQDAS), N-vivo. This software is developed based on content analysis as a research technique (Oskan, 2004; Thayer *et al.,* 2007; Garcia-Horta and Guerra-Romos, 2009). The nine Colombian Artisanal Fisheries Communities case studies were easy to analyze given that N-vivo is designed to organize the data as case approaches (Yin, 2003; Saldaña, 2009). Consequently, the nine cases are compared within and across communities, as well as between regions (Caribbean and Pacific coasts).

Coding

Based on Miles and Huberman (1994) and Saldaña (2009), coding of interviews and audio recorded conversations were conducted by the meaning of phrases or sentences, following the ELEMENTAL METHOD and incorporated into N-vivo. This method is commonly used for "microcosms", such as the particular microworld of Colombian artisanal fishing communities. Codes were derived from the participant's words more than the researcher's words, it was important to try to organize codes by "Fisher's words" and "researcher's words" such that they reflect the traditional knowledge of Fishers expressed in their own words as closely as possible, and at the same time retain the research perspective. N-vivo coding is an example of SIMULTANEOUS CODING, in which the same text can have more than one code. As semi-structural interviews provided a large amount of information, sometimes in addition to the questions that were asked, simultaneous coding was necessary for processing. STRUCTURAL CODING was used with ELEMENTAL METHODS to pre-code questions by creating main categories of common subjects that allow different opinions to be combined into a single category. Each category corresponds to the common subjects under which the codes are aggregated. Each category became a tree-code. However, not all categories fall under each question because not all subjects were discussed in each question. Categories occasionally overlap, but this reflects the way that the respondents themselves organized the information expressed in their answers.

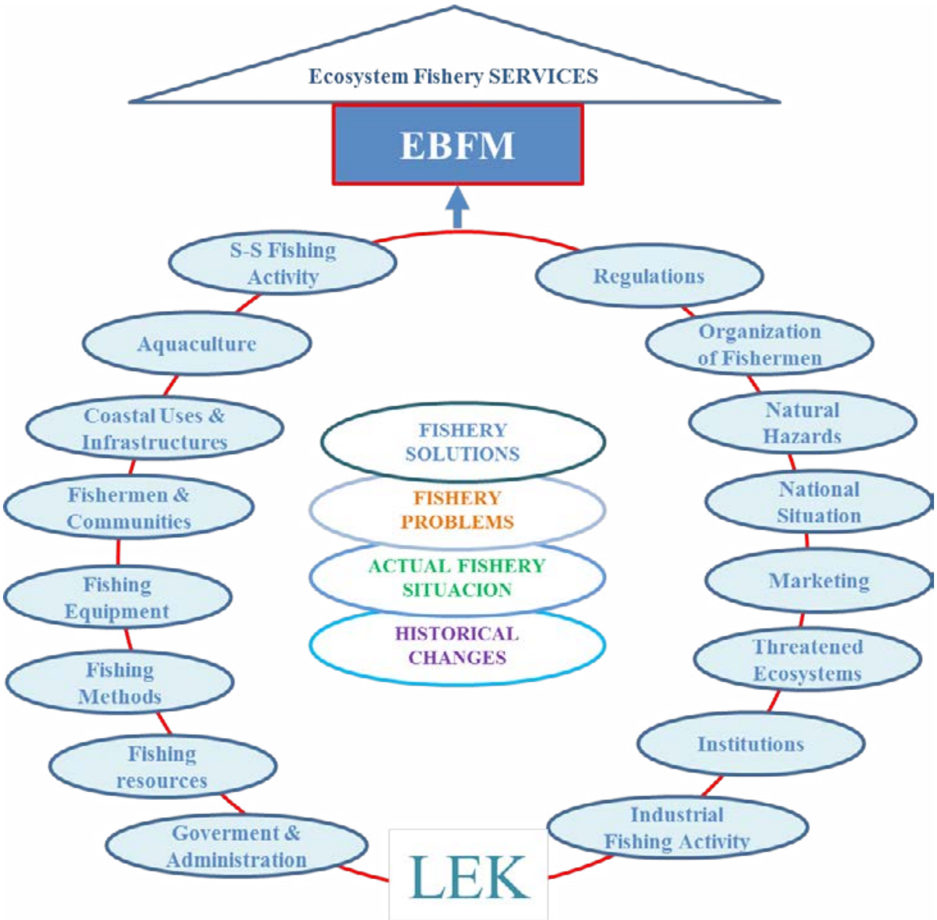
RESULTS AND DISCUSSION

The diversified LEK shared by Colombian Fishers was categorized and grouped in four "pillars": 1. Historical changes; 2. Actual fishery situation; 3. Fishery problems;

and 4. Fishery solutions. Based on the combined knowledge of history with the actual situation of Colombian marine fisheries, Fishers were able to propose future steps to address the problems affecting a given community. Expert Fishers revealed how much they knew and how much they could contribute as part of a decision-making team. Figure No. 3 divides the variety of LEK into sixteen categories, and shows how each of them contributes to maintaining fishery ecosystem services in in the EBFM conceptual framework. These LEK categories were the result of the coding process combining the methods applied:

- **Aquaculture**: social and ecological effects of fish and shellfish cultivation on artisanal fisheries and fishing communities, and the opportunities and weaknesses of different approaches to date.
- **Coastal uses and infrastructures**: structural development and human activities affecting coastal ecosystems and fishing communities.
- **Fishers and communities**: cultural attitudes, behavior, and perceptions of fishers and communities of fishing households.
- **Fishing equipment**: boats, motors, navigational equipment, coolers, special clothing, etc., Used in open water and inshore fishing, equipment ownership, and trends over time.
- **Fishing methods**: gear used directly in harvesting fish, crustaceans, and shellfish, such as lines, hooks, harpoons, nets of various kinds, equipment ownership, fishing effort, and trends over time.
- **Fishing resources**: changes in fisheries resources, including depletion, loss and recovery, as well as trends over time and causes of change.
- **Government-administration**: supervision of the fishery sector by city, state or national government agencies and the problems and solutions reflecting the current agenda.
- **Industrial fishing activity**: the effect of powerful industrial fisheries on the artisanal fisheries sector including bycatch, overharvesting, overlapping territories, competition for resources and, occasionally cooperation.
- **Institutions**: public, private, non-profit and for-profit organizations that interact successfully or unsuccessfully with the artisanal fisheries sector, often with their own agendas and weaknesses.
- **Threatened marine ecosystems**: marine ecosystems that have been damaged by fishing or other human activities that affect marine resources.
- **Marketing**: weaknesses in marketing, handling and processing of fishery products, as well as the mutual interactions between market owners and fishers.
- **National situation**: negative national influences due to violence, drug trafficking, corruption, etc.
- **Natural hazards**: hazards affecting the community itself beyond fishing activity, such as earthquakes.
- **Organization of fishers**: all the parameters related to fisher's associations and other community organizations that involve and affect fishers.
- **Regulations**: inadequate rules and regulations governing the fishing sector explicitly describing weaknesses that harm fisheries resources and impede fisheries management, as well as the identification of those regulations they are willing to try.
- **Small-scale fishing activity**: disadvantages of fishing as a way of life, and proposes solutions to improve it.

FIGURE 3
Graph combining the four pillars and sixteen categories of LEK. Each category is represented in each pillar. All categories can inform ecosystem-based fishery management (EBFM) initiatives to maintain fishery ecosystem services



HISTORICAL CHANGES

Historical changes were detected through interviews and focus groups. Interviewed Fishers explained changes observed in the fishery through their daily practice. For examples of perceived changes in fishery resources, Fishers were asked if they had noticed species that are difficult to catch now but were easily caught in the past. Some species, such as groupers and snappers, were named by all nine communities as depleted, whereas others were named only on the Caribbean coast (*Sábalo-Tarpon*) but not on the Pacific coast and vice versa (*Dorado*) (Table 2).

In addition, there were species that were only named by specific communities. Simultaneously, Fishers were asked about perceived changes in their fishing activity since they started fishing. In all communities they have increased effort and gear diversity over time in order to maintain catches or income (Table 3).

In focus groups, veteran Fishers built a timeline of historical changes in the fishery per each fishing community. Decadal time lines were established so that it was possible to record events as far back as the age of the eldest Fisher present in each group. Historical analysis included two principal components:

Changes in the main fishery resources: Veteran Fishers named all the species that they used to fish in their area, they identified by consensus the decade during which they first noticed a decline for each species and, in some cases, the decade when the

TABLE 3
Information on relative (perceptual) changes in the fishing activity and perceive resource abundance. Percentage of Fishers in each community that has identified a change in their interviews

INTERVIEWS	Small-scale fishing communities								
	Caribbean					Pacific			
Changes	Ahuyama	Taganga	Las Flores	San Antero	El Roto	Bahía Solano	Pizarro	Juanchaco	Tumaco
Increase in effort in terms of time allocated to fishing	38.9	43.5	41.9	52.8	64.7	50.0	46.7	50.0	34.8
Increase in gear diversity	33.3	30.4	38.7	36.1	17.6	42.9	46.7	38.9	34.8
Decrease in abundance	72.2	82.6	67.7	75.0	82.4	92.9	80.0	83.3	95.7

species disappeared entirely from the catch. Each veteran Fisher's group made a list of traditional species caught in that community. Then (see Table 4), using the symbol "▼", the Fishers identified the decade in which they observed that each species started to decline, even if it was still being caught. Depleted species that "disappeared" were pointed out with the symbol (†), and populations that changed little and remained in good shape with the symbol (-); species that have never changed are not shown.

Subsequently, the focus group analysis complemented and extended the information given by the interviewed Fishers (Table 2). Interviewed Fishers named depleted species and the focus groups extended this information by not only detecting the depleted ones but also identifying the decade in which the depletion was first noticed, as well as historical tendencies.

TABLE 4
Subset of the database with some of the main changes identified for several fish species caught from 1970 to the present in the fishing community of *Bahía Solano* from the Pacific coast, showing the decade during which some species started to decline (▼), disappeared (†) or remained unchanged (-)

	Decades			
Fish common name	1970'	1980'	1990'	2000'
Atún	-	-	-	▼
Bonito	-	-	-	▼
Bravo	-	-	▼	▼
Burica	-	▼	▼	▼
Cabrilla	-	▼	▼	†
Chame	-	▼	▼	†
Cherna	-	-	▼	▼
Dorado	-	-	▼	▼
Gallo	-	-	-	▼
Merluza	-	-	▼	▼
Mero	▼	▼	▼	†
Murico verde	-	-	▼	▼
Pámpano	-	-	-	▼
Pargo	-	▼	▼	▼
Pez vela	-	-	▼	▼
Róbalo	-	-	▼	▼
Sierra castilla	-	-	▼	▼
Sierra guaju	-	-	▼	▼
Toyo	-	-	▼	▼

Changes in fishing methods and equipment: Veteran Fishers identified the decade (sometimes year) in which each fishing method was introduced in their community and described the basic features of that method, including past and present modes of use. Such differences in use included length (in the case of nets), number of hooks (longlines), types of materials, and number of crew members, among others. At the same time, they identified changes in boat type and fishing equipment (Table 5).

Either individually or in groups, Fishers identified short and long term changes in fishing activities and fishery resources. Group interaction allowed them to discuss, recall and validate their memory with others, while individual information was useful for identifying short-term changes and to corroborate the information given by focus groups.

LEK was also used to identify depleted species that need urgent management, to identify "disappeared" species that need urgent conservation or repopulation programs, and to detect negative changes that have become the source of the present problems.

TABLE 5
Subset of the information shared by Fishers in the historical fisheries analysis (decades from 1950 to 2009) from the community of *Tumaco* on the Pacific coast

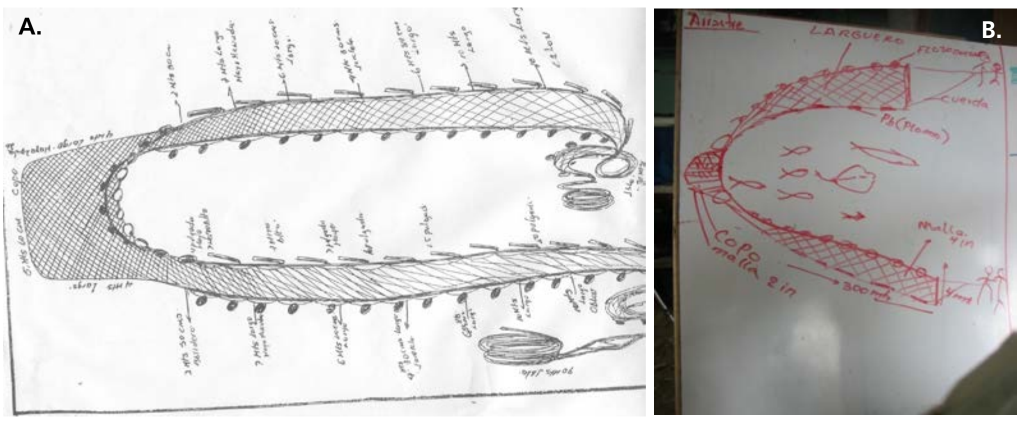
Variables / Decades	1950	1960	1970	1980	1990	2000	2009
Fishing methods							
Longlines (hooklines)	**50** hooks						**2000** hooks
Tangle nets				**1320** ft (length)			**4800 – 6000** ft
Beach seines	**328** ft (length) Crew: **5** Fishers						**1640 – 3280** ft Crew: **5 – 50** Fishers
Boats and motors	Sailing wood canoes	Inboard motors		Outboard motors	Fiber glass boats		
Fisher´s population	**100**						**6000**

ACTUAL FISHING ACTIVITY

Fishing activity and Fisher´s living conditions

Interviewed Fishers shared information regarding each fishing community in terms of: 1. Dependence of household or community economy on fishing; 2. The type of fishing methods and gear used (Figures 4 and 5); 3. General description of Fishing boats (including size, material composition, etc) and motors (size); 4. Living conditions in small-scale fishing communities (housing and public services); 5. Marketing conditions and informal economic interactions; and 6. Seasonality of fishing and fish prices.

FIGURE 4
Fisher's drawings of the fishing gear "*Chinchorro*". A. Drawn by Cisto Matos from the *Taganga* community, and B. Drawn by Fabio Iguaran from the *Ahuyama* community



It takes time to build confidence with Fishers to a level that they are open to the interviewer (researcher) and willing to share information. The quality of interaction between the researcher and the crew before the interview will determine the reliability and value of information collected. Key local leaders or key professionals to introduce the interviewer to Fishers could aid with the quality of the information obtained.

FIGURE 5

A and B. *Chinchorro* used on *Ahuyama* community, C. on *Taganga* community, D. on *San Antero* community and E. on *Tumaco* community. F. "*Guia*": a Fisherman enters the *chinchorro* to observe the catch and notify the Fishers on the beach when to pull the net

FIGURE 6

A Fisher from the *El Roto* community drawing on the map the grounds where he and his crew used to fish

Fishing Territory

As part of the co-management hearings, Fishers identified their community fishing territory using a participatory mapping approach. This mapping technique proved useful for creating awareness among local stakeholders of natural resources and fishing grounds used by each community, whilst promoting local empowerment (Craig *et al.*, 2002 and Chapin *et al.*, 2005). Fishers identified fishing grounds by highlighting them in different colors on a printed map of the region, and each color represented a particular fishing method previously identified by consensus as the most used in each community (Figure 6).

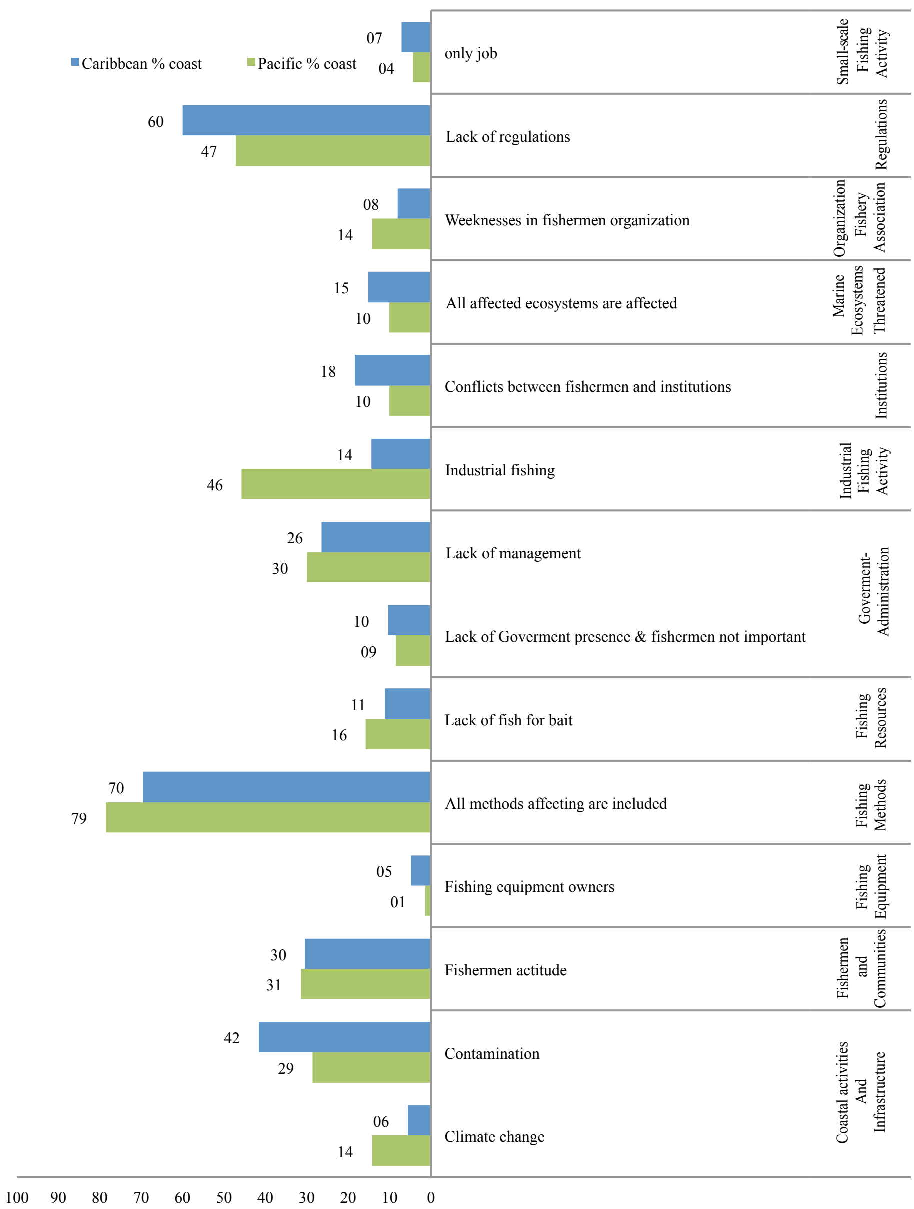
Such LEK provides community-based and spatially-explicit information about the fishing areas and specific gear used in each community, as well as on the prevalence/occurrence of shared fishing grounds with Fishers from neighboring communities and/or "gypsy" Fishers.

FISHERIES PROBLEMS

During the interview process, a set of principal questions led to the detection of primary (priority) and secondary problems in each community. Among these there were: 1. **Bi-coastal** problems that affected all communities on two levels: high frequency (problems present in 7 to 9 communities on both coasts) and low frequency (problems present in 2 to 6 communities on both coasts) (Figure 7), 2. **Uni-coastal** problems that affected communities on only one coast (Caribbean or Pacific), and 3. **Infrequent** problems that were particular to specific community.

FIGURE 7

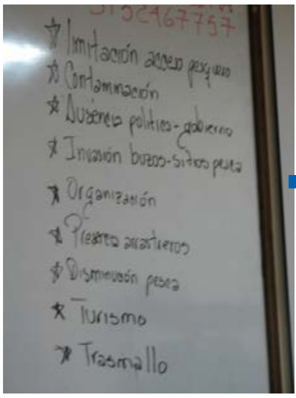
Main problems identified by Fishers on both coasts, distinguished by categories. Caribbean (blue) and Pacific (green). Problems shown were identified by more than 5% of Fishers in each LEK category



Once all the problems in each community were listed at the fishery problems hearing, Fishers discussed the list amongst themselves, prioritizing problems according to the degree to which they found themselves affected, and in this manner selected the main problems for analysis. In general, no more than five problems were discussed and analyzed in depth for each community (see example in Figures 8A-B). A "fish skeleton analysis" diagram aided the group in sorting and analyzing priority problems. The diagrams divided each problem into three parts: reasons (causes), effects, and possible solutions as proposed by the Fishers (Figure 8C). Thus, this communal activity determined the most important environmental problems that local people believed were affecting their wellbeing, and at the same time promoted a sense of unity within the community.

FIGURE 8

Example of list of existing fishing problems affecting the Artisanal Fishing Community of *Taganga*, as defined by Fishers at the hearing. * marks priority problems for analysis and discussion through the use of a "fish skeleton" diagram, identifying causes, effects and solutions as discussed by Fishers at the hearing



- Fishing territory has been limited by the protected park area (*)
- Contamination (*)
- Lack of government presence and lack of fisheries regulations (*)
- Divers invading fishing areas
- Lack of organization (*)
- Industrial trawl nets
- Fish stock depletion (*)
- Tourism
- Gill nets
- Deforestation

While during interviews fishers named problems and sometimes explained why they were proposed, the hearings permitted Fishers to analyze in depth each main problem by identifying, articulate their understanding causes, effects and solutions, and ultimately reaching robust conclusions about each problem being validated by the community. In this study design, both methods became complementary not only for the purposes of this research but also for each Fisher. Hearings were a means to broaden their own knowledge by considering others Fishers points of view.

Identification of bi-coastal problems can be informative for planning and management at a national scale (e.g. when priority problems from the Fishers' points of view were related to the inadequate use of fishing methods and lack of regulation; Figure 7) via government or NGO projects to support communities. Uni-coastal and infrequent problems could enhance the need for management plans adjusted to the particularities of each coast or community.

Conflict among Fishers may arise at the hearings, as certain fishing methods or fishing areas commonly used by others may be proposed as problems. However, the community can be empowered by this activity as Fishers share different points of view about the same problem, and may find agreement when discussing potential solutions (see in detail next pillar).

PROPOSED SOLUTIONS

General solutions

Fishers recommended solutions to proposed problems not only in the course of individual interviews but also during the collective analysis conducted at the fishery problems hearings. The interviews included questions regarding: 1. Solutions proposed to the problems named, and 2. Opinions about implementing local marine fisheries co-management, and what would be required to make co-management effective. Fishers proposed important solutions and most solutions were related to fisheries management.

Fishery management and co-management

The second community hearing occurred in each community before the end of the field work. During these hearings, top-down and bottom-up fisheries management strategies were explained by the researcher to the community members involved in participating. The exchange of information and opinions, and the discussion of the co-management process took place in three main steps:

1. Fishers learned about fisheries management strategies, in particular about co-management**.** The basic concepts and features of the major types of top-down and bottom-up fisheries management were explained. Examples of traditional management were analyzed and then contrasted with co-management to show the benefits and drawbacks of the alternatives. This basic set of information allowed Fishers to understand how fishery management has been applied in other countries, what alternatives exist, the benefits communities might gain from co-management, and the importance of working with other fisheries actors (stakeholder groups) in this process.
2. An open discussion focused on the following questions (see Table 6 for examples of the information relative to each question):
   - What opinions do the Fishers have about management in general and co-management in particular? Do they think the community is ready to move forward in that direction?
   - What weakness and strengths within the artisanal fisheries community might affect the success of co-management?
   - What first steps could the community and government take to start the co-management process?
3. Fishers identified main actors in the community and institutions (stakeholder analysis) that they believe should be key partners in co-management (Table 6).

TABLE 6
Example of the type of information obtained at fisheries management hearing in one fishing community (*Las Flores,* on the Caribbean coast)

Fishing community	Agree or not agree	Weaknesses	Strengths	Steps to be taken	Stakeholders to be involved
CARIBBEAN					
Las Flores	Yes, but doing it together: community and government.	• Lack of Union • Lack of comradeship • Lack of identity of the community with the fishery sector. • Weak Fishery Administration in structure and low credibility from fishers in them (low participation). • Acknowledge they have practiced too much pressure over the resources in the past.	• Human capital: Community has strong knowledge and experience in fishery issues. • Local leaders believe i fishery management and can influence other fishers.	**Community:** get together and work all Fishers as a group in order to recognize and identified them. They proposed as a solution to have a general Fisher´s assembly with all F.A. and the non-associated Fishers. They named some Leaders that were in charge of the organization of this event, and the present Fishers took the compromise to help Leader with the organization of a "Fisher´s day". Through this time to decide about implementing co-management. Fishery Associations should be strengthened and each member should get the compromise to be a real member. **Government:** Provide economic support. Restrictions: dislike the close seasons due to the majority fish migrates, to restrict the use of gillnets for 4 months and meanwhile Fishers should obtain subsidy at least (half minimal salary). Establish fishing areas and other areas for navigation in order to minimize conflicts.	**Internal:** Fishers non-associated and associated (Asopesba, Asopescar, Coopez and Asopesflores). **External:** Big supermarkets (Olimpica, Carrefour), fish shops, hotels, restaurants (to regulate the fish price). Universidad del Magdalena, U. del Atlántico, U. Nacional, U. Simón Bolívar, SENA, Governors State house, ICA, INCODER, MinAmb, MinAgri, MinSalud, MinSocial Protection,MinTrasnport, JAC, owners of fishing equipment, NGO Jaica, Industrial sector; Monómeros, Cementos Caribe/Argos, Energía Solar, Tecnoblas, Dupon, Quintal and la Sociedad Portuaria/Carbón. **Key stakeholder:** Capitanía de Puerto (many do not want to work with them and some want).

LEK was valuable to identify management solutions in which Fishers are willing to be involved and contribute to the decision-making process. Collectively and individually, the community analyzed if they are ready to move forward with fisheries management, and if they needed support from the fisheries governmental authority. They also identified their own strengths and weaknesses with regards to implementation of fisheries management. Meanwhile, members of the communities were able to decide by consensus what steps were needed on the part of the community and of the government. However, the number of Fishers attending the hearings was low in comparison to the large number of Fishers in the communities and it may be necessary to replicate the meetings to obtain more comprehensive information._

General methodological considerations and limitations

The great variety of fishing communities on the Colombian coast imposed important methodological limitations for this study. For instance, fishing communities varied in population size from 50 Fishers in villages such as *El Roto*, to 4000 Fishers in municipalities such as *Tumaco*. In highly populated fishing communities such as *San Antero* on the Caribbean and *Tumaco* on the Pacific it was difficult to have a representative sample of Fishers. Consequently, a purposive sample was undertaken in these communities with community leaders helping to identify neighborhoods where Fishers lived and worked. Some municipal fishing communities overed a much larger area than others (e.g. *Tumaco* extends over 167 counties). As a result, the number of *Tumaco* Fishers involved in the study was low compared to the total number of Fishers in other smaller communities; most individuals interviewed came from the municipal center, and so that peripheral communities were under-represented. Another complication was that communities with more Fishers had a greater variety of fishing methods, hence required a greater sample size. Small communities, with fishing populations of around 200, were more manageable. The researcher was able to live in the community and develop a greater understanding of the situation that Fishers faced. Small communities were better understood by the researcher than large ones in terms of fishing activities. Based on this experience, future studies should have a research team per community, not just one researcher.

The timing of fieldwork also introduced bias. Each community was visited once, during either the summer or rainy season. This was a weakness in fieldwork design, since fish abundance and diversity vary seasonally. Some fishing communities were visited during a time of low overall fish abundance or when only certain species were present in great numbers. In seasonal fisheries, some fishing gears were absent for most of the year. On the Pacific coast fishing activity was also highly correlated with tide cycles. Where tide cycles were short, fishing time was limited.

Seasonal variation also affected the use of fishing gear. Some common fishing methods were not observed because the fishing communities where they were used were not visited during the appropriate season. Consequently, future studies at the national level should plan visits to the communities at other times of the year. Bad weather conditions or low fish abundance (or catch) may influence Fishers' moods, affecting their attitudes with when answering questions and participating in group activities.

Initially, the research plan only involved "native" Fishers who fish near the community in which they live. Non-native transients or "gypsy" Fishers who fished in the same areas and occasionally or temporarily resided in the same communities were not considered in the design of the study. Yet, it soon became clear that understanding of the role of non-native Fishers was important to evaluate the health of coastal fisheries and the dynamics of small-scale fishing communities. Unfortunately, many of them were apathetic and reluctant to be interviewed once the research project started. More non-native Fishers participated on the Pacific coast, where this fishing lifestyle is typical. On the Caribbean coast transient Fishers are found only in the Gulf of Urabá. Surprisingly, survey timing and fishing methods also influenced the status of Fishers. "Native Fishers" who fished near home some parts of the year occasionally became "gypsies," venturing farther away to fish in other areas during certain seasons, for other species or with different gear. Thus, over time, it was necessary to take external factors (such as status of Fishers as native or non-native) into account in both data collection and analysis.

Violence affects many regions in Colombia, making it necessary to include this parameter in the process of selecting fishing communities. Although seven of the nine communities were affected either by violence or drug trafficking, those with lower incidence were selected even though violence was not a parameter in the design. Safety of the researcher was a necessary consideration, and it influenced the research outcomes.

CONCLUSIONS

The sixteen LEK categories identified by this study reflect the variety of knowledge held by Colombian marine and coastal Fishers. This LEK diversity highlights the importance of involving Fishers in the decision-making process related to the four "pillars' defined in order to guarantee EBFM and maintain ecosystem fishery services: (1) Historical changes, (2) Actual fishery situation, (3) Fishery problems, and (4) Fishery solutions.

Colombian Fishers from the Caribbean and Pacific coasts have developed a national small scale fisheries vision that was captured by our research and is available in written form for the first time. This will enable the national fisheries authority and other decision-makers to fully account for what is happening in this sector in order to take better decisions in the future.

LEK held by small-scale Colombian Fishers allows decision makers to achieve a more in-depth understanding of the problems facing Fishers and their communities. The results presented here draw from the communities specific approaches to some of these problems and solutions at the community level.

Some emergent issues were broadly supported and government concurrence will be essential to address them. The results of this study, based on the LEK of Fishers, have the potential to help the Colombian fishery administration to prioritize key issues for government action, as well as identify problems that can be addressed by the Fishers themselves if they were empowered.

Non-governmental organizations that supported this study in part, such as Conservation International, can also play a role by supporting and enabling community action around problems that can be dealt with in a co-management context. Given the difficulties of obtaining sufficient government resources for assessment, management and enforcement, it is vital to mobilize non-governmental resources to support action within communities.

Fisheries in Colombia and many other developing countries are key to food security for some of the poorest members of society. Using local knowledge in a manner that empowers these communities can give them a sense of identity and control of their own destiny. Moreover, acknowledging the problems perceived by community members is an important step to achieving social and economic sustainability. This study is an example of the type of research needed to support community empowerment and co-management possibilities.

Internal war, violence and drug trafficking disrupt most Colombian fishing communities. While this adds difficulty to approaching those communities, not involving Fishers into the fishery management becomes an additional form of social injustice. Those problems should not be an obstacle to taking Fisher's opinions into account.

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How much we can learn from fishers about ecology and fisheries management: case studies on spiny lobster fishery in Mexico

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ABSTRACT

Spiny lobster (*Panulirus argus*) is a very important resource for countries in the Caribbean area, however catch trends have shown important changes in the last decade. Lobster fishers in Mexico are organized in fishing cooperatives and have long tradition fishing this resource. Concerns from government, fishers, and scientist regarding the conditions of the resources have promoted collaborative actions to contribute to the knowledge and management of this important resource and its fishery. In this paper we present two case studies undertaken in Yucatan, Mexico to show how fisher's knowledge and technical knowledge matched when evaluating preferential habitats of lobster. We also report on the government program implemented in the region using this knowledge to introduce artificial habitats (AH) to catch lobster selectively, involving fishers and scientist. The actions that allowed gathering knowledge regarding the best options to place the AH were: a) interviews to fishers who had used artificial habitats previously, enquiring for the best places and conditions to place the AH, b) undertaking workshops with fishers and government officials to develop the project for introduction of AH, c) gathering scientific information about lobster habitat and preferential areas for different population components. The matching information on scientific and fishers knowledge confirm the wide experience fishers gather along their life, that allow them to be an important source of information about coastal resources and their behavior. The successful experience on the implementation of the government program is another way to appreciate the usefulness of taking into account fisher's knowledge to manage fishing resources.

Keywords: Spiny lobster, traditional knowledge, artificial habitats, preferential habitats, management.

INTRODUCTION

The decline of catches in Mexico like in many other regions in Latin America and around the world has been reported by several authors and has raised concerns (Alfaro–Sigueto *et al.*, 2010; Fernández *et al.*, 2011; Salas *et al.*, 2011a). Deterioration of habitats by pollution and hurricanes, red tides, fishing pressure and poor governance are listed among potential factors that have generated this situation (Hilborn *et al.*, 2004; Mexicano-Cíntora *et al.* 2009; Salas *et al.* 2011b). The demand for seafood, on the other side, keeps going up, given an increase on touristic development along the coast, maintaining then, an incentive to go fishing, despite the weakening of the resources (Fraga *et al.*, 2008; McElroy, 2003). The consequences are livelihoods threatened, rent dissipation and local conflicts, which can increase vulnerability of coastal communities (Béné, 2009; Pedroza and Salas, 2011; Salas *et al.,* 2011b).

The challenges faced by fisheries call for a holistic approach to assess and manage the resources involving government, fishers, and scientist. In this context several international organizations have promoted an ecosystem approach, in which the human component has acquired more visibility (Garcia & Cochrane 2005; Barnes and McFadden, 2008; De Young *et al.,* 2008). Fishers are an important part of this large puzzle, as they accumulate knowledge about the ecosystems they exploit, which defines the ways they deal with their natural, economic and social environment (Salas *et al.,* 2004; Orensanz *et al.* this volume). Taking advantage of this knowledge can help to develop better governance for fisheries (Grant and Berkes 2007; Aswani and Lauer, 2006; Chuenpagdee, 2011).

Is has been reported in several case studies that fishers knowledge can match or complement technical knowledge, such a way that, if taken into account it can improve information for decision makers in charge of fisheries management and conservation programs, that could be otherwise costly or inaccessible (Haggan *et al.,* 1998; Salas *et al.* ,1998; Close and Brent–Hall, 2006; Saenz-Arroyo *et al.,* 2005; Grant and Berkes, 2007). Fisheries research can also be enrich with the participation of fishers in monitoring programs (Baelde, 2003; Begossi this volume). The case studies presented here, illustrate some experiences in this direction.

Integrating fishers in assessment and management of fisheries can contribute to improve the conditions of natural and fishing resources and finally it can help to maintain fishers' livelihood. In this paper we present two case studies undertaken in Yucatan, Mexico. The first case deals with an intergovernmental program for the introduction of artificial habitats (AH) for fishing lobsters selectively and improvement of habitat conditions for this resource, involving fishers from the design to the implementation of the program. The second one focuses on the identification of preferential habitats for lobster using fisher's knowledge and technical knowledge. Learning about the lobster habitat can provide some light on ways to protect such habitats in addition to protection of the marine resources targeted for commercial fisheries.

The lobster fishery in Yucatan and the fishing communities

The spiny lobster (*Panulirus argus*) is widely distributed on the great Caribbean and its status is considered critical in many countries of the region (FAO, 2006). In the Yucatan peninsula, Mexico, the lobster fishery started in the 1950s and reached the highest yields in the 1980s. This fishery had gone through different stages of development and currently it has reached its maximum level of exploitation (Ríos-Lara *et al.,* 2012). Among the most profitable resources in the area, together with the octopus fishery, it provides great proportion of the fishers' income in the region (Salas *et al.,* 2012).

Since the last decade concerns about this fishery, are linked to threats associated with natural phenomenon, contamination and over-exploitation (Salas *et al.,* 2012). Changes in the availability of some fishing resources like lobster finally have impacts on the ecosystems that support the sustainability of this activity. Switching gears and fishing effort to other resources (Salas *et al.,* 2004; Fraga *et al.,* 2008), changes in fishing practices that expose fishers to risky conditions like the bends (divers going deeper and farther) (Huchim *et al.* 2012). In addition, the market options for lobster are limited for the fishing organization of the Yucatan peninsula, despite the increase in the demand internationally, as the product is caught with hook which sometimes damages the lobster (Salas *et al.,* 2012).

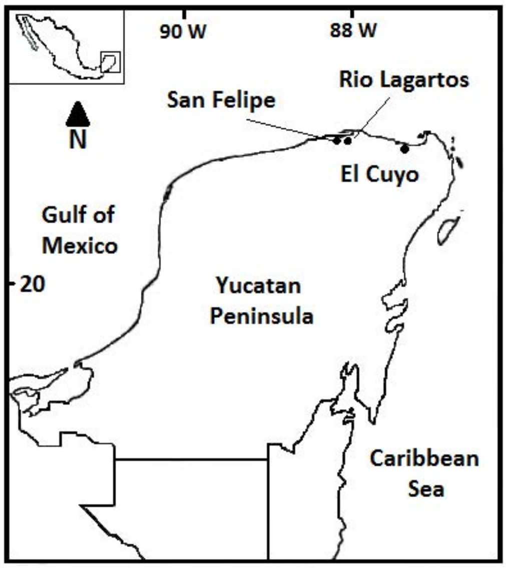
Since lobster fishery generates important income to most coastal communities (2500 jobs and $3.5 million in foreign exchange). Several attempts have been done to improve its conditions and search for management options that best suit the context of the fishery (Ríos *et al.,* 2012). One of the approaches was directed to improve the habitat conditions in the region as fishers had claim that hurricanes have affected the sea bottom, hence generating degradation of natural and artificial habitats for lobster. On the other hand, for several years government programs have attempted to incentive selective fishing of lobster in order to widen the option for selling lobster (whole and tail, currently only tails are sold); introduction of artificial habitats has been considered for this purpose as they have proved to be useful in other countries (Pickering and Whitmarsh, 1997; Powers *et al.*, 2003; Salas *et al.*, 2008).

Regarding the information about lobster habitats, despite its importance, few attempts have been made to characterize suitable habitats (HS) at different stages for this important resource. Technical studies in this regard include characterization of habitat for lobster in Arrecife Alacranes, Dzilam de Bravo, and Río Lagartos (Ríos *et al.*, 2007; Ríos *et al.*, 2010). On the other hand, fisher's knowledge applied in the region in the context of fisheries has been limited (Zapata-Araujo *et al.*, 2008). In this paper we explore the idea of integrating fishers knowledge (FK) and scientific knowledge (SK) by emphasizing their complementarity across spatial and temporal scales through two case studies.

Fishing communities and fishing cooperatives

The fishing communities of San Felipe and Río Lagartos in Yucatan were the targeted communities for these cases. They are located at the eastern region of the Yucatan Peninsula (Figure 1). The Yucatán platform is a recent emerging limestone with absence of superficial rivers, and wide undercurrents network of fossil salt and freshwater, which dipped into the Gulf of Mexico. According to Ríos-Lara (2009) the structure of the seabed, shows a heterogeneous conformation characterized by the presence of unconsolidated materials (mud, sand, seashells, etc.) and complex karstic topography, which could offer habitat for demersal fishes, octopus and lobster.

FIGURE 1
Location of the study site at the Yucatan Peninsula, Mexico



Fishing organizations in the eastern region of Yucatan have built a cohesive Federation of fishing cooperatives that comprises four fishing cooperatives, this alliance have facilitated the market process, and management of the resources by self-regulation. For instance, in one of the communities, San Felipe (SF) people established a Protected Area where surveillance has been undertaken by community members. In this community and the surroundings (Río Lagartos) fishers shortened the fishing season one month when realized that large amount of juveniles appeared in catches that month; agreements are always done in meetings organized by the cooperatives. The level of organization and cohesion of community members and fishing cooperatives from these ports and the one from El Cuyo (all member of the Fishing Federation) had facilitated the implementation of different programs in the area by NGOs, government and scientists (Fraga *et al.*, 2006; Salas *et al.*, 2008; Chuenpagdee 2011).

INVOLVING FISHERS IN ASSESSMENT AND MANAGEMENT: THE PROCESS

Two case studies are presented here associated to a government program to introduce artificial habitats in 2005. This process allowed gathering information in the field about the lobster habitats as a base for the proposed program. The information obtained was widened with a survey in 2011 to complement the evaluation of suitable habitats for lobster. The two case studies presented here are linked as common information was used for the analysis (Survey of the sea bottom), but with a different aim. The steps followed in each case are described and the results hence are explained independently. General discussion is presented at the end.

Introduction of artificial habitats

The introduction of artificial habitats in Yucatan was promoted in 2005 by the fishers from The Federation who requested financial support to the National Commission of Fisheries (Conapesca). One small cooperative from the west coast also participated in this government program (results from this area are not presented here), making up to five fishing cooperatives that integrated 550 fishers in total. One program to introduce AH in Yucatan 10 years before did not yield the expected outcomes as fishers were not involved in the process, neither in the implementation of the government program (Torres and Salas 1993). If well the first time AH were introduced, fishers did not trust their efficiency, after 10 years they found its usefulness and wanted to participate in a new program. The government gave support in two faces one for the development of the project and one for its implementation. Fishers were asked to contribute with some funds, labor, and get a technical adviser; scientist from CINVESTAV partnered the project.

a) Development of the project to get the grant

Introduction of artificial habitats (casitas cubanas) has been perceived in the Caribbean Region as an option to increase habitat availability for lobster (Seijo, 1993; Sosa-Cordero *et al.,* 1998; Briones-Fourzán *et al.,* 2001). Positive and negative effects have been reported with the use of casitas (Cruz *et. al.*, 1987; Cruz y Phillips 2000; Deleveaux and Bethel 2001; FAO, 2003). Selection of the site to place the AH is critical in this case, animals behavior, availability of natural habitat and availability of food as well as ecosystem capacity are factors that need to be addressed when considering the introduction of AH (Pickering and Whitemarsh, 1997; Sosa-Cordero *et al.,* 1998; Briones-Fourzán *et al.,* 2007; Salas *et al.,* 2008). Despite of the acknowledgement of the need to learn more about these aspects, limited reports exist in this regard. The purpose of the project was to define the best locations to place the AH so they would not affect vegetation, overlap with natural refugees, or were placed so close to shore, making juveniles accessible for fishing.

Meetings in the field, the offices of the fishing cooperatives and the fisheries laboratory at Cinvestav took place for the development of the project (Figure 2);

FIGURE 2
Meetings with fishers in the development of the project and planning implementation of the project

fishers participated in the design of the casitas, suggesting adding some support to the device to avoid sinking. The project was accepted and sponsored for implementation by Federal government and supported by State government. Fishers supervised the construction of the casitas which were built by a private company and participated in the surveys for mapping the sea bottom and the introduction of the AH.

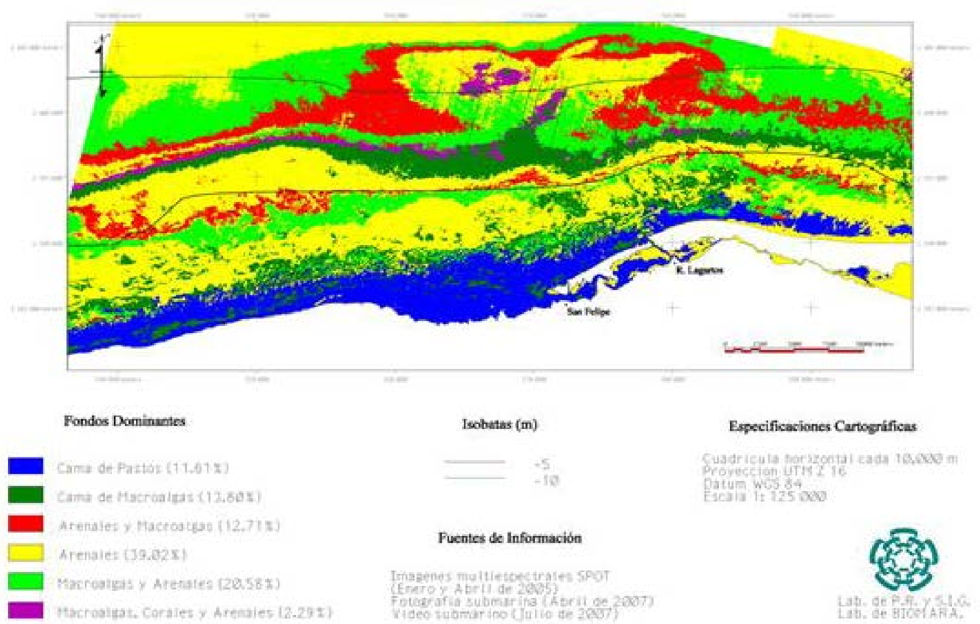
b) Mapping the sea bottom to select the best locations to place AH

Submarine photos and video-transects (Aronson and Swanson, 1997), and spot checks (Kenchington, 1978), were used to map the sea bottom to select the places for the casitas. The photos and video-transects were taken between July 2006 and April 2007 in San Felipe, Río Lagartos, El Cuyo and Celestun after a preliminary visual evaluation of sea bottom characteristics; scientists were always guided by one or two fishers from the community.

Diving was conducted at between 5 to 20 m depth and within 3 to 25 km perpendicular to the coast line. A total of 24 survey sites were monitored, a total of 3000 photos were taken in the area, this area covers about a third of the fishing grounds given in concession to fishers to catch lobster. The coverage in terms of percentage and the distribution for each element were quantified and described in terms of its concentration and dominance in the study area through the use of geo-statistical and GIS analysis tools.

FIGURE 3

Map of the sea bottom in Río Lagartos/San Felipe generated from photo transects to identify areas appropriate for introduction of artificial habitats



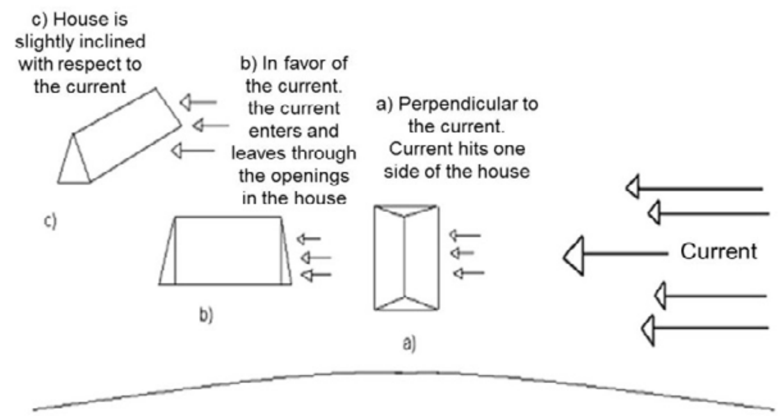
One map was obtained for San Felipe and Rio Lagartos (Figure 3) due to the fact they share fishing grounds, independent maps were generated for El Cuyo and Celestun. The characteristics of the sea bottom show a combination of seagrass, (shown in blue in Figure 3; mainly *Thallassia testudinum* and *Syringodium filiforme*) and sandy area close to shore and long flat ridges (yellow; could extend up to 100 m), and can give space to caves, and holes that are suitable places for lobster and demersal fishes. Gorgonians, Brown and Red macroalgae (in light and dark green in Figure 3) were also part of the life elements in the site. Yellow areas on the map can be risky areas to place AH as they can sink.

Fishers' knowledge regarding the conditions that ensure good performance of AH

In addition to the sea surveys, interviews were applied to fishers with previous experience with the use of artificial habitats. Fishers from San Felipe and Río Lagartos in Yucatan and fishers from Punta Allen, Quintana Roo, were interviewed enquiring for the best places and conditions to place the AH, as they had previous experience on the use of AH locally named "casitas". Fishers in Punta Allen in fact use this means exclusively to fish lobster in the Bay where they operate (Sosa *et al.*, 2008).

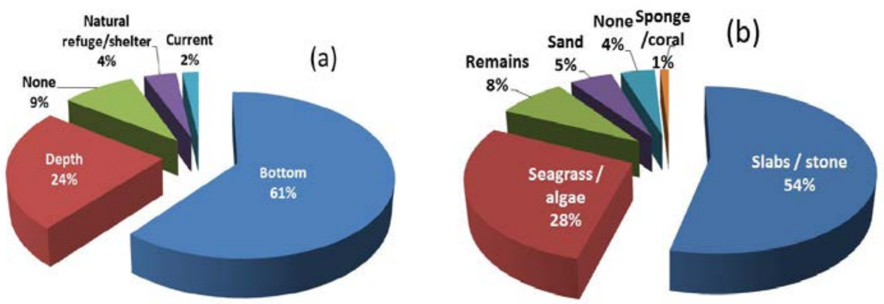
The questionnaires applied included semi-structured questions considering the following components: i) required conditions in the sea bottom to place the casitas so they operate efficiently accounting for depth, orientation according to current, type of bottom, characteristics of the bottom including live and no live components); ii) forms of fishing operation while using the casitas; iii) management of the casitas and institutional arrangements associated to its use. We reports results on the component (i) in this paper. A diagram was shown to fishers so they could indicate what could be the position of the devices under water to avoid sinking, overturn or the like and also to favor colonization by lobsters (Figure 4).

FIGURE 4
Diagram presented to fishers to enquire for the best suggested orientation of artificial habitats regarding the water current



Fishers from Punta Allen and Río Lagartos agreed with the fact that the best place to locate casitas was in hard bottom to avoid sinking and close but not over seagrass, such a way lobster can have access to food but avoiding the impact of natural habitats (Figure 5). Scientific literature also agreed with this declaration (Butler *et al.*, 2006,

FIGURE 5
Responses of fishers based on interviews regarding characteristics of the bottom to place casitas and orientation regarding the current



Ríos *et al.,* 2007). Regarding the position of casitas, in Rio Lagartos 55% of the fishers suggested placing casitas in favor of the current and 37% fishers indicated that they should be placed perpendicular to current. In Punta Allen more people were inclined to place the casitas perpendicular to the current (84%); the differences could be due to the characteristics of the fishing areas and the use fishers from each community give to the casitas; fishers from Punta Allen clean manually the casitas, while fishers in Yucatan take advantage of currents for the clinging, although they also agree that exposure to current could be risky for lobsters.

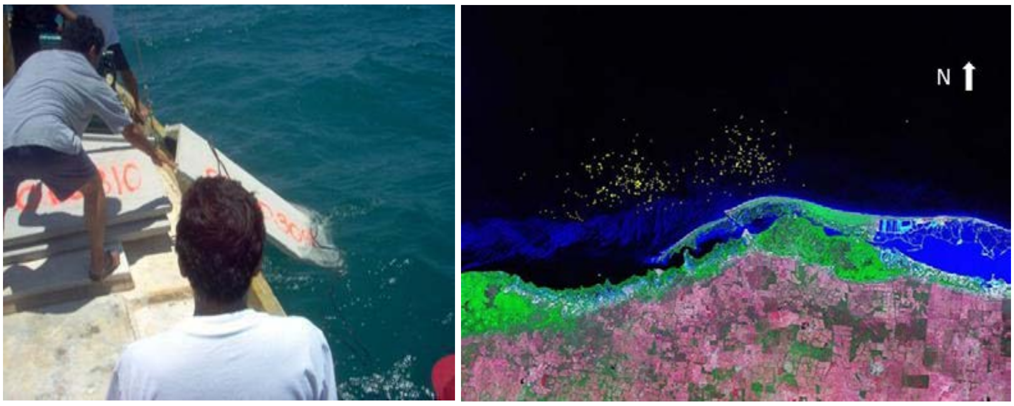
Placement of the artificial habitats

Information from the analysis of the sea surveys and interviews with fishers helped to define the best locations to pace the AH. The criteria defined in agreement between fishers and scientists based in the study in the field that generated the maps and in the information gathered from fishers experience using AH previously includes place the casitas in locations that agree with the following criteria: i) depth between 6 and 10 m, ii) avoiding sea grass areas, iii) avoiding sandy areas, rocky areas were preferred, and iv) orientation of casitas towards current. A total of 4000 AH were introduced between San Felipe and El Cuyo (1000 for each fishing cooperative) and a 100 more were placed in Celestun.

People from the same communities were in charge of distribution and supervision of the placement of AH where it was defined in agreement between fishers and scientists. Previous to the placement of casitas into the water a workshop was run in the communities to explain the advantages of following instructions to place the AH in order to improve conditions of the resource and consequently the fishery they depend on. Most of the fishers followed the indications, very few casitas were broken in the process of been placed and some were sunk when been placed in sandy areas (Figure 6).

FIGURE 6

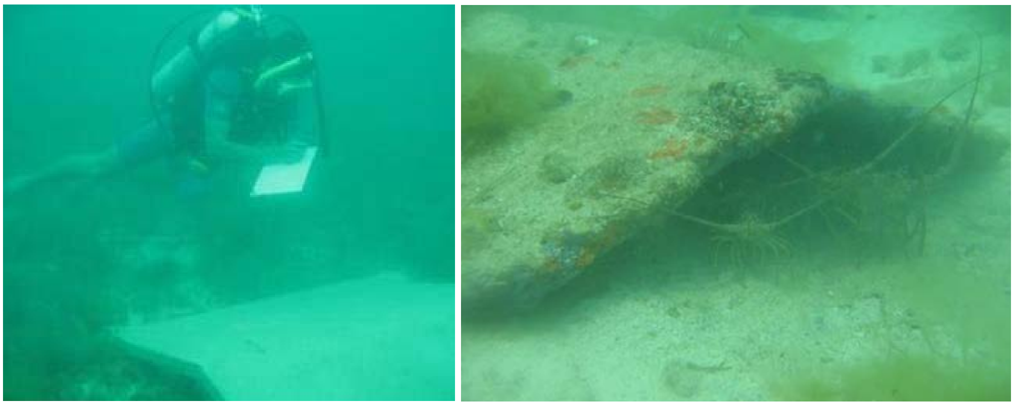
Placement of casitas and map generated with the location of all casitas placed in the (yellow dots) in the eastern region of the Yucatan coast, Mexico



Monitoring colonization of the AH by fisher with the help of scientist

The casitas were under monitoring to evaluate the process of colonization; after three months the AH were placed, they were already colonized (Figure 7). When the fishing season started, five months after the casitas were placed, fishers started to visit them to catch lobster. One year after the introduction of casitas they indicated that most of them have been colonized by lobster and that they tend to fish in the areas with casitas at the beginning of the season to move afterwards to other areas with natural refugees when abundance is reduced in this area.

FIGURE 7
Monitoring of colonization of casitas by lobsters in Río Lagartos, Yucatan, Mexico



What have we learned?

When one thinks about lobster fisheries improvement, that does not mean only an increase in catch, it involves providing habitat for lobster, an improvement on fishing operations, security for fishers and improving quality of the extracted products to increase the income derived from fishing. Looking at the fishery in an integrative way from the species habitat to the fishing operations for selective fishing by fishers who shared knowledge and responsibilities in the project made a difference in the implementation process. Participation of fishers in the project since the beginning generated the appropriation of it more than just accepting a government funding as a subsidy for developing a program or project they do not feel part of. After eight years, fishers, scientist and government official refer to this project as a success. The factors that could contribute to the success of the project of introduction of AH include:

a) Fishers were involved since the beginning
   - Participated in study for diagnosis
   - Participated in the generation of proposal
   - Participated in the study for mapping the sea bottom as fishers were always integrated in the research team
   - Contributed with money and time for implementation of the project

c) Good organization of fishing cooperatives and high participation of its members in the project.

d) Previous contact of researchers with fishers that generated trust.

e) Government officials showed open and supportive attitude.

Habitat suitability

In this case study the interest was placed on learning about the habitat requirements of lobster at different life stages and to find out if the Yucatan coast could offer the conditions to provide suitable habitat for the development of lobster and sustainability of its fishery.

The approach followed to achieve the goals was based on three sources of information:

a) Literature review to gather technical knowledge regarding the requirements of lobster in terms of habitat at different stages of their life cycle.

b) In site interviews with fishers that have been fishing lobster for long time (key informants), to elicit information on the characterization of sea bottom and the suitability of the area for lobster at different life stages. A total of 43 fishers in San Felipe and 41 in Río Lagartos were approached using semi-structured interview. They were queried about the type of bottom where they have seen juveniles, young adults and adults of lobsters, and they were asked to describe the conditions required for the permanence and development of this species along its life cycle. The snow-ball approach was used for this purpose, in agreement to Aswani and Lauer (2006).

Questions were designed to obtain information of the following information: a) importance of benthic elements and its association with lobster abundance, b) characteristics were juvenile and adult lobsters are abundant, c) preferred sites and refugees that lobsters select at different life stages, d) types of bottom where lobsters are abundant, including vegetation and other components, e) depth and distance from the coast where lobsters are more common and f) characteristics of recruitment zones for lobster.

c) Geostatistical analysis techniques were used and different interpolation methods to create maps of different benthic components. The information used for this purpose was the same used to map the sites for the selection of locations to place the AH referred in the former case study. Two habitat suitability models based on the multi-criteria weighted average approach were generated. The maps of habitat suitability were done using the TNTmips program applying different interpolation models based on the minimum error estimation. The newly habitat suitability map based on scientific experts (based on sea survey and literature review) were enhanced by integrating another habitat suitability map based on fisher's expertise, through the multi-criteria weighted average approach, both maps were given equal weight (0.5).

1) Mapping the habitat using technical knowledge

As a result of a visual analysis, fifteen live and non-live elements were observed, characteristics of the study site include: Octocorals, Stony corals, Sea grasses, Sea sponges, and Macro algae (Green, Rhodophyta, Calcareous, Filamentous, Phaeophyceae, and Encrusting algae), which agrees with reports in the literature (Carranza-Edwards *et al.*, 1975; Merino, 1992; Ríos-Lara *et al.,* 2007; Ríos-Lara, 2009).

According to the authors referred in the previous paragraph, the platform of the Gulf of Mexico and the Yucatan area are characterized by the presence of hard calcareous materials and the structure of the seabed shows a heterogeneous conformation characterized by the presence of unconsolidated materials (mud, sand, seashells, etc.) and complex karstic topography. This marine landscape is an important forage and development area for many marine species of ecological and commercial importance.

The analysis of the information collected during the survey involved different interpolation methods were essential to obtain a fairly accurate coverage estimate and distribution of the different benthic elements found in the study area, where the lowest estimated mean error, mean absolute error, highest standard correlation, and coefficient of determination (R^2), were used to test fitness of the models used. An example of these indicators used to select the appropriate method of interpolation for hard, rocky stony materials coverage is given in table 1. The same were done for each analyzed element found.

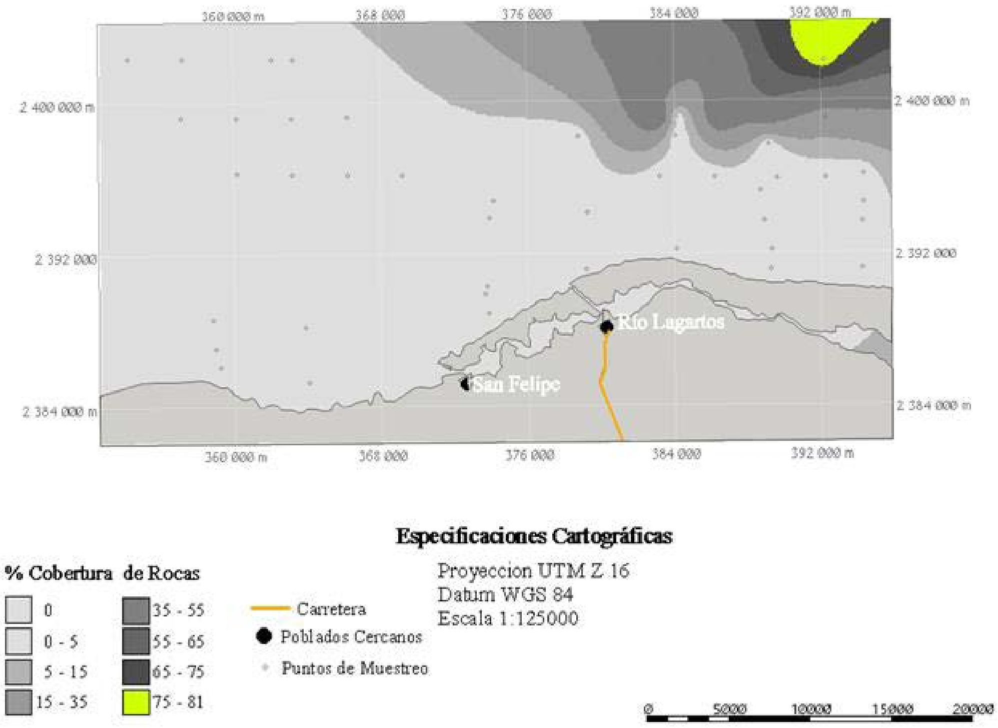
TABLE 1

Results between observed coverage values and estimates Rocky and hard Stone Material

Interpolation method	Average error	Average absolute error	Standard correlation	Determination Coefficient
Triangle (Quintic Interpolation)	-6.174	7.038	0.930	0.864
Kriging (Spherical)	-5.907	8.377	0.837	0.701
Minimum Curvature (search distance 10000 m)	-9.614	11.324	0.691	0.478
Inverse Distance	-5.132	14.178	0.318	0.101

The study are was characterize by Calcareous slabs, flat stones with caves and crevices, mostly northeast and live coverage such as Sea grasses, Macroalgae and Octocorals near to the coast. An example can be viewed in Figure 8 were Rocky and hard Stone material are shown to be concentrated at Northeast, close to Rio Lagartos.

FIGURE 8
Rocks and slabs distribution and their coverage in the study area.



Other hard materials like, scrap, shells, and sediments were found towards the northwest zone, covering an area of 366.87 km^2 and 108.07 km^2 respectively, with depths ranging from 2 to 13 m for scrap, and shells, and 5 km^2 with depths ranging from 11-13 m for sediments. Similar findings have been reported by Seijo *et al.* (2013). The Sand coverage was found continuously distributed with concentration patches throughout the study area, as reported also by Barrientos (2011) for the northeastern coastal area of the Yucatan Peninsula. The region was characterized by a high presence of Octocorals, although it was not dominant in relation to other elements: These elements which were distributed in connected irregular patches throughout the study area, a larger concentration point was observed to the north of Río Lagartos (RL) community. Stony and dead Corals were more concentrated toward the fishing grounds of San Felipe. Results are consistent to the information reported in the area by Cuevas *et al.* (2007).

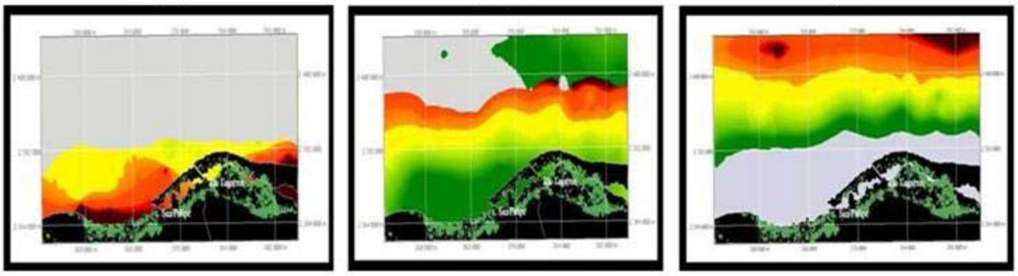
Sea grasses were elements with the highest percentage of coverage, near the coast, its dominance decreased with respect to increase in depth, leading to green algae development. The results of this study agreed with those reported by Barrientos (2011).

2) Mapping suitable habitat for lobster using technical and fisher's knowledge
Juvenile and adult habitats were described by fishers to have similar characteristics, and similar bottom types preferences (hard rocky, stony, bottoms, with slabs). According to Ríos-Lara *et al.* (2007) juveniles prefer caves and crevices within flat stones and slabs, were as adults prefer larger spaces and caves within stones and corals.

The models developed to identify suitable habitat for lobster at different life stages based on technical scientific and local traditional knowledge, agreed that lobster habitat for earlier juveniles were strongly influenced by the presence of sea grass and coastal vegetation with dominant coverage (Figures 9-10) Other elements such as rocks and hard stones, Rhodophyta algae, and Green algae were also present.

FIGURE 9
Suitability maps for lobster (a) Nursery, (b) Juvenile, y (c) Adults sites, based on fishermen knowledge

(a) **(b)** **(c)**



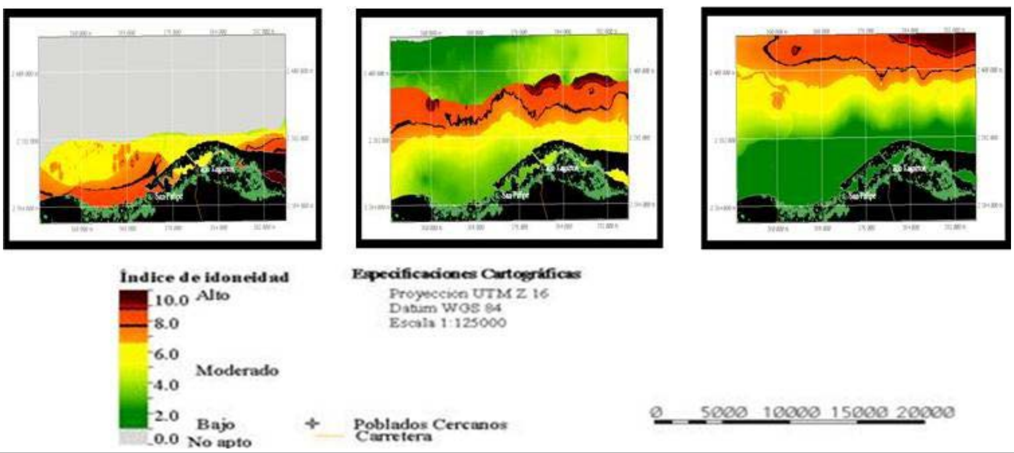
Suitable patches identified as good grounds were found to the northern limit of the breeding region (Figure 9a). These grounds appear to be suitable for juvenile lobsters at late stage as they prefer harder structures for sheltering such as artificial shelters near the coast. Other areas with presence of sand, sea grasses, and macro algae like those reported by Cuevas (2004) in the eastern zone of Yucatan, could hence be a good ground for lobster juveniles.

In general most high suitability grounds for juvenile settlement were found to the east of Rio Lagartos (Figures 9 and 10b). This means that only 2.3% of the area studied was considered with ideal characteristics for maintaining juvenile population. However given the presence of artificial shelters, stony bottoms, and high coverage of rocks, stones, slabs, hard rock materials, and live corals in a wider range, the eastern zone of Yucatan zone could offer a suitable area for juvenile settlement.

In the case of adult lobsters both scientific information and local fishers helped to generate maps with similar results. Both maps (Figures 8 and 9c) agreed that considered high suitability sites for adult lobster were located northeast in the study area, in zones greater than 9 m depth. Only 3.8% of the study area could hence be considered as ideal

FIGURE 10
Suitability maps for lobster (a) Nursery, (b) Juvenile, y (c) Adults sites, based on fishers and scientific knowledge

(a) **(b)** **(c)**



for adult lobster distribution (Figure 10c). However, high suitable sites were observed increasing with depth. This was consistent to that reported by local fishers and results reported by Ríos-Lara *et al.* (2007).

Although the study area, showed little presence of reef and complex refuges structures, which is preferred by adult lobster at this stage of life, high suitability habitats were observed with high percentage and dominance of rocks, and hard stone materials coverage (caves among rocks and stones (Figures 9-10); these results are consistent to those reported by Ríos *et al.* (2007).

What have we learned?

Differences in the bottom types were observed given changes in depth on the surveyed areas, these conditions features coverage that favors the opportunities for shelters for lobster at its different stages of life cycle.

The use of two protocols to explore a wide range of topics resulted in the convergence of fisher's knowledge toward limited but utilizable information about lobster habitat, which led to conclusive results obtained about the characteristics and seabed preferences for lobster habitats, as well as the location of nursery areas. Fishers displayed knowledge about changes in abundance of lobster in the fishing grounds and acknowledge making adaptations on their fishing strategies according to this learning process.

The interaction with fishers in this study allowed confirming the wide knowledge they have on the areas and resources they use. Both models agreed on preferential areas of lobsters at different life stages, but in terms of the extent, the model base on scientific information was more conservative than the local knowledge component. Differences were observed between fishing communities in terms of habitat suitability for lobster at different stages.

Classification of lobsters stages among fishers were considered different from those referred by scientists; difference lies on the fact that fisher's information is based on direct observations on frequently visited sites during their day to day fishing operation. For instance, what they recognize like nursery sites, involve presence of post larvae juveniles that can easily be spotted (approximately 2 to 3 cm CL), which has the characteristic of preferring harder structures such as artificial housing near the coast. On the other hand, lobsters under the size of 13.5 cm TL were defined as juveniles by fishers and all of those above that size were defined as adults. This also may explain to certain extent the minor differences observed in developed maps.

The area under study has characteristic of a karstic region as reported by several authors (Cuevas 2004, 2007, Ríos-Lara *et al.* 2007). This area includes vegetative cover of sea-grass beds dominant to the south, near to the coast. All types of macro algae were distributed throughout the study area without a particular pattern, except for filamentous algae which were not dominant, likewise sponges and stony corals. Definition of these habitats can provide an idea of the spatial distribution of the resource given their preferences for some types of habitats. The close association of juvenile lobsters with benthic habitat may also be linked to supply food, according to Barshaw and Lavalli (1988). Learning about lobster habitats can lead to understand fishing patterns of operation and allocation of fishing effort. Conservation of lobster population and its fisheries hence also involve habitat conservation.

Most suitable habitats for lobsters in all stages were located in RL, which is known as a main nursery area, and one of the most productive zones of lobster in Yucatan, Mexico. This grounds host lots of juvenile and sub adults whose habitats coincide with frequent fishing sites, which increases recruitment to the area but also could put at risk its population if there are not management regulations and surveillance in the zone. Recent studies such report close to 30% of total catches that include sublegal animals in the landings (Ríos-Lara *et al.* 2012). Given the results of this study enough evidence exist to indicate that the studied area is an important foraging and development region for lobsters, special attention is hence required in this marine area. Therefore the basic maps developed in the present can make a contribution for to the scientific community, fishers and for decision makers, to help in the definition of management schemes, including probably a zonation according to the components of the lobster population that could be at risk.

FINAL CONSIDERATIONS

The matching information on scientific and fishers' knowledge confirm the wide experience fishers gather along their life, that allow them to be an important source of information about coastal resources and their behavior. The successful experience on the implementation of the government program is another way to appreciate the usefulness of taking into account traditional knowledge to manage fishing resources.

Public policies can fail if recipients of government programs do not get involved in the decision process required for the generation of such policies; they need to be oriented to strengthen local capacity and generate opportunities using a long-term perspective. Knowledge improvement in several fields associated to the socio-ecological systems (resources, users, managers and their environment) is necessary. In this context, the benefits derived from the incorporation of fisher's knowledge cannot be dismissed. Research and management can be improved if the outsized knowledge of local people in coastal areas can be used optimally, especially in those cases where previous failures of introduction of government programs creates lack of trust of fishers and local people to accept new initiatives.

There are scientists that can be skeptical about what information can be obtained from fisher's knowledge, expecting to find even contradictory results. In this study the use of a tool as the multi-criteria technique allowed to combine information from different sources, in this case technical and local knowledge. Agreement on results ranged from 70 to 80% with fairly differences between both, hence the reliability of FK concerning its possible use as a source of information to identify suitable habitat lobster, can be considered as appropriate. The combination of geo-statistical and multivariate techniques resulted to be efficient for mapping marine benthic habitats, obtaining good accuracy.

The study on habitat suitability contributes with a powerful spatial tool for the detection of important elements integrating some components of the coastal zone, aiding future decision makers to design and implement conservation and management strategies towards lobster habitat protection in Río Lagartos and San Felipe, where an important number of juveniles occur. The maps developed through modeling from different bottoms types, criteria established by fishers and scientists together, reveals that hard bottoms, complex hard structures, and other topographical factors like depth and gradient (slope) are important factors to provide shelter for lobster and thus increases its abundance.

Several authors have shown how incorporation of local traditional knowledge of fishers becomes relevant when viable management strategies need to be implemented (Davis *et al.* 2004; Silvano and Begossi 2005; Aswani and Lauer 2006). These actions have shown to be a cost-effective approach within coastal and fisheries management schemes. The case study on the introduction of AH can also be an example to support these statements.

On the other hand, Castilla and Defeo (2001) and Salas *et al.* (2011a) affirm that involvement of fishers in management decisions can improve trust and hence compliance among resource users to support long-term management programs and development initiatives. The matching information on scientific and fishers' knowledge (Valdés-Pizzini and García-Quijano, 2009; Begossi this volume) confirm the wide experience fishers gather along their life, that allow them to be an important source of information about coastal resources and their behavior. The successful experience on the implementation of the government program is another way to appreciate the usefulness of taking into account fisher's knowledge to manage fishing resources.

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2.2
How to inform the ecosystem approach to fisheries

Integrating fishers' ecological knowledge and the ecosystem based management of tropical inland fisheries: an Amazon case study

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ABSTRACT

Fishers of necessity are ecosystem specialists, close observers of the environment through which the fish they seek move to feed and reproduce. The relationship between habitat and fish communities is especially salient in inland, floodplain fisheries because the main habitats of the ecosystem and the seasonal changes the ecosystem undergoes are clearly evident. Despite the great diversity of tropical floodplain fisheries and the increasing use of non-selective fishing gear, fishers are often highly selective in the fish they target and catch, a testament to their precise knowledge of the habitats and habits of the fish they seek. This detailed understanding of the natural history of the floodplain and of fish biology and behavior, makes floodplain fishers especially sensitive to the importance of the ecosystem which sustains local fish communities, and to the ecological modifications caused by competing land and resource use activities. To varying degrees this awareness of the impacts of human induced habitat modifications on key fish species is reflected in community fishing agreements. These can provide the basis for development of ecosystem-based fisheries management systems, which integrate scientific models and concepts of aquatic ecosystems with fishers' knowledge of the natural history of these ecosystems and the fish communities they sustain. This paper reviews the literature on fishers' knowledge of aquatic ecosystems, explores approaches to integrating fisher's knowledge and scientific understanding of aquatic fisheries and ecosystems, and makes recommendations for integrating fisher ecologicall knowledge into ecosystem based approaches to managing inland fisheries. The paper will also draw on experience with the adaptive management of the pirarucu (Arapaima gigas) in the Amazon basin.

1. INTRODUCTION

Fisheries management has been undergoing a major transformation over the last quarter century. This change has been precipitated by the growing perception that the scientific management model that dominated fisheries management since the beginning of the twentieth century has proven not just incapable of halting the steady decline of the World's major fisheries, but is in some ways partly responsible for this decline (Holling and Meffe, 1996; McGoodwin, 1990). The changes in fisheries management now underway have two main origins, the move towards more integrated, ecosystem approaches to fisheries management and the growing involvement of fishers in management decision-making.

The ecosystem approach to fisheries management has developed in response to the understanding that fisheries are also affected by environmental processes that can occur at larger scales, can have their origins outside the fishing grounds and can introduce high levels of uncertainty into stock assessments and management decision-making (Curtin and Prellezo, 2010). Furthermore, human activities affect environmental conditions within the fishery, including water quality, community structure and habitat integrity and distribution (Roberts, 2007). Ecosystem management, then, involves moving from a three dimensional volume of water to a complex, multi-layered mosaic of communities which interact with larger coastal or fluvial systems.

The second major change in fisheries management is the trend of increasing fisher involvement in management decision-making. (McGrath *et al.,* 2004; Sen and Jentoft ,1996, McGoodwin 1990). Here two distinct trends are evident. The first relates to efforts in the developed world to reduce polarization between commercial fishers and government fisheries managers (Van Densen and McCay, 2007). The second has its origins in the resolution of conflicts involving traditional fishing communities and outside commercial fishers in the developing world. While the problem in the first is excessive government control and fisher dissatisfaction with management decision-making, in the second it is the absence of government presence to mediate conflicts and protect community interests. While their origins differ both processes are leading towards greater fisher involvement in management decision-making.

These two trends, from stock assessments to ecosystem management and from centralized scientific management to decentralized participatory management, are converging on a new management model in which fishers' ecological knowledge is of increasing importance. There is considerable expectation regarding the potential contribution of fishers' knowledge to the construction of a new participatory, ecosystem management paradigm in which fishers, scientists and managers cooperate in the design, implementation and monitoring of management systems.

As the shift to more participatory management approaches has evolved, it has become increasingly evident that this is not just a question of including fishers in management decision-making. This integration also involves a new concept of the fisher as the central actor in the fishery and new relationships between fishers, scientists and managers. These relationships depend in turn on the development of methods for reconciling and integrating different kinds of information, especially scientifically collected data on the fishery and its ecosystem, on the one hand, and fishers' own knowledge of these same fisheries and environment, on the other (Ruddle, 1994, Johannes *et al.*, 2000).

One consequence is that the science and practice of fisheries management are becoming increasingly interdisciplinary. A field that for decades was dominated by biologists who knew a great deal about fish and the dynamics of fish populations, is now having to accommodate ecologists who understand marine and aquatic ecosystems and social scientists whose expertise is in the study of people, their societies and economies (Symes, 2006). It is increasingly clear that fisheries management is not about managing fish but fishers and dealing with the web of social, economic and ecological relationships that connect fish and fishers to the larger regional ecosystem.

While much attention has focused on small-scale marine fisheries, these same issues and evolving management approaches have also characterized the evolution of the major inland fisheries of the Tropics, including the floodplain fisheries of the Amazon River. In this paper we present a case study of a major Amazon initiative that integrated scientific and local knowledge to develop an adaptive management system for the pirarucu (*Arapaima* spp.), one of the most important and most threatened commercial fish species in the Amazon basin. The paper is organized into three main parts. In the first part we briefly explore the changing conceptions of fishers and the relationship between fishers and managers and the nature of fishers' ecological knowledge and its relevance for fisheries management. In the second we present a case study of how scientific and fishers' knowledge were integrated in the development of an adaptive management system for the pirarucu (*Arapaima* spp), and in the final part we discuss a proposal for integrating local fishers and their knowledge into an institutional framework for the ecosystem management of floodplain fisheries.

2. THE CONCEPT OF THE INDIVIDUAL IN APPROACHES TO FISHERIES MANAGEMENT

The transformation of fisheries management science and practice now underway involves a fundamental change in the concept of the fisher as an individual and consequently in the relationship between the fisher and the manager. Three distinct perspectives on individual behavior are evident in discussions of LEK and its contributions to the science of fisheries management. These are: 1) the individual as economic rationalist, 2) the individual as part of a social (and ecological) system, and 3) the individual as boundedly rational.

Individual as Economic Rationalist: The scientific management model assumes that fishers are opportunistic (short term) profit maximizers whose behavior must be controlled or constrained. This is the model of the fisher that is assumed in most of the mainstream quantitative work in fisheries biology and management, especially that portion which draws on the long tradition in fisheries biology and economics (Clark, 1973; Gordon, 1954 and Scott, 1955, McGoodwin, 1990). This concept of the individual is also assumed in Hardin's classic paper "The Tragedy of the commons" (Hardin 1968). The economic rationalist model has been an extremely fruitful approach to understanding fishers as economic actors and the complex interactions between fishers, managers and other actors. The problem, here is that the profit maximizing opportunist is an inaccurate (or incomplete) representation of human behavior that reinforces more authoritarian, government centered management approaches and decision-making and underestimates individual capacity for cooperation and collective action (Ostrom, 1998). It also feeds into the view that fishers' ecological knowledge is biased and unscientific.

Individual as Part of a System: A second major line of research, covers a range of different and often antagonistic approaches, roughly grouped here into systems theory (including ecosystem theory), structuralist social theories and socio-ecological systems. These perspectives share a holistic, structure oriented and/or systems perspective, best exemplified in fisheries research by the socio-ecological systems approach, but also ecosystem theory. In these approaches, individual motivation and behavior are not well defined, because the emphasis is on understanding the larger social and economic systems (structures/political economy). It is more or less assumed that human behavior is a function of larger scale social processes and that prevailing social structures and relations explain human choices. Individual human agency is limited and the group, not the individual, is the main focus of analysis (for example, Berkes and Folke, 1989). There is an underlying assumption (of variable strength) that human behavior, local beliefs, rules and practices, are to some degree functional to the logic and operation of the socio-ecological system. Whereas in the economic rationalist model collective behavior is assumed to be the aggregate outcome of individuals pursuing their own short term interest, in structuralist and systems approaches, societies have emergent properties that cannot be explained as the aggregate of individual behavior. Consequently, there is a tendency to downplay the problematic relationship between individual and collective interests, leaving the impression that there is little contradiction between them. Here, while individual behavior and motivations are not a central concern, the collective local ecological knowledge of fishers is central to understanding socio-ecological sustainability and resilience (Berkes and Folke, 1998).

Bounded Rationality: A third approach, occupying a middle ground between reductionist and systemic approaches, is that of the individual as "boundedly rational". In this model there is a well-defined concept of the individual with drives and motivations, who also monitors and adjusts his/her behavior to the social and cultural environment. In this model individual behavior diverges significantly from that of a short term, profit maximizer. While the economic rationalist model assumes that individuals have full information to make decisions in their own short-term interest, in the bounded rationalist model the individual has limited information and time to make decisions. Consequently, individuals tend to rely on heuristics, rules of thumb, developed through their past-experience to guide decision-making in the current situation (Ostrom, 1998). In addition, individuals often initiate cooperative behavior or simply cooperate with others if they perceive that conditions are favorable. Whether individuals are active participants in managing the fishery, or free-riding poachers depends on their confidence in local management institutions, the cost/benefit of poaching and likelihood of being caught, and the potential short and longer term benefits of complying. In the "bounded rationality" approach the focus is on understanding individual and collective behavior in managing local fisheries and in how individual and collective interests are or are not reconciled (Ostrom, 1998). As with the socio-ecological systems approaches, LEK is basic, here, although there is more concern with how it varies within a population of fishers and how it influences differences in fishing behavior and local management performance.

3. CHARACTERISTICS OF FISHERS' ECOLOGICAL KNOWLEDGE

As noted earlier, the shift towards more participatory and ecosystem management perspectives has driven the interest in and engagement with the knowledge and perceptions of fishers, variously referred to as "Local", "Traditional", or "Fishers'" Ecological Knowledge, shortened respectively to LEK, TEK and FEK, here referred to as LEK. Drew quotes Berkes' (2000) definition of traditional ecological knowledge (TEK) as:

> *A cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (Berkes et al., 2000: 1252).*

This definition, with its emphasis on intergenerational cultural transmission is consistent with the socio-ecological systems approach in which the focus is on the system rather than the individual (Berkes and Folke, 1998). It captures a core element of prevailing concepts of LEK or TEK as a distinctive body of collective knowledge shared by fishers in a regional fishery.

We can distinguish at least three general processes through which fishers acquire knowledge of the fishery and its broader ecosystem. The first process is through fishers' direct experience during fishing trips and related activities and through other activities such as farming, hunting, forest collection and animal husbandry, all of which involve interacting with the natural, social and economic environment of the fishery. A second process is through observation and conversation with other fishers and those involved in some way with the fishery. Most fishers learn to fish as children while fishing with relatives and friends and acquire additional knowledge through informal conversations with other fishers, both active and inactive. These interactions broaden their knowledge of fisheries beyond their immediate experience. A third process, which may the one most closely associated with cultural transmission, is through growing up as a member of the local community/society and culture (Berkes and Folke, 1989). This body of knowledge includes religious beliefs, cultural histories and traditions, as well as the social and economic relationships that structure interactions within the community and between the community and the larger society. All three of these sources of knowledge influence not only how fishers fish, but also the norms and formal and informal rules that govern access and use rights to local fishing grounds and other natural resources.

An important theme in research on LEK is the scientific quality of LEK research and how the information obtained can contribute to fisheries management science. This concern has focused primarily on methodological issues related to how to collect and analyze LEK and secondarily on how to integrate science and LEK in a scientifically grounded approach to fisheries management (Huntington 2000, Neis *et al.,* 1999, Ruddle and Davis, 2013). As Davis and Wagner (2003:466) observe, "In our view it is essential to design and conduct LEK research in a manner most likely to produce research results that will thoroughly represent the breadth, depth, and comparability of LEK, while positioning the research outcomes to withstand rigorous public inspection."

Over the last fifteen years, considerable effort has been invested in developing scientifically rigorous methods for obtaining LEK from fishers and comparing the information so obtained with scientific data on the same subjects. Through this process researchers have identified areas in which LEK has much to contribute and others where LEK may have less to offer (Johannes 2000, Drew, 2005; Ruddle, 1994, Ames 2007, Baird, 2007, Mackinnson, 2001. Neis *et al.* 1999, Wilson *et al.,* 2006). While much progress is being made in identifying the kinds of management information that LEK provides, less progress has been made in integrating LEK and scientific information in the design of regional management systems. As some researchers have noted, the lack of success may be due more to the limitations of the models on which scientific fisheries management is based than to the relevance of LEK to the management of local fisheries (Johannes, 2000; Ames, 2007).

3.1 Fish biology and population dynamics. Fishers are not casusal observers of fish. Their wellbeing and that of their families depends on their success in catching particular species of fish (Neis *et al*., 1999). This in turn depends on the quality and especially the accuracy of their knowledge of fish biology, the characteristics of schools, population dynamics, community composition, and feeding and migratory behavior. They must know where and on what species fish are feeding over the course of daily and seasonal cycles and the most effective gear and bait for catching them in each location. Moreover, through cleaning their catch, fishers (men and women) accumulate detailed knowledge of the diet and physical and reproductive changes each species undergoes over its lifecycle. These and other kinds of information that fishers acquire could make possible more geographically detailed management plans, more focused management rules tailored to the status of individual populations and enable management to be more responsive to changes within the fishery.

3.2 The ecosystem with which the fishery interacts. Through fishing and other activities, fishers acquire considerable information on the natural history of the fishing grounds and surrounding region, habitat preferences and interactions between fish and other aquatic species (Johannes, 2000, Neis *et al.*, 1999, Drew, 2005, Ruddle, 2004). They have detailed spatial knowledge of the topography, substrate and habitat distribution within the fishing grounds, as well as spatial variation in current and water quality throughout the fishery (Ruddle, 1994, Hall and Close, 2007, Drew, 2005, Eddy *et al.,* 2010). They also have detailed knowledge of species associations and of how fish move between habitats on diurnal and seasonal scales (Garcia-Quijano, 2007). They constantly update this information through their own experience and through the observations of other fishers. In many cases fishers are able to identify processes that contribute to the degradation of local habitats and how these processes affect local fish populations and communities before they become evident at regional scales (Drew , 2005, Johannes, 2000, Lauer & Aswami 2010; Neis *et al.,* 1999; Rochet *et al.,* 2008). In addition, because many small- scale fishers, especially those in inland fisheries, cultivate crops and raise large animals, they have considerable knowledge of the larger regional ecosystem and the changes it is undergoing.

3.3 Social and Economic Environment: As noted earlier, fisheries management is about managing fishers and only indirectly fish (Berkes and Folke, 1998). Thus, fishers' knowledge of their society and economy are central to the sustainable management of local fisheries. A key aspect of LEK is the social capital of the community, the capacity of the community or group of fishers to cooperate in collective actions. Fishers' knowledge of the local norms and rules is also part of social capital and the basis for management of the fishery (Putnam, 1993; Ostrom, 1998). A second aspect of LEK is fishers' collective knowledge of local social organization and the political structure of the community, essential information for navigating the different interests that must be taken into account in negotiating management plans. Aswani (2005), for example, assessed cultural attitudes with respect to governance and management of marine resources and found that understanding the effectiveness of existing local governance institutions is key to predicting the outcome of introduced management systems. A third aspect is fishers' understanding of economic relationships and especially the role of traders and intermediaries who buy fish and may supply fishers with gear and supplies. Through these economic relations, traders and other intermediaries may exert considerable influence on fishers' and community management decisions.

3.4 Characteristics of Fisher knowledge relevant to management

1) Success oriented: Fishers' livelihoods depend on their success in fishing and this success depends on their knowledge of local fisheries (Ruddle, 1994; Joahannes, 2000, Neis *et al.,* 1999). This information may be biased from a scientific perspective, but from a practical management perspective it is of critical importance to understanding the decisions that fishers make and their response to management regulations.

2) **Heterogeneous**. Fishers are not equally knowledgeable or observant (Johannes, 2000, Drew 2005, Davis and Wagner, 2003). One important focus of research has been on methods for identifying those fish ers who are most knowledgeable about local fisheries (Davis and Wagner, 2003, Drew, 2005, Huntington, 2000). In this regard, it should be noted that the qualities that make talented leaders are not necessarily the same as those of especially observant, skilled and knowledgeable fishers. Several researchers have noted that fishers who use various kinds of small-scale gear tend to have more LEK than those who use only one larger scale gear type (Wilson, 2006).

3) Dynamic. Numerous researchers have noted that LEK is a dynamic body of information that evolves as local fisheries respond to changes of endogenous and exogenous origin, such as increased pressure on local fisheries (population and market), pollution, erosion and sedimentation, and/or dams and flood regime (Ruddle, 1994, Mackinson and Nøttestad, 1998). This dynamism is an essential feature of the adaptive capacity of local fishers (Drew, 2005; Ruddle, 1994).

4) Iterative learning: Related to the dynamism of LEK is the observation that learning is an iterative process of trial and error. Some researchers have observed that LEK and the way fishers use their knowledge of local fisheries on a day to day basis is similar to an expert system based on a sequence of heuristics (Mackinson, 2001, Grant and Berkes, 2007, Drew, 2005). As fishers encounter specific situations, they draw on previous experience to decide which of the available courses of action to take. This view of learning and decision-making is consistent with the view of fishers as boundedly rational, creating and using heuristics to make decisions when they have only partial information and limited time (Ostrom, 1998).

5) Scientific versus local ecological knowledge: Numerous researchers have compared fishers' knowledge with scientific understanding of the same questions. In general they have found that there is a high degree of agreement between fishers' and scientific views. In those cases in which there is disagreement, it is often related to different scales of observation and or to different sources of information (Wilson, 2006; Huntington, 2000, Rochet *et al.,* 2008, Daw *et al.,* 2011). In contrast to conventional scientific management, which has difficulty incorporating the habitat complexity of fisheries, for fishers the fishery is differentiated into a mosaic of habitats and associated physical conditions, each of which vary over the annual cycle and can play different roles in the feeding and reproductive behavior of individual species. Fishers' success depends on their knowledge of this underwater landscape and where, when and how to catch the fish they seek.

6) Integrating LEK into fisheries management. A number of barriers to integrating LEK and scientific management have been noted in the literature. First, they are different kinds of knowledge. Scientific management is based on quantitative information and models while LEK is qualitative and not easily integrated into quantitative models. LEK is anecdotal composed of individual observations, rather than systematically collected according to statistically valid methodologies. It tends to be drawn from biased rather than random samples. Moreover, obtaining LEK from fishers often requires the use of social science methodologies with which fisheries biologists are not acquainted. Finally, Ames and others note that the stock assessment models on which scientific management is based are very restrictive and limited in terms of the information needed and the results that are generated (Ames, 2007, Drew, 2005). The question is not so much how to integrate LEK into scientific management, but how to organize processes through which scientists, managers and fishers can contribute their information to developing a common knowledge base. As Wilson *et al.* (2006: 801) conclude, "LEK has a critical role to play in making management effective . . . To make an effective contribution, however, such information can only be revealed as part of comprehensive studies involving ongoing interactions between fishers, scientists and other stakeholders. . ."

The potential role of LEK to fisheries management is more revolutionary than this statement implies, because as Ames recognizes, the value of LEK is best realized though a very different approach to fisheries management, one that draws on fisher knowledge, not just to manage fishing practices and effort, but also to conserve the habitats fish depend on. As Ames observes with regard to the role that LEK can play in the recovery of cod stocks in the Gulf of Maine, "Fishermen's knowledge can play a new and positive role in the restoration of commercial stocks. Their local, fine scale information offers a new paradigm based not solely on annual stock assessments, but on strategies that protect and enhance local spawning grounds, local nursery areas, and maintain local forage stocks and critical habitats." (Ames, 2007: 188).

4. CASE STUDY OF LEK AND THE ADAPTIVE MANAGEMENT OF THE PIRARUCU (ARAPAIMA SPP).

4.1 The Floodplain Fisheries and Ecosystem Management

The floodplain or *várzea* as it is called in the Amazon, defined here as the area flooded by the sediment laden waters of the Amazon River, is the major habitat of the pirarucu, *Arapaima* spp. Along the Solimões River[1], location of the case study presented here, the floodplain consists of a scroll-bar topography in which the lateral migration of floodplain channels forms parallel rows of long narrow lakes. These lakes are linked together longitudinally by narrow channels to form systems of lakes that occupy the floodplain interior, each with one or more connections to the main river. From the perspective of fisheries management, these networks of interconnected lakes and channels, which form a more or less discrete unit over much of the year, are the basic unit of ecosystem management. The landscape of these lake systems has a washboard like topography consisting of parallel rows of lakes, forested levees of varying height and lower swampy woodlands. River channels carve the floodplain into islands each with one or more lake systems.

Human settlements and economic activities are organized to exploit the resources of the main habitat types of the floodplain lake ecosystem. Houses are located on the higher levees as is most annual and perennial crop production. Timber and other forest products are extracted from levee forests. Fishing occurs year round in floodplain lakes and seasonally in nearby river channels. Timber extraction and shifting cultivation are the main human impacts on the floodplain ecosystem reducing forest area and degrading remaining forests, which are the major feeding grounds for most floodplain fish species.

The main driver of the floodplain ecosystem is the annual flood pulse (Junk e Bayley, 1989). The river rises slowly from October to its maximum level in June and then falls to its minimum level in late September (Castello, 2008a). The slow rise and fall of the river divides the year into two main phases, an aquatic phase of rising and high water levels and a terrestrial phase of falling and low water levels. Plant and animal species have adapted to take advantage of the alternating terrestrial and aquatic phases. As floodwaters rise, many tree species fruit and nuts and seeds are dispersed by the rising floodwaters. Fish and other aquatic species move into the forest to feed on fruits and nuts as they fall into the water, accumulating fat for spawning and upstream migration once water levels begin to fall (Goulding 1980). As water levels fall, fish move out of the flooded forest and into the deeper lakes or into the main channel, migrating upstream to spawn when the waters begin to rise and then reentering floodplain lakes to feed.

Human economic activities also follow this seasonal rhythm (McGrath *et al.,* 1993). Crops are planted as floodwaters fall, to be harvested before the next flood. Loggers cut trees and prepare logs during the low water season, and then float them out to the river during the flood season. The period of falling water levels is the most productive time for fisheries. Fishers fish migrating schools as they move out of floodplain lakes and swim upstream to spawn, as well as more sedentary species, such as the pirarucu, which move into the deeper floodplain lakes and canals. The pirarucu fishery, the subject of this case study, concentrates on the deeper lakes and channels where the fish aggregate during the low water season (Veríssimo, 1895; Castello, 2004).

Floodplain lake fisheries have been the focus of a grassroots movement similar to that of the Rubber Tappers, which emerged in response to the development of the commercial fisheries beginning in the 1960s and 1970s (Hall 1990, McGrath *et al.,* 1993). Technological changes, which increased the catch and storage capacity of fishing boats, combined with new sources of demand for fresh and frozen fish, drove expansion of commercial fishing throughout the Amazon River system, greatly increasing pressure on floodplain fisheries. Communities concerned with the depletion of fish in local lakes, responded by seeking to prevent commercial fishing boats from entering lakes. Many crafted collective agreements to define rules and regulate fishing in nearby lakes. Originally considered illegal by the government, these agreements became the

[1] Brazilian name for the section of the Amazon River between the Colombian border and the confluence with the Rio Negro.

basis for a co-management policy, which defined criteria and procedures for the legal recognition of community fishing agreements (McGrath *et al.,* 2004, Ruffino, 2004). While the agreements are based on the ecological knowledge of floodplain fishers, they are a recent response to the threat posed by growing commercial fishing pressure on lake fisheries (Berkes & Folke, 1998; McGrath *et al.,* 1993). The pirarucu management system described in the following sections grew out of collaborations between floodplain communities and scientists from local NGOs and government research institutes, which sought to integrate scientific and community approaches to managing lake fisheries (Castello, 2011, McGrath *et al.,* 2008).

4.2 Background

The pirarucu has been one of the most important commercial fish species in the Amazon since early in the Colonial period (Veríssimo, 1970). Until the last quarter of the 20th century, pirarucu were filleted upon capture and dried and salted for storage and marketing, earning the nickname of "*bacalhau* (cod) of the Amazon." For most of this period, the trade in dried salted pirarucu is estimated to have ranged between 1 500 and 5 000 metric tons, annually (Crampton *et al.,* 2004, McGrath, 1989). With the development of commercial fisheries, and widespread adoption of gill nets, pressure on the pirarucu intensified. Bessa and Lima (2010) note that landings in Manaus fell from an average of 100 metric tons between 1976 and 1978 to 28 tons between 1994 and 1996. In many areas the pirarucu had become locally extinct. The depletion of pirarucu stocks led to its inclusion in the Red List of threatened species (IUCN, 2006). However, the lack of accurate landing data have complicated efforts to gain a more accurate assessment of the state of pirarucu fish stocks.

Government efforts to manage pirarucu stocks began when IBAMA, the federal Institute responsible for fisheries management established a minimum size limit of 150cm and a closed season between December 1st and May 31st. In 1991 the Amazonas Superintendency of IBAMA decreed a five-year moratorium on commercially oriented fishing for pirarucu. Shortly thereafter the pirarucu was included in Annex II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). However, enforcement has been sporadic at best, and fresh and dried pirarucu of all sizes can be purchased in fish markets throughout the year.

4.3 Development of the Pirarucu Management system

The pirarucu's unique biology and ecology combined with its high economic value sparked interest in developing community-based management systems for the species. In the late 1990's the Mamirauá Institute of the Mamirauá Sustainable Development Reserve, near the town of Tefé on the middle Solimões region of the State of Amazonas, began exploring the potential for community management of the pirarucu building on local community management initiatives that had their origins in the lake reserve movement of the 1980s (Lima, 1999; Queiroz and Sardinha, 1999).

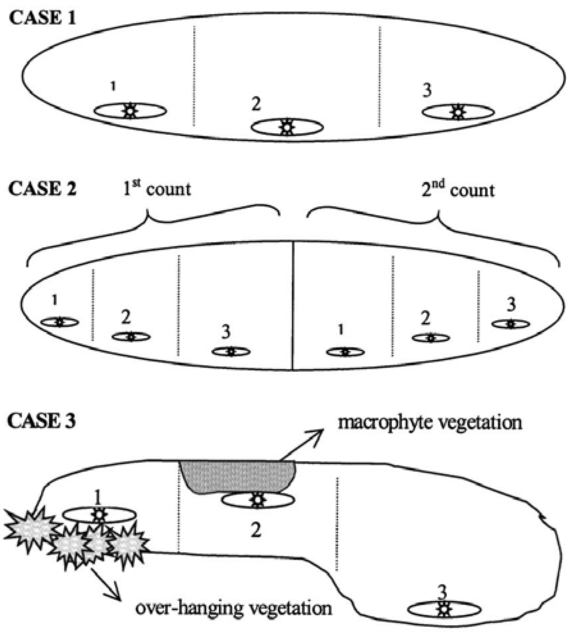
4.4 Biological characteristics of pirarucu & Pirarucu fishers' knowledge and skill

The pirarucu (*Arapaima* spp.) is the iconic fish species of the Amazon, because of its large size and unique biological characteristics and the skill required to catch them. Pirarucu can reach three meters in length and 200 kg in weight (Arantes *et al.,* 2010) and are among the most sought-after commercial fish species in the Amazon (Viana *et al.,* 2004). They are obligate air-breathers adapted to hypoxic conditions and must surface every 5-15 min to gulp air (Luling 1964). They are most abundant in whitewater river floodplains of the Amazon River, where they inhabit lake and channel habitats during low water and flooded forest habitats during high water (Castello, 2008a). They form couples and mate as water levels begin to rise, construct nests on the margins of floodplain forests and care for their young during the first three months (Castello 2008b). Pirarucu grow to about 77 cm in length during the first year and reach adulthood between the ages of 3 and 5 years when they measure about 160 cm (Arantes *et al.,* 2010). The parental care behavior and fast body growth rates combine to give the pirarucu relatively high intrinsic rates of population increase (Castello *et al.,* 2011a).

Pirarucu fishers are considered to be the most highly skilled fishers in the basin due in part to the fact that *Arapaima* have traditionally been caught with harpoons. Fishers wait silently in wooden canoes for a pirarucu to surface. When they spot a surfacing pirarucu, they throw their harpoon where they think the pirarucu will be, taking into account the direction, depth, and swimming speed of the targeted pirarucu. Even the most experienced fishers will take a day or more to catch a large pirarucu. They estimate that it probably takes about a thousand successful harpoonings for a fisher to develop a significant level of LEK. It is thus not surprising that pirarucu fishing is highly specialized: only 10% of all fishers in the Mamirauá Reserve were considered to be pirarucu specialists, but they were responsible for between 50 and 60% of the total catch (Queiroz and Sardinha, 1999).

Research to develop a stock-assessment method based on counts of pirarucu populations made when they rise to the surface to breathe began in the late 1990s. Fieldwork and discussions with local fishers indicated that while it should be possible to count the pirarucu, few fishers thought that it could be done. The co-author of this paper, L.C., teamed up with two expert pirarucu fishermen to develop a method for counting pirarucu populations in floodplain lakes. During the initial phase of fieldwork, it became clear to L.C. that the fishermen could recognize individual differences among the surfacing pirarucu, the very ability needed to reliably count the number of pirarucu in a given lake. The three worked together for the next six months to develop the ability to count pirarucu into a standardized and reliable, replicable, and verifiable method of fish stock assessment. The three developed the following standardized method for counting pirarucu in lake environments.

FIGURE 1
Description of pirarucu counting methods in three different situations. Case 1 is a small lake, Case 2 is a large lake, and Case 3 is a lake with vegetation and a shape that complicate visual monitoring



Source: Castello (2004).

A team of fishers divides each lake into sampling units of varying size based on the perceived degree of difficulty in observing and listening for pirarucu breathing in each unit. Fishers then enter their unit area and simultaneously count the pirarucu over a 20-min interval. Only fish longer than 1 m are counted. The length of individual fish is estimated from the size of the dorsal region and by listening to the fish's breath. Each fish is classified as either a juvenile (1–1.5 m) or adult (>1.5 m, corresponding to regulations regarding minimum catch size). When the area of the lake is larger than the area the team can cover in one step, the lake is divided into two or more sections and the team repeats the pressure in the remaining sections of the lake (Castello, 2004).

In order to evaluate the pirarucu stock assessment method, two sets of experiments were conducted. The first assessed the accuracy of the fishers' pirarucu counts by comparing them with mark–recapture abundance estimates calculated for the same lake populations. The second assessed the potential for fishers to learn how to count pirarucu from the fishers involved in the previous set of experiments using the same comparative method. This second assessment sought to determine whether the knowledge and skills necessary to count pirarucu could be passed on to other fishers with sufficient accuracy to dispense with the use of the slow and expensive mark–recapture method.

The counts made by the group of eight specialist fishers had a strong positive correlation with mark-recapture estimates of abundance (r = 0.98) and the counts in each lake varied by only 10.4% on average (Castello, 2004). Validation of the accuracy of the counts prompted additional research to assess the possibility of training fishers from different regions to count pirarucu. Trainee fishers were given a short training course in pirarucu counting and their ability to accurately count pirarucu was assessed using the same mark and recapture method used previously. Counts of pirarucu and mark-recapture estimates of abundance were also highly positively correlated (i.e., r = 0.97, 0.97, 0.99; Castello, 2004), indicating that other fishers could be trained to count the pirarucu, and that the method could be reliably passed from one fisher to another.

Fishers explained that they use two methods to count pirarucu. The first is through individual identification on the basis of subtle visual and acoustical cues when fish rise to the surface. The second involves the detection of "waves" of individuals surfacing more or less simultaneously at different locations. This is an example of the importance of LEK. The skills and knowledge base that allow them to distinguish individual fish is acquired through long practice observing and listening to surfacing pirarucu and harpooning them immediately afterwards. These skills and knowledge base are improved further when fishers use artisanal fishing methods such as harpoons. Although all fishers involved in this work succeeded in counting, fishers report that not all fishers are successful at counting. They say that fishers who are less experienced and/or who use modern fishing methods (such as gill netting) do not have as much knowledge of the species nor the skills needed for accurate counting.

4.4. Pirarucu management system: The pirarucu management system developed out of this research had four main components: an annual census, a minimum size limit, determination of the quota and a six month closed season corresponding to the pirarucu breeding season.

Annual population census in managed lakes: Fishers undertake annual counts of the number of adult and juvenile fish (between 1m and 1.5m) in managed lakes during the month of January, when water levels are low and rising and after the pirarucu fishing season has closed.

Annual Quota: The annual quota is limited to 30% of the number of adult pirarucu estimated from the population census. This proportion provides a reasonable catch for fishers while also permitting the pirarucu population to grow rapidly.

Closed spawning season: The management system follows existing government regulations for a closed period during the spawning season. This is the period when adult fish are most vulnerable as they care for their offspring.

Adult fish: Following government regulations, only fish 1.5 meters or larger can be harvested, ensuring a sufficient number of fish will be recruited into the stock in the following year.

Individual transferable quotas: The annual quota is divided into individual transferable quotas, a system that was developed by the fishers themselves. Association leaders assign individual harvest quotas based on fisher participation in management activities. All fishers get a "standard quota", which was set at 18 pirarucus in 2005. These individual fishing quotas can be transferred between fishers.

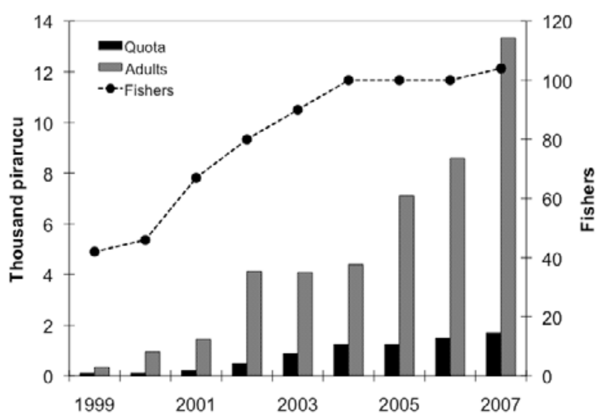
Motivation, Monitoring and Enforcement: There is no formal **monitoring** system in the Mamirauá model, although there is in many other pirarucu management systems in the Amazon where poaching is a problem. Because of the close connections between families, and the fact that members of the community are often fishing in the managed lakes, the community is generally able to monitor illegal fishing without organized patrols. Continuing with the example from the previous paragraph, **motivation** to participate in management activities is reinforced by awarding an extra five fish to those who participate in the one-month pirarucu population census. **Sanctions** consist of reductions in the basic quota. Those fishers caught fishing illegally have their quota decreased by two or more fish. The effectiveness of this "kinship-based" approach to monitoring and sanctions seems to have improved compliance, as there is ample anecdotal evidence indicating that the number of offenses has decreased significantly (Viana *et al.*, 2007).

4.5 Results: Impacts in terms of population growth

The management scheme has been continuously operational since it was first implemented. Between 1999 and 2007, the adult pirarucu population almost tripled from 4500 to 12 000 individuals, while the number of fishers more than doubled from 40 to over 100 (Castello *et al*., 2009, 2011). The observed population growth trends in Figure 1 are real as other studies have concluded that no other factor (e.g. environment) affected the local pirarucu population (Castello *et al.* In Review). Furthermore, most fishers involved in counting pirarucu in participating communities have had the accuracy of their counts assessed by comparison to mark-recapture or total catches, and technicians from the Mamirauá Institute have accompanied the fishers during census work to deter possible cheating.

There were also important benefits in terms of social organization and gender equality. Half of the increase in the number of fishers in the original communities of Mamirauá were women, the wives of fishers who were also participating in the management system. The fishers' association increased from 42 members in 1999, all of whom were men to 71 male and 29 female members in 2006. This increase has been almost entirely spontaneous, as men and women became interested in the economic benefits of the management system.

FIGURE 2
Trends in numbers of fishers and pirarucu and annual quotas with implementation of management system



Source: Castello *et al*., 2011.

The pirarucu management system was disseminated to other communities within the Mamirauá Reserve so the number of communities involved increased from four in 1999 to 16 in 2005 (Figure 2, Arantes *et al.*, 2006). The management scheme has also been implemented in the lakes of the Maraã district of the Reserve, with the involvement of the local fishers' union. Between 2002 and 2009 the managed pirarucu fishery in Maraã increased from 50 fishers and a total catch of 5.5 tons/year, to 510 fishers and a total catch of 119 tons (Amaral *et al.*, 2011).

4.6 Management policies based on work

The RDS pirarucu management initiative did not have formal linkages to state or federal fisheries management agencies, although staff members participated in discussions of fisheries management policy at state and federal levels. Formal engagement with IBAMA's Amazonas Superintendency, responsible for the moratorium, on pirarucu fishing, began with the implementation of the original management system in 1999. The RDS applied for a harvest permit and presented documentation on the management system. After much negotiation a permit was granted for the requested pirarucu quota (Viana and others, 2004). In the following year, fishers and technicians from the Mamiraua´ Institute requested a larger harvest quota, because the population of pirarucu had increased. However, IBAMA officials granted a quota that was only two-thirds the size of that requested. The official technical statement explained that the requested quota was "too much" (Viana and others, 2004). In 2002, the counts of pirarucu indicated that the population had increased by about 480% relative to 1999. The fishing quota set by the fishers and technicians of the Mamiraua´ Institute for 2002 was five time the 3 tons approved in 1999 (Viana and others 2004). Government officials denied the requested harvest quota; explaining that "[local fishers and technicians of the Mamiraua´ Institute] were proposing weird ideas" (Viana and others, 2004). In response, technicians of the Mamiraua´ Institute invited government officials to come to the Reserve, meet with the fishers and technicians and visit the managed lakes (Viana and others, 2004). The visit convinced government officials that fishers actually could count pirarucu, that the management scheme was sound and that it had already resulted in a significant increase in the pirarucu population. After the visit IBAMA no longer contested quota requests.

The success of pirarucu management in the RDS Mamirauá stimulated the adoption of a state-wide program for the development of community-based pirarucu management. In 2005 the Amazonas Superintendency of IBAMA issued regulations for the sustainable management of pirarucu based on the management system developed in the RDS Mamirauá (IBAMA 2005). Similar regulations were implemented in the Brazilian State of Acre in 2008. The regulations made possible the sustainable management of pirarucu in conservation units and areas under formal fishing agreements. Under these regulations community associations can submit proposals for management based on counts made using the method developed by Mamirauá. IBAMA then approves an annual quota based on the count and releases documentation permitting transport of the catch. By the end of 2011, there were 13 management areas in the state with 2,100 registered pirarucu fishers. Total production from nine state management areas was 721 tons in 2011 (SDS 2011).

4.7 Main Points:

In many ways the management system developed for the pirarucu is a good example of the importance of LEK for fisheries management and of how the integration of fishers' and scientific knowledge can play a decisive role in the effectiveness of the management system. Here we summarize some of the main points/lessons learned from the pirarucu management system.

4.7.1 Importance of building on fishers' ecological knowledge and skills

The pirarucu management system is based on LEK and equally important their skill in extracting information on the size of pirarucu from subtle clues when the pirarucu surfaces to gulp air. The skill aspect of LEK is often not recognized and may be overlooked in many situations in which it is a critical element of the fishers' knowledge. In this regard Wilson *et al.* (2006) and others have noted an association between the quality of fishers' ecological knowledge and their use of a diversity of types of small scale gear. In this case, the expert fishers' with the necessary knowledge to develop the census methodology were all skilled harpoon fishers. As this technique is abandoned in favor of fixed hooks and line and gill nets, these skills and knowledge are being lost.

4.7.2 Expert Fishers

Davis and Wagner (2003) and several other researchers have noted that LEK is not evenly distributed throughout a community of fishers. The process of developing the counting method is an example of the importance of identifying the expert fishers, those with exceptional observational skills and knowledge, and working with these fishers to develop key elements of a management system for local fisheries.

4.7.3 Integrating LEK and scientific knowledge

The pirarucu census method is an excellent example of how collaboration between scientists and fishers can lead to the integration of their respective knowledge (Wilson *et al.,* 2006, Carter and Nielsen. 2011). In this case a biologist and two expert fishers worked together to solve a concrete research problem that required the skills of both fishers and researchers. Equally important here was the use of scientific methods to evaluate the accuracy of fishers' estimates. In the eyes of government managers, this scientific corroboration both legitimized the method and the fishers' ability to undertake scientifically valid assessments. The process also inculcated in fishers an understanding of and appreciation for the methodological rigor required to produce scientifically credible population estimates.

4.7.4 Horizontal Transfer

Dissemination of the counting method and associated management system depends on the horizontal transfer of information from accredited pirarucu counters, whose skill has been confirmed, to other fishers using the same procedures. The combination of a rigorous system of training and accreditation and the horizontal transfer of the method via local fishers greatly enhances the legitimacy of the system in the eyes of other fishers.

4.7.5 Adaptive learning

The pirarucu management system is an example of an adaptive management system based on the rigorous assessment of the status of the resource, the implementation of management regulations based on that assessment, the realization of regular evaluations to assess changes in the population and if necessary the revision of management rules. This system also fosters trial and error experimentation and learning that can be applied to other aspects of the fishery, for example, to evaluate habitat associations for spawning and feeding.

4.7.6 LEK and the organization of the management system

The management system that fisher communities devised and especially the system of transferable individual quotas, is an excellent example of how fishers can use their knowledge of community social organization, norms and rules to design a system that provides incentives to participate through individual quotas, as well as, a system of graduated sanctions to discourage free riding. The system for monitoring compliance takes advantage of community capacity to informally monitor the activities of individual fishers and to use community disapproval to discourage poaching.

4.7.8 Empowerment

The whole process of developing and implementing the counting methodology, the management system and the mechanism for disseminating the system empowers the fishers and communities that are involved. Key elements include: 1) the collaboration between fishers and scientists, 2) the scientific validation of fishers' knowledge and skill, 3) the horizontal transfer of the counting methodology via the fisher training and accreditation system, and 4) the endogenous system of motivation, monitoring and enforcement. Finally, the regular feedback on the performance of the system based on changes in the population of adult pirarucu, the annual quota, individual catch and fisher income give the community pride in their ability to sustainably manage such an important resource and to improve their livelihoods and the environment they depend on.

4.7.9 Pirarucu and ecosystem management

While the pirarucu management system is not in itself an example of ecosystem management, it does provide an effective organizational framework for developing an ecosystem management system (McGrath *et al.,* 2007, 2008). Towards this end, the pirarucu serves as a cultural keystone species that can motivate community groups to develop ecosystem management systems for local fisheries (Butler *et al.,* 2012). First, the ability to count pirarucu and monitor changes in pirarucu populations reduces uncertainty regarding the status of the fish population and provides positive (and negative) feedback on the performance of the management system, helping to strengthen community organization (McGrath *et al.,* 2007). Second, the scientific rigor in training and in verifying counts establishes a culture of adaptive learning. Together these two attributes strengthen organizational capacity and increase economic incentives for fishers to invest in habitat restoration and include other valuable commercial fish and aquatic species (river turtles and caiman) in the management system. As the value generated by the fishery increases, there are strong economic incentives to strengthen regulation of economic activities, such as shifting cultivation and timber extraction, which degrade habitats that are critical to the productivity of the lake ecosystem (McGrath *et al.,* 2007). Through this process the management system can expand incrementally to take a progressively more comprehensive approach to managing not just the pirarucu but the entire lake ecosystem.

5. OVERCOMING BARRIERS TO INTEGRATING FISHERS' KNOWLEDGE INTO MAINSTREAM FISHERIES MANAGEMENT

5.1 LEK and Mainstream, Fisheries Management Training

One of the major barriers to integrating fishers' ecological knowledge into mainstream fisheries management is the fact that most government fisheries management professionals have been trained as fisheries engineers. Training in this field tends to be oriented towards larger scale commercial and industrial fisheries. Consequently, students receive training in the more technological aspects of fisheries including naval construction, and technologies for capture, storage and processing fish. Consistent with this engineering perspective, their training in fisheries management draws primarily from the scientific management tradition with its emphasis on quantitative stock assessment models. They are also more likely to have courses in aquaculture than in small-scale fisheries management. Consequently, most have little training or experience in working with small-scale fishers or with participatory approaches to managing small-scale fisheries.

In contrast, those working with small-scale fisheries and community-based management tend to work for NGOs and or universities and academically oriented research institutions. They come from a variety of academic backgrounds including fisheries biology, ecology, anthropology and geography. While they may lack the basic technical knowledge that fisheries engineers possess, they are often more comfortable working directly with participatory management methods that integrate fishers' ecological knowledge.

Integrating LEK into mainstream fisheries management will require modifying the current curriculum for fisheries engineers and managers, to introduce courses and field experiences through which students can acquire the knowledge base and skills needed to work with small scale and community fishers. This is a long-term process, which may only be concluded when the first generation of fisheries managers trained to work with small-scale fishers and integrate LEK into fisheries management reaches decision-making positions within government fisheries management agencies.

5.2 Barefoot Ecologist Proposal

The Barefoot Ecologist Model proposed by Prince (2003 and 2004) is an approach that could contribute to developing the capacity of fisheries management professionals to work with fishers and integrate their knowledge into management decision-making (Castello *et al.,* 2013). Prince originally developed his proposal to address the problem of the prohibitively high cost of monitoring and managing large numbers of widely dispersed and highly localized small-scale fisheries (Prince, 2003). To solve this problem, Prince proposed training leaders from each local fishery so they could organize the monitoring of local fisheries and work with regional fisheries managers to design local management systems adapted to the characteristics of each micro-fishery.

He called these local leaders "barefoot ecologists" after the "barefoot doctors" model developed in China (Prince, 2003). These "barefoot ecologists" would be leaders of local fishing communities who have been trained in the use of a simple but robust set of tools for assessing the status of their local fishery. According to Prince (2004: 365), "Barefoot ecologists will need to be pragmatic generalists, skilled in the multiple disciplines required to work effectively with micro-stocks and in diverse fishing communities . . . the barefoot ecologist will catalyze change and build social capital within fishing communities. Their role will be to motivate and empower fishers to research, monitor and manage their own localized natural resources . . . the barefoot ecologist can support the development of social structures that foster community-based management and data collection." We suggest substituting the name "barefoot managers" as this better captures the range of functions that Prince envisions for these community leaders.

Prince does not see barefoot managers as replacing government fisheries management agencies or academic/research institutions, but as serving as intermediaries between the larger scale and sophistication of government management agencies and scientific research institutions, on the one hand, and individual fishing communities, on the other. Barefoot managers would organize community fishers to collect data on the status of the local fishery and work with researchers and/or government fisheries managers to analyze the data and develop management strategies to address the specific conditions found in each fishery. This collaboration between managers and barefoot ecologists would make possible the full integration of fishers' and scientific knowledge in the design of local management systems.

Prince's (2004) proposal provides a promising solution for the problem of supporting the decentralized, user based management of micro-fisheries, such as the lake fisheries of the Amazon floodplain (Castello *et al.,* 2013). In this connection, the adaptive management system developed for *Arapaima* is a good example of how this "barefoot manager" system could work. Here a professional fisheries manager/scientist works with one or two certified community managers from each community fishery. These "barefoot managers" lead local teams of trained counters to undertake the annual census of their lake pirarucu populations. The "barefoot managers" then work with the manager/scientist to analyze the data, evaluate the status of the fishery and propose adjustments to the system if deemed necessary. The barefoot manager would then be responsible for organizing the implementation of management regulations and monitoring fishing activity to ensure that fishers comply with harvest quotas and other rules.

5.3 Institutional sustainability: a role for regional universities

While Prince's (2003 and 2004) proposal provides a promising solution for the management problems he identifies, the institutional sustainability of a "barefoot managers" program will depend on its integration into an institutional setting that can provide the long-term human and financial resources needed to maintain a program of technical support. In contexts such as the Amazon basin, where fisheries management agencies are understaffed and have limited resources and technical capacity, regional universities could play a critical role in the long-term institutional sustainability of a "barefoot managers" network, coordinating the monitoring system, analyzing the data and providing the results to each barefoot manager.

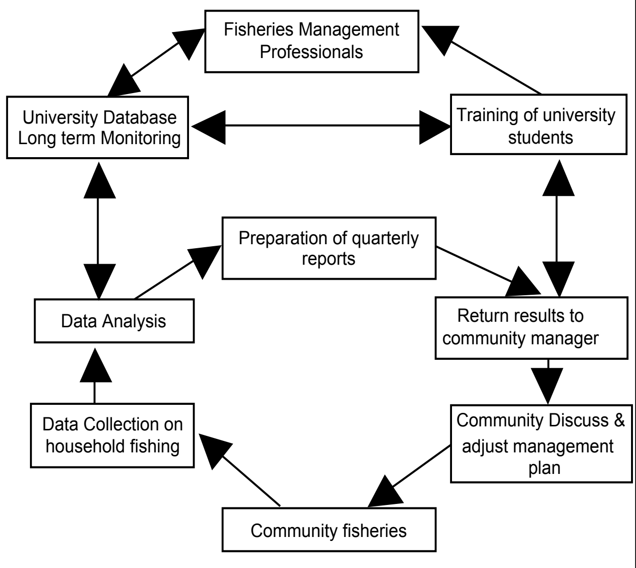
Universities have several characteristics that could enable them to provide a more stable, long-term institutional base than most government fisheries management agencies. They have the basic infrastructure needed, access to university funding sources for teaching and research, as well as research capacity and abundant student labor. University researchers and professors have an incentive to maintain data collection for their own research and teaching, while students gain valuable research experience. Finally, university administrations and extension programs gain public and political recognition for supporting economically important local sustainable development initiatives.

One or more university professors could coordinate a program in support of a network of barefoot managers in partnership with a local NGO, community fishers' organizations and the regional fisheries management agency. The university team could provide technical support to barefoot managers in the collection and analysis of data on the local fishery. Barefoot managers would then return to their communities with the results and evaluate the management implications with other community fishers.

Much of the cost of the program could be absorbed through existing university funding and infrastructure for teaching and research. From a scientific perspective, a "barefoot managers" program could provide opportunities for the kind of long term, fine-scale research on the ecology and management of artisanal fisheries and other aquatic resources, which would be difficult and costly to undertake through conventional research programs (Prince, 2003 and 2004). The monitoring data collected by each community could be stored in a project database along with other data on each fishery and linked to a GIS of the region that integrates key data layers on the geographical, ecological, social, and economic characteristics of the regional fishery. The regional GIS provides a platform for: 1) analyzing spatial patterns and temporal trends in the regional fishery and the factors influencing these processes, 2) designing regional management policies and programs that take into account processes occurring at different scales, and 3) planning the sustainable development of the regional fishery. The database would be continuously updated by the Barefoot Managers network, and supplemented with data from the analysis of satellite imagery and other sources.

From a teaching perspective, the program provides an effective way to develop a new generation of fisheries management professionals who understand

FIGURE 3
Schematic flow diagram of a University-based program in support of a Barefoot Managers Network



artisanal fisheries, are skilled in working with fishers to integrate LEK and scientific knowledge and who understand the methodological approaches and tools of adaptive management. The GIS database could be used as a resource in courses on Geographic Information Systems, statistics, ecosystem management, methods for integrating LEK in fisheries management and the development of small-scale fisheries. Professors and students involved in the program could use the database in their own research projects and theses and the data they collect could be integrated into the overall database. Through programs such as this, it may be possible to finally conclude the transition from a centralized scientific management model to a decentralized, user-based management system that integrates the scientific and fisher knowledge of small-scale fisheries and the ecosystems with which they interact.

6. CONCLUSIONS

Over the last quarter century considerable progress has been made in understanding the potential of LEK to contribute to better management of small-scale inland and coastal fisheries and in developing scientifically valid methodologies for collecting LEK. As numerous authors have noted, LEK has become more important as management has sought to incorporate fishers into management decision-making and move from a focus on a few target fish species to one that takes a broader approach to the fishery ecosystem.

Two important points can be drawn from the literature on LEK and from the case study presented here. First, the integration of LEK and scientific knowledge requires a real, long term engagement between fishers and the scientists studying the fishery. They each contribute their knowledge and expertise and work together as equals to understand what is going on in the fishery and to decide how to move forward to recover the former productivity and/or more sustainably manage the fishery. Here it is important to recognize that it is the fishers, not the scientists, who will implement the system. The second is that this integration inevitably leads to a fundamentally different approach to managing the fishery, one that can be called ecosystem management, if by that we mean one that is also closer to how communities and small-scale fishers manage fisheries in the absence of intervention from formal scientific fisheries management agencies. This in the end is the promise of LEK to fisheries management. LEK is not just more information to squeeze into scientific management models that have little use for it. LEK offers the possibility of a fundamentally different kind of fisheries management that uses fishers' knowledge to restore the habitats and fish populations of inland and coastal fisheries, rather than simply managing their continuing decline.

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Artisanal fishers' knowledge applied to the ecosystem-based approach for fisheries conservation: an experience in Panamá

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ABSTRACT

In the framework for the Proposal for Integrated Coastal Zone Management Plan of the Southern Zone of Azuero submitted to the Aquatic Resources Authority of Panama (ARAP), one of the action plans presented provides the ideal setting to apply an ecosystem-based approach to management. First, the marine area located south of the Azuero Peninsula, in Panama was delineated as a Responsible Fishing Area, proposed, defined and named based on consensus of artisanal fishermen, in response to the many concerns of fishermen, conservationists and other marine resource users. Prior to this decision to propose a Responsible Fishing Zone, a small study was to characterize the fisheries within the designated area. Six advisory workshops and ten visits to various coastal fishing communities were held in the area. Those present at meetings included (local) fishermen, particularly those from three coastal fishing communities in the area and groups interested in listening, discussing and validating information obtained during the study. The data collected comprises monthly values for CPU, commercial values , characterization of fishing gear and the fishing boats, the principal species caught, landings and landing areas, seasonality of fishing operations and fishing areas. All compiled information was validated by fishermen and stakeholders in various workshops, through consultations and group exercises, and conclusions of the study were presented a query performed. The participation of fishermen, including their experiences and their knowledge, was of great value to the conclusions drawn from the management proposal for the Responsible Fishing Zone. The experience also served to highlight problems facing artisanal fishermen and fisheries management.

Conocimiento de los Pescadores Artesanales al Servicio de un Enfoque Eco Sistémico para la Conservación de las Pesquerías: Una Experiencia en Panamá

En el Marco de la Propuesta para el Plan de Manejo Costero Integrado de la Zona Sur de Azuero presentado a la Autoridad de los Recursos Acuáticos de Panamá (ARAP), uno de los planes de acción presentado contempla el escenario ideal para aplicar una ordenación basada en ecosistema[1]. En primer lugar se delimitó un área marítima, denominada Zona de Pesca Responsable; esta zona es propuesta, delimitada y nombrada en base al consenso expresado por los pescadores artesanales, ubicada al sur de la Península de Azuero; en Panamá surge como respuesta a las muchas inquietudes de los propios pescadores, conservacionistas y otros usuarios de los recursos marinos. Previo a esta decisión de proponer una Zona de Pesca Responsable se realizó un pequeño estudio que caracterizó las pesquerías del lugar. Se hicieron seis talleres consultivos y diez visitas a diferentes comunidades pesqueras ribereñas a la zona, estuvieron presentes en las reuniones, los pescadores, en especial de tres comunidades pesqueras ribereñas a la zona y grupos

interesados a fin de escuchar, comentar y validar la información que se obtuvo durante el estudio. La información del estudio contiene datos mensuales de CPU, valores comerciales, caracterización de las artes de pesca y embarcaciones de la pesca artesanal, principales especies capturadas, desembarques y áreas de desembarques, temporalidad de las operaciones de pesca y áreas de pesca. Toda la información fue validada por los pescadores y grupos interesados en los distintos talleres realizados, mediante consultas y ejercicios grupales, a tal efecto se presentó las conclusiones del estudio y se realizó una consulta. La participación de los pescadores, sus experiencias y sus conocimientos fue de gran valor para las conclusiones obtenidas para la propuesta de manejo para la Zona de Pesca Responsable; la experiencia sirvió también para evidenciar los problemas que enfrenta el pescador artesanal y la administración pesquera.

ASPECTS OF THE FISHING INDUSTRY IN PANAMÁ

Historically exportable fisheries products have represented a significant proportion of total domestic goods exported (between 25% and 35%) from Panama. However, in recent years, productivity has dropped to 15% of total domestic goods exported, which has been affected by many factors, particularly in relation to the low catch of shrimp by industrial vessels and more recent limitations on the use of hydraulic machinery on longline fishing vessels.

According to the data from 2011, total marine product (fisheries and aquaculture) exports had declined by 37.1% to their current prices and by 21.9% in value added at constant prices with respect to the previous year. As for the amount of product exported, fish products (the most important) fell 13.4% in metric tons during 2011, while crustaceans, mollusks and live fish increased (CITE 2).

Under the Law 17 of 1959 (3), fishing is defined according to the use of the fisheries product and its technological level. The law defines subsistence fishing, commercial fishing, industrial fishing and sport fishing. Due to the absence of a clear legal definition of artisanal fisheries, riparian fishing was later defined by Decree 124 of 1990 (4) from a practical point of view as the group comprising artisanal fisheries users and employees. Riparian fishing is thus defined as: "that which is conducted in near-shore areas, using fishing gear and equipment such as *chichorros*, trammel nets, gill nets, seine nets, hook and line, traps, longlines, being deep or superficial and in general terms low-tech" (4).

Fishing Permission

Fishing in Panama can be exercised when in possession of a fishing license or a permit for Riparian fishing in the case of artisanal fisheries. In the case of industrial fishing, the acquisition of a fishing license is regulated by decrees that in most cases try to limit fishing effort, as in the case of fishing licenses for anchovy and herring as well as shrimp, snapper, grouper and shark. The Riparian (artisanal) fishing permit is limited to one per boat and one boat per person who must be of Panamanian nationality. Riparian permits can be obtained for fish or shrimp. A boat with a permit for fish, by statute, cannot catch shrimp, but a boat with shrimp permit can catch fish.

Other forms of fishing authorization for industrial fleets include Shrimp fishing licenses, the Fishing License for Snapper *Lutjanus* spp., Grouper *Mycteroperca xenarcha* and Shark, International Fishing License, and the Fishing License for Anchovy and Herring.

INSPECTION, MONITORING AND CONTROL

Law No. 44 of 2006 (5) that created the Authority on Aquatic Resources (ARAP) in Panama established the General Directorate as responsible for the functions of control and monitoring. According to this Law, "inspection, monitoring and control is exercised by the Naval Air Service and Aquatic Resources Authority. There are several cases in which fishermen have offered their services to enhance monitoring in the sea."

Inspection, monitoring and control is generally scarce and in the case of artisanal fisheries is almost nonexistent. For example, the obligation to bear the permit number on both sides of the boat hull is not fully adhered, resulting in the potential for duplicate vessels. In addition to this is the fact that there are many landing sites for artisanal fishing, most of which are not inspected by competent authorities nor are they suspect to control of the gear used. The period of greatest effort to exert control is during the closed seasons for shrimp, when traditionally there is budget for increased activity.

CULTURAL AND HISTORICAL ASPECTS OF FISHERIES

Artisanal fishing has been recognized for many efforts to organize but with few positive results. Cooperativism has not permeated in a strong sense and there are few fishers' cooperatives. Nonetheless, there are good examples of fishers' organizations, to the extent that, in the communities of the region of Azuero, most organizations are oriented towards conservation and fisheries.

TABLE 1
Organizations for fisheries and marine resource conservation in the south of Azuero according to District in November of 2010 and January of 2011 (6)

District/Township	No. of organizations	Type of organization
Pedasì/Pedasi	9	Sport Fishing Association, Artisanal Fisheries Cooperative
Tonosì/Tonosì	8	Sport Fishing Association, Artisanal fishing Association, Association for the Conservation of Sea Turtles
Tonosí/Guànico	7	Artisanal fishing Association
Tonosì/Cambutal	16	Artisanal fishing Association, Association for the Conservation of Sea Turtles
Pocrì/Pocrì	9	Fishing Association

Socioeconomic aspects

Fishing in Panama benefits some thirty thousand families, according to the National Coordinator of Artisanal Fishers (CONAPAS) (7). The artisanal fisheries sub-sector is the largest contributor of human resources with respect to national fishing.

Artisanal fishing communities generally maintain a humble lifestyle that satisfies basic needs (8).

On average boats south of the Azuero Peninsula carry three fishers (ranging between averages of 2.5 and 3.4) and make 7 to 11 trips per month per vessel. The average landings per fishing trip is 106 lbs. of product corresponding to a net gain of PAB (Panamanian Balboa) 55.6 per trip. Given the monthly average of fishing trips of 7-11 trips, an average boat can obtain a net monthly gain of PAB 390 to 612, which is generally distributed among crewmembers on board (15).

With regards to the sale of products caught by an artisanal boat, after discounting "advances" received by intermediaries for the purchase of fuel, ice and other supplies, the income is divided into parts, including a portion allocated to the vessel itself. The share for the vessel covers investments in equipment and replacement thereof.

Over the years, the number of artisanal fishermen has increased (9), suggesting that their current situation and activity is the result of increased economic value, and artisanal fishing within the sector and, as a result of this form of drive has not had the fisherman, a trend toward asset accumulation, or economically or in other particular expertise and build their knowledge of fishery 8. Sign in artisanal fisheries, therefore, has not been prevented by higher impairments other than financial, activity is based on the extraction, and only in some cases, very particular, there is a relationship with the other stages of the process as activities are threaded or other processing, cold storage, transportation and marketing market.

Thus, there are intermediaries who are responsible for processing and marketing fish in each community.

Artisanal fishermen in Panama, organized into unions, maintain as a goal the possibility of extraction of fisheries products and the necessities that implicates such as aid and support from the state, local governments and environmental NGOs. We know of no entrepreneurial strategic partnerships with other sectors to market the product of artisanal fisheries. Fishers are generally organized to address aspects that affect them as a group at a macro scale as well as their fishing activities, but economic and social activities are performed individually.

TABLE 2
Intermediaries of fresh fish according to species and quantity in the South Zone of Azuero, Panama[6]

Intermediary	District	Species	Quantity (pounds of fish/year)
Francisco Díaz	Pocrí	Red snapper and grouper	50 000
Sr. Acosta	Pocrí	Red snapper and grouper	50 000
Cooperativa Virgen del Carmen	Pedasí	Red snapper and grouper	50 000
Gabriela Gutiérrez	Pedasí	Various	30 000
Melvin Barahona	Pedasí	Red snapper and grouper	30 000
Edgard Acosta	Pedasí	Red snapper and grouper	30 000
José R. Flores	Tonosí (Búcaro y Cambutal)	Red snapper and grouper	200 000
Daniel Ávila	Tonosí (Cambutal)	Red snapper and grouper	30 000
Orlando Solís	Tonosí	Red snapper and grouper	30 000
Enrique Cano	Tonosí	Red snapper and grouper	20 000
Sr. White	Tonosí	Red snapper and grouper	30 000

Source: Datos suministrados por el Gerente de la Empresa Salva-Mar, S.A.
Common names: pargo (snapper) and cherna (grouper)

CONSERVATION OF PANAMANIAN ARTISANAL FISHERIES

In the 1970s fishing effort increased with the introduction of trammel, which together with the fact that there is in practice open access to artisanal fishing and that anyone can obtain a Riparian fishing permit, brought as a consequence the rapid development of artisanal fishing.

The indiscriminant allotment of permits, only restricted to some extent for shrimp fishing since 1990, provoked a notable increase in the use of nets per vessel, growing from total of 1 296 units in 1986 to 14 000 in 1995 and 8 607 in 2006 (10).

It is interesting to note that shimp fishing today is overexploited and some 40% of industrial shrimping vessels do not currently practice the activity.

The use of gill nets for fishing in restricted areas or without appropriate gear, as well as the fishing of individuals below the minimum catch size placed a much larger effort on fishing. This brought as a consequence a reduced catch per unit effort as well as a decline in fisheries such as shrimp, pargo, and cherna, and, more recently, coastal sharks.

PARTICIPATION OF FISHERS IN THE MANAGEMENT OF FISHERIES RESOURCES

One of the problems that fisheries administrators confront is noncompliance with conservation and management measures as well as continual rejection and poor acceptance of the norms that the institution proclaims is a product of the limited participation that fishers have in their formation.

Nonetheless Law No. 44 (13) created by the Authority of Aquatic Resources establishes as functions, among others, in the fourth article:

> 8 - Promote the genuine and direct participation of interested civil society in the activities of fishing, aquaculture, and commerce of fisheries products and sub-products.
>
> 19 - Ensure the participation of fisheries, aquaculture and related activity-based producers in the creation of programs and action plans.

The Commission for Responsible Fishing, created by Law No. 44, is comprised of 17 representatives of which:

- 5 are employees of distinct agencies of the State
- 2 are academics and researchers
- 1 is from an environmental NGO
- 1 is from the Maritime Camera (organization dedicated principally to marine service activities
- 8 are representatives of the fishing sector, including 1 from artisanal marine fisheries and 1 from lacustrine artisanal fishing.

Despite the existence of legal framework to facilitate governmental management, one of the principal characteristics of the fisheries administration in Panama is its verticality. The decisions and plans come from the administration of the Authority of Aquatic Resources, located in Panama City. The model that permits participation of fisheries resource users in decision-making of fisheries administration, despite its deficiencies, was present in Panama until 1999 when the Panamanian Maritime Authority (PMA; 14) was created, which despite an Executive Order to establish the National Fisheries Committee, decided to not invite the Commission to form. In 2002, the Maritime Authority signed an Administrative Resolution, as solicited by fishers, to create a national fisheries commission that also never coalesced.

Since 2006, when the Aquatic Resources Authority of Panama (ARAP) was created and the National Commission on Responsible Fisheries was ascribed as a consultative body, which to date has not been convened. Article 25 of this law Act states:

Article 25: Creates the Commission for Responsible Fisheries ascribed to the Authority as a consultative body that aims to recommend initiatives to achieve sustainable development of the fisheries sector as well as the policies and measures necessary to regulate fishing in the territorial waters of the Republic of Panama.

The experience with the past National Fisheries Commission established by Cabinet Decree No. 368 of November 26, 1969 (15), the only functioning commission, leads us to think that although artisanal fisheries are represented, industry interests are more represented by the Commission. For example, of the seven members that composed the former Fisheries Commission, two were government officials, three represented the fishing industry, one represented small-scale fisheries, and finally one represented marine fishermen, which are strongly associated with industrial fisheries.

In general, although there is a reference legal framework, the participation of fishers, and much less so artisanal fisherman, has not been institutionalized due not only to the lack of specific guidelines for fisheries regulation, but also to the lack of political will for this to occur.

On the other hand, the artisanal fisherman, as one of the subsectors of fisheries in the country shows an organizational weakness that hinders their effective representation in the few forums oriented towards decision-making in which fishers can participate. One of the problems particular to artisanal fisheries is the lack of stability in leaders or a tendency for leaders to act on behalf of their own interests. In addition, the presence of artisanal fishermen in these fishery commissions is generally seen only as a representative of the sector's own interests, which is essentially the role for which they are elected, but not as a representative of a sector that can provide knowledge.

The participation of communities through their representatives in decision-making processes related to the use and management of fisheries resources and the goods they produce has not reached a sufficient level to be considered as participatory representation in the analysis or in the evaluation and selection of management alternatives, project design and development of activities corresponding to plans and projects. As a result, fishermen tend to consider all actions, plans or projects created by authorities as an imposition, creating situations of conflict with local communities whereby since they are not incorporated in such activities, they see them as threats. Additionally, fishers' knowledge of the resource, ecosystem, or fishing activity are generally not utilized. This situation creates an environment that fosters the failure of conservation and management measures as well as misunderstanding and apathy towards the activities of administrative bodies, ultimately generating externalities that hinder the sustainability of resources.

The fostering of communication between these groups - the institution and the user - offers benefits to both parties, producing more knowledge of better quality to science and ultimately facilitating improved implementation and compliance regarding different conservation and management measures. Their knowledge that fishers have is holistic, encompassing various aspects, all of which are practical, and with them we can focus the way we manage resources as based on their underlying ecological knowledge. The active participation of artisanal fisheries in the co-management of resources should be understood as a generating process that benefits both communities and marine resources, which must be understood by both managers and users.

CASE STUDY IN PANAMA

In 2011, the consulting agency Arden and Price of Panama developed a series of events, actions and research activities to propose a Plan for Integrated Marine Coastal Management to ARAP (ARAP-IDB Loan (CP-1724) / LPI-02-08) for the Southern Zone of the Azuero Peninsula. Among these activities were the characterization of fishing in this study site (1).

The coastal marine area surrounding the southern portion of the Azuero Peninsula has the oceanographic characteristics of open water and is influenced by seasonal variation in oceanographic conditions in the Gulf of Western Panama. These conditions are related to wind patterns that circulate seasonally across the isthmus from the Caribbean Sea. The region lacks natural harbors to facilitate the development of local fishing fleets. Rather, winds creating frontal surges along coastal beaches, making the operation of smaller vessels difficult and the operation of industrial fishing vessels impossible. In general, there are very small landings for local subsistence fishing that provide access to a secondary road or river that reaches the coast. Only three sites: La Concepción (Pocrí District), El Arenal (District of Pedasí) and Bucaro (District Tonosí) have substantial groups of artisanal vessels, ranging from 13 to over 25 vessels per site (16).

With respect to fishing, the Azuero Peninsula is very important for the country because of its production of fish, particularly snapper and grouper. The almost oceanic characteristic of this region, together with the existence of large rocky outcroppings at great depths and areas of coral reefs and mass nesting (*arribada*) of turtles, contribute to its importance from a conservation perspective.

Problems among artisanal fishers exist in the Southern Zone of the Azuero Peninsula regarding, for example, the use of gillnets for fishing snapper and grouper by fishers not from the region, the use of driftnets (*volantín*), the entrance of industrial longline vessels into coastal areas, the large number of ghost nets, as well as the decrease in commercial fish catch and the threat of fishing to sea turtles.

Developments in real estate and tourism are also new competitors both with respect to availability of landing areas and human resources, but also may present an alternative as new job opportunities in sport fishing and local construction.

The large number of ghost nets - nets lost or entangled in rocks that continue to catch fish in the deep seawaters - are a major environmental problem, forcing fisheries management to develop methods to recover these nets. The use of nets for fishing snapper is prohibited by law, but remain in frequent use in the region. Fishers in surrounding communities within the region do not use fishing nets to catch snapper, but those from other regions or those who have settled in the region but are originally from other regions, use this gear.

The consulting agency conducted a study to characterize artisanal fisheries in the region. The study was conducted in a traditional manner, supplemented by interviews with artisanal fishermen in their respective communities and by meetings that involved the participation of other users. To enhance participation of fishers and to present the results of the research, three workshops with fishermen and other users of marine resources were held and fishers were visited in their own communities. Face to face meetings with fishers were used to obtain information regarding their own experience, while large meetings served to validate the information with assistance from other users.

Empirical knowledge of fishermen provided valuable information for making suggestions for research. This information was only achieved in direct visits to the communities through meetings in small groups or interviews with fishers that were community leaders.

Examples of information provided fishermen included: first, the abundance of snappers at an average weight of half a pound by the end of February, a rare and surprising finding; and, second, the existence of a snapper located in deep areas where no fishing activity occurs and where, according to fishers, fish did not bite because they were frightened by the nets in the rocks.

From a methodological point of view, the information obtained through these interviews encourages further investigation and, based on certain evidence of scarce fishing of snappers in the region and the country, indicate the existence of an unexploited resource and potentially new recruits to the fishery. We thus ask ourselves, how can we make use of artisanal fishers' knowledge to facilitate compliance with conservation and management measures, accepting that they are necessary for the sustainability of their activities?

Among other types of knowledge that artisanal fishers have is their experience and understanding of their environment. Fishers have submitted proposals and have reached consensus among them regarding use of fishing gear such as the use of nets under certain conditions as well as regulation during certain time periods.

Results

The consulting firm presented its findings to artisanal fishers so that they could validate information based on their own experiences (Figure 1).

The key findings were: The number of artisanal vessels had increased in Tonosí and Pedasí, but had decreased in the Pocrí community.

In the country, there is emigration within the agricultural sector, and more so in the construction sector. In Puerto Caimito, a predominantly fishing community, the women go out to sea to fish to help the men who are working in construction (Eric Ariel Montenegro, La Prensa 7/30/13). Pocrí fishermen in Azuero, are more engaged in agriculture and construction for income security. The largest number of fishermen in Tonosí corresponds to artisanal fishermen who have settled in communities like Búcaro, an important fishing site in Tonosí.

These movements are also the product of a fishing reality (Figure 2).

The largest number of fishing trips occur during the rainy months, in timing with the availability of the resource, trade winds (which are very strong in the dry season and hamper fishing operations), and the greater size of snapper and red grouper, the target species of these communities.

FIGURE 1

A) The number of fishermen in the village of 1 = Pedasi, 2 = Tonosí, and 3 = Pocrí. B) The total number of artisanal fishermen for all locations by year (16)

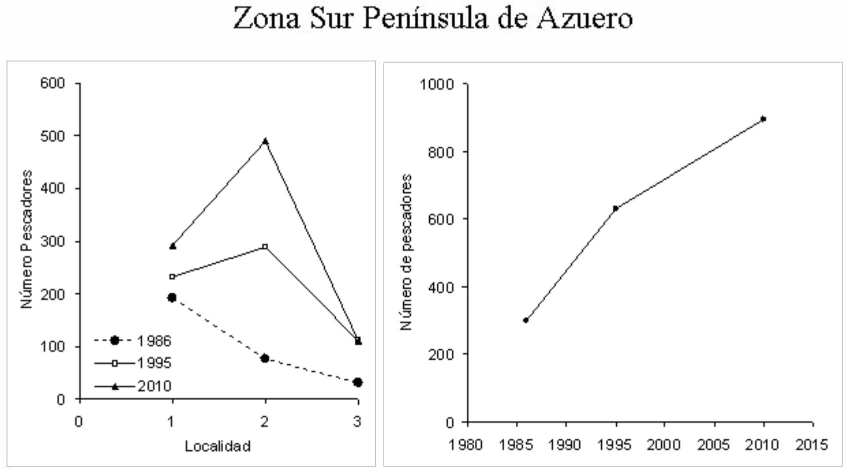


FIGURE 2

Seasonal distribution of fishing effort measured in percentage, which represents the monthly effort measured in artisanal fishing trips on the total exerted on average in the region (16)

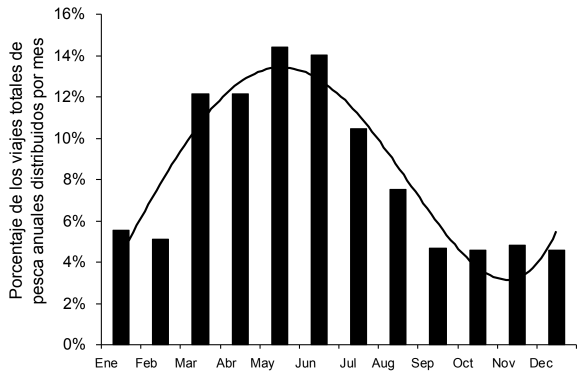
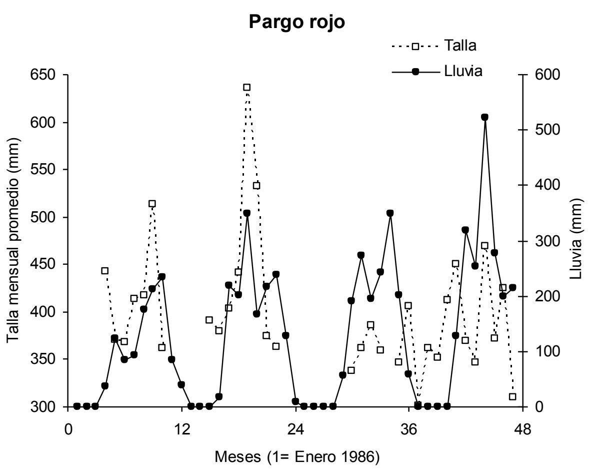


FIGURE 3

Seasonality in the catch size of red snapper and rainfall

Source of size data: ARAP; Source of rainfall data: ETSA; (16)



Fish size and abundance, in particular case of the red snapper, is greater during the rainy months, coinciding with what fishers have experienced, and is reflected by an increase in the number of fishing trips during those months. During the months of drought and resource scarcity, fishers tend to engage in farming activities and, more recently, in construction.

Another important information obtained was that during the months of resource abundance, i.e. the rainy season (the months of highest rainfall in Panama from April to December), the catch per unit effort is reduced by increased competition (given the experience of the sizes and abundance) attracts fisherman return to their activity.

These figures indicate that there is a limit to the number of boats and fishing gear that could be used in different locations after which, fishing efficiency decreases, creating an economic impact. What is relevant here is that the empirical knowledge of fishers permitted them to arrive at the same conclusions: How can fishing effort be reduced without affecting income?

To have a competitive advantage over the capture of the resources, fishers tend to do just the opposite by further increasing effort, resulting in the over-dimensionalization of the artisanal fishing fleet. Despite an awareness of the problem, there is no alternative for fishers facing the certain fact of income at these distinct locations within the riverside community.

The result of all the consultations and workshops and following presentation and evaluation of results to fishers was the recommendation to the Aquatic Resources Authority (ARAP) for a Coastal Southern Azuero Peninsula in Program Management Plan to create a zone fishermen designated the "Responsible Fishing Zone". This zone, without limiting the existing rights of local fishers and other locations outside the river communities in the area, was to be regulated in compliance with appropriate norms that address local issues and provide answers to fishers, while providing opportunities to make decisions regarding government management of their activity. Fishers requested a census of all fishers in the area, whether craft, sports or industrial, declaring an exclusive area for research in which there can be no resource extraction activity, areas prohibited for longline fishing in order to protect turtles under conservation standards more stringent than those established under current legal regulations for conservation areas to protect the tortoise. Finally, fishers also requested to participate in business emerging from sport fishing and whale-watching.

The consulting firm also proposed in the Action Plan a Co-Management approach to fisheries, with the participation of artisanal fishers and other users of marine resources.

The Responsible Fishing Zone of Southern Azuero (Zone 5, Figure 7) extends from the coordinates north of the Mensabé village where the Special Management Area of Azuero (SMZA) begins, along an imaginary vertical line to the coast and twelve nautical miles out to sea, and maintaining twelve nautical miles from the coast, joins another imaginary line that runs vertically from the coordinates at end of the SMZA on land west of Búcaro village.

Special Areas within the Responsible Fishing Zone of Southern Azuero (Zone 2, Figure 7) include:

- All protected areas within the RFZSA are governed according to the norms by which they were created as well as management plans, when available. When management plans exist, the competent authority (ANAM) is responsible for compliance with these standards.

FIGURE 4
Seasonal distribution of snapper catch data and fishing effort in Arenal, Pedasí (16)

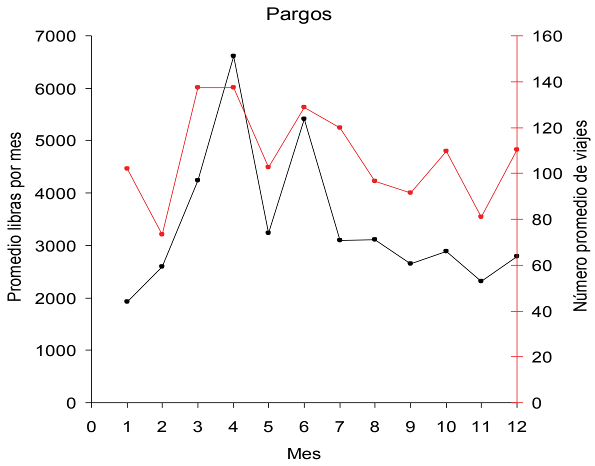


FIGURE 5
Monthly distribution of fishing yield per vessel per day over the year (15)

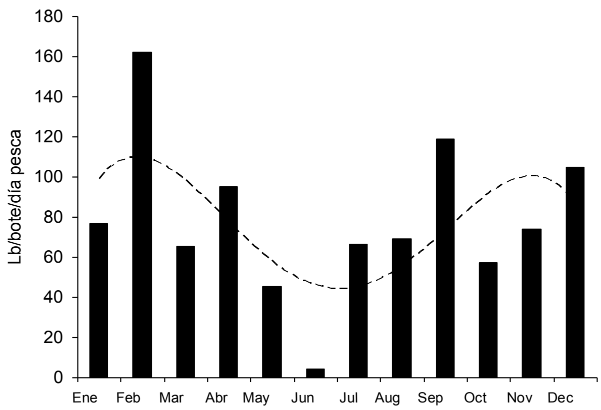


FIGURE 6
The interaction between total fishing yield on the left Y-axis and fishing effort on the right Y-axis, measured as the percentage of operating vessels of the total number of vessels available (15)

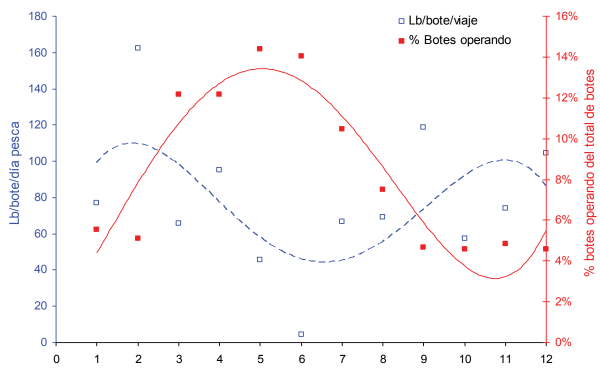
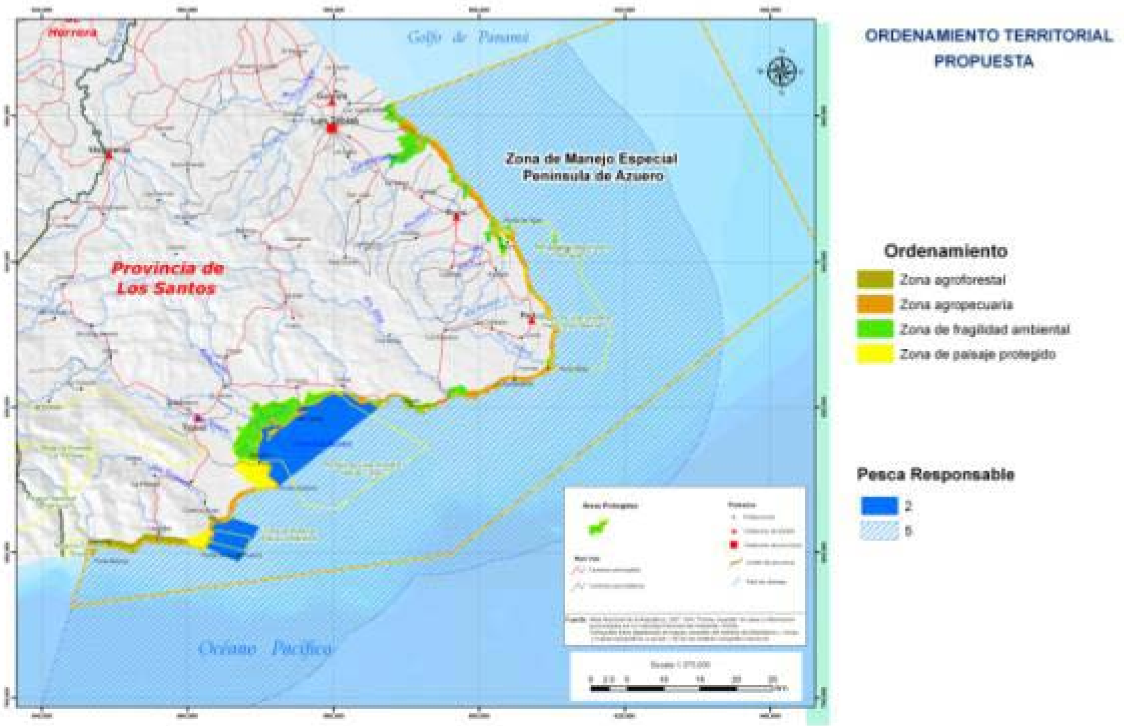


FIGURE 7
Map of the Responsible Fishing Zone. Source: Azuero Coast Management Plan Atlas, ARAP 2012



- An area of conservation and research was designated within which all extraction is prohibited under the responsibility of the ARAP.
- Regardless of existing legislation in each zone, two areas of absolute prohibition of longline fisheries were established to promote the protection of sea turtles in the following areas:
  - From Punta Guánico to Zaina, including part of the Caña Island Wildlife Reserve.
  - From Punta Guánico, traveling down 3 nautical miles at sea and, maintaining that distance, to a point perpendicular to Morro de Puerco Point, opposite the Reserve Zone of La Marinera Beach.

The following prohibitions are respected in the Responsible Fishing Zone of Southern Azuero:

- use of trammel and/or gillnets, except those used in lobster fishing in clearly defined coastal areas where an inventory of existing fishing gear and the number of fishers has been made.
- industrial fishing in all its forms
- use of seine nets
- extraction of corals and coral stones or coral fragments.
- use of chemicals and/or dynamite for fishing
- use of surface longlines with over 600 hooks.

Under the same regulations, the following activities are permitted:

- Artisanal and subsistence fishing by use of bottom and surface longlines with no more than 500 hooks.
- Marine aquaculture in all its forms
- Sport fishing and recreational fishing, limited to 3 fishing units per individual, exercising the release of peak fish caught.
- Sighting of marine mammals in compliance with the relevant existing rules and the safety of navigation, crew and passengers.

- Scuba fishing with the use of spear, without the aid of oxygen tanks, with a retention capture three units per angler.
- Sailing and water sports.

CONCLUSIONS

We begin by acknowledging what we know and seldom recognize. Fishers have knowledge and experience adjusted to the reality of their marine and fisheries surroundings as a product of years of observations and oral traditions passed down from generation to generation that enrich their own experiences.

Prior to putting conservation and management norms into action, it is essential to consult and take into consideration the fisher and their knowledge, given that this ultimately mandates fisher behavior.

In general, fishers accept the enacted standards, but their behavior is usually governed by what they believe to be true. Thus to dismiss such knowledge, which is demonstrated to be effective in ensuring their survival via their activities, would be non-positive.

The effective participation of artisanal fisherman and, above all, the integration of their knowledge and judgment regarding their environment and their own needs, is amply demonstrated by the conclusions that emerged from this work, culminating in the proposal of a designated area of responsible fishing.

Our experience indicates that in order to achieve proper management of fisheries in a harmonious and efficient manner considering the scarce resources held by the state, it is essential to involve fishers, with particular inclusion of artisanal fishers in coastal fisheries management. The application of an ecosystem approach to fisheries management based on knowledge and experience of stakeholders of the ecosystem, in particular artisanal fishers, can be more efficient (16) than traditional administrative approach.

The following elements are essential to the effectiveness of management with participation of artisanal fishers:

- Provide legal status to the organization such that by any legal standard the organization and functioning of the organization for co-administration of fisheries is created.
- Define an area of use, on behalf of the organization, that is governed by rules that establish its conservation status. Despite the absence of provincial or district boundaries, it is essential to establish an area where management of the organization is effective.
- Represent artisanal fisheries by leaders within artisanal fishing communities. It has been broadly demonstrated that community leaders are those who lead communities in the resolution of local problems. Each community should be represented.
- Involve representatives of artisanal and industrial fisheries not residing but operating within the Zone.
- Enforce compliance with established standards, whereby the organization must guarantee compliance and collaborate in monitoring and enforcement.
- Confirm technical information obtained with the experience of fishers, using visual aids to explain situations they are familiar with but may not internalize.
- The means of compliance with norms within the use zone should be proposed by users, whereby flexibility grows as benefits are obtained by other means. For example, more hooks can be used under the condition that more areas are created where they cannot be used.
- The tragedy of the Commons will always be a good model for understanding the situation of fisheries. It must be used considering the values of fishers, which are included therein.

- Conservation training is essential and the care of oceans, swamps, beaches and rivers should be part of this training.

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Piloting of an ecosystem approach to fisheries management in a freshwater reservoir, Uruguay

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ABSTRACT

Uruguay provides an example of an initiative to integrate ecosystem-related principles and concepts into national legislation and planning to develop sustainable fisheries. Here we present the results of research and extension activities undertaken within a FAO Pilot Project for artisanal fisheries in Uruguay, using the Rincón del Bonete Reservoir pilot site as a case study. The reservoir extends 114 000 ha along the Negro River and is considered one of the largest reservoirs in South America. The project aimed to organize the fishery and implement EAF principals and institutional tools for sustainable management. Over a three-year period, important advancements included the creation of a representative group of fishers, the execution of workshops to exchange and systematize traditional knowledge together with scientific knowledge, the development of participatory research, the establishment of a Zonal Fisheries Council, and the development of concrete actions to improve the status of resources and the fishery. In addition, we initiated the inclusion of other users in the reservoir, including sport fishers, sturgeon aquaculturalists and sand harvesters, into an ecosystem management plan. Overall, this case study demonstrates the use of the participatory approach as an effective strategy to conserve fisheries resources and support co-management.

INTRODUCTION

Efficient fisheries management requires knowledge of the fishery, as well as biology and population dynamics of target species, in addition to reliable effort and catch data that provide the basis for monitoring and evaluating the effectiveness of management regulations. Despite available scientific knowledge and predictive models developed to guide the "rational" use of target species, traditional fisheries management has failed to sustain stock productivity. This dilemma is due in part to the fact that the concept of uncertainty was rarely applied in fisheries management until recent decades and that institutions were delayed in responding to the actual needs of many artisanal fisheries. Currently, fisheries management is a broad and complex activity, in which the impacts of fishing and other human activities must be incorporated into the management model, ultimately seeking to avoid biodiversity loss and maintain the efficiency of ecosystem function as well as the socio-economic sustainability of fishing communities.

The Ecosystem Approach to Fisheries (EAF) aims for the rational and balanced use of aquatic ecosystems, where all direct and indirect users seek to meet their basic needs while avoiding conflict (Bianchi, 2008). This new approach was developed in response to the increased global demand for water, aquatic resources and the landscapes contained therein, as well as to the failure of traditional management models to prevent collapse or overfishing of many fish stocks. The resulting global fisheries crisis (Hall et al., 2010) is thus an indication that regulating institutions have been unable to respond to demand (Pitcher *et al*., 2009; Mora *et al*., 2009). In this sense, the EAF proposes to change the paradigm of management from that of unlimited access to resources touted by the prevailing economic model based on a few species to a strong focus on social control of the ecosystem (FAO, 2003), which could have its origins in ancient practices of use based in traditional ecological knowledge (Berkes *et al*., 1994).

It is perhaps for this reason that the discussion on fisheries management revisits the conflict for shared resources where all evidence suggests that fishing models should incorporate social, political and economic aspects in addition to ecological aspects (Ostrom, 2009).

Local fisheries knowledge and participation of fishers for effective co-management

When scientific knowledge about specific resources is limited or nonexistent, but there is an established fishery and social demand for those resources, the general management guideline is intervention using the precautionary principle (Cadima, 2003). Participation from the onset of a fisheries management process based on fishers knowledge allows managers and researchers to: i) understand and systematize what fishers know about the biology, ecology and dynamics of target species; ii) identify indicators that fishers use to monitor the fishery over time; iii) identify the risks assumed by fishers in decision-making, which integrates multiple aspects of the fishery (e.g. resource accessibility, market demand, operating costs, control, and economic alternatives); iv) understand stock response to changes in fishing effort or other dynamics (e.g. changes in abundance, behavior or vulnerability) that are difficult to integrate into scientific models but can be used in local level planning; and vi) understand the relationship of fisheries dynamics with hydrological and climatic factors at different scales, as well as the impact of other human activities that may adversely affect fisheries.

Risk as an opportunity cost is understood and accepted by the traditional fisher. A fishers' longevity in fishing as a livelihood is a result of their ability to experiment, learn and adapt their equipment and behavior to available resources, while surviving market fluctuations and overcoming the lack of socio-economic policies for this sector (Salas & Gaertner, 2004). The socio-economic marginalization of artisanal fisheries in Uruguay has been a constant challenge. In order to survive and persist, artisanal fishers have been forced to develop an informal and marginal system in which they feel secure. Nonetheless, this same system marginalizes fishers themselves, preventing their social inclusion, access to credit, and active participation in the development of policies for the sector.

A fisher confronts daily the question as to whether or not to go fishing, depending on the weather, river or tidal level, resource distribution and behavior, and the success of other fishers. Via trial and error, the typical fisher seeks a good catch that compensates for bad fishing days and approaches the ideal catch, which is preserved in the collective imagination.

Fisheries management based solely on scientific information is complex. Although institutions seek to incorporate scientific knowledge into fisheries management in Latin America, often the researcher or manager is not trained to take risks in adapting novel management approaches, potentially limiting the possibility to understand the response of the resource to one or more management measures. In the best case scenario, some fisheries administrators that attempt to adapt to fisheries demands, seek to incorporate new analytical approaches into the decision-making process and generate new management tools, such as co-management and EAF (Armitage *et al*., 2008, Defeo *et al*., 2009).

National strategy to promote fisheries development under the EAF in Uruguay

The Uruguayan artisanal fishery is defined by the following features: small scale boats < 10 Gross Register Tonnage (GRT); low capitalization; use of traditional fishing gears (e.g., gillnets); and its multi-specificity (Horta & Defeo, 2012). While the sub-sector represents only 3% of the total landing, it supports approximately 46% of the total number of fishers (the sector supports 1 250 full and part-time fishers and an additional 3 750 indirect workers; Defeo et al., 2011, Horta & Defeo, 2012). Most landings are sold in local markets and represent a substantial source of income for low income families (ca. USD 150 per capita). Artisanal fisheries are based primarily in coastal waters extending from the inter-tidal to some 7 nautical miles (nm) offshore but tend to concentrate at the mouths of rivers, coastal lagoons and in waters adjacent to rocky and sandy shores; areas considered critical for fish reproduction, nurseries and food supply (Defeo et al., 2009).

The project GEF-DINARA-FAO (GCP/URU/030/GFF) funded by the Global Environment Facility (GEF) and implemented by the National Directorate of Aquatic Resources (DINARA - MGAP) in 2010-2014 aims to foment the sustainable development of fisheries in Uruguay within an EAF framework. The work focuses on artisanal fisheries in four pilot sites in order to, promote sustainable production systems, based on the rational use of the ecosystem (www.pescaresponsable.gub.uy).

The major institutional stakeholder is the governmental agency for aquatic resources, DINARA. Other key players are the National Directorate of the Environment (DINAMA), the Coastguard, and local governments, as well as artisanal fisheries associations and independent delegates. The activities received substantial input from FAO (Food and Agriculture Organization of the United Nations), the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP) that are all part of the Project Advisory Council. Direct target beneficiaries included artisanal fishers from: (i) Coronilla - Barra del Chuy villages; (ii) Punta del Diablo village; (iii) fishers between the Santa Lucia and Solís Grande Rivers; and (iv) San Gregorio de Polanco and Paso de los Toros villages on the Rincón del Bonete Reservoir (Figure 1).

The four pilot sites represent distinct aquatic ecosystems and fisheries. In the easternmost marine site extending from the villages Barra del Chuy to La Coronilla, fishing activity focuses on harvesting of the yellow clam (Figure 2a). The second marine site in the vicinity of Punta del Diablo is characterized by shark fishing and shrimp harvesting (Figure 2b). The estuarine site at the mouth of the La Plata River between the Solís Grande River and the Santa Lucia River target whitemouth croaker (*Micropogonias furnieri*) and Striped weakfish (*Cynoscionguatucupa*; Figure 2c). The sole inland freshwater fishery is located on the largest reservoir in Uruguay, - the Rincón del Bonete Reservior - including fisheries based out of the villages of San Gregorio de Polanco and Paso de los Toros, where fishing targets wolf fish (*Hoplias* spp), catfishes (*Rhamdia quelen*) and armored catfish (*Hemiancistrus fuliginosus*; Figure 2d).

Context: Foundations for the project on ecosystem management in the uruguayan artisanal fishery

Uruguay signed the Convention on Biological Diversity (CBD) at the Rio Summit in 1992 and ratified it by Law No. 16408 in Parliament on 18 August 1993. As such, the principles established by the CBD are National Law whereby the State of Uruguay is a member of this international agreement. In particular, the National System of Protected Areas (SNAP) in Uruguay and associated implementation of Law 17.234

FIGURE 1
Map of the four pilot sites of the GEF-DINARA-FAO Project in Uruguay, indicated in red. The case study site, Rincón del Bonete Reservoir, is located on the Negro River in the center of the country

FIGURE 2
Artisanal fishing in the four pilot sites: (a) clam extraction on the beach of the La *Coronilla - Barra del Chuy zone*; (b) fishing boat of *Punta del Diablo*; (c) typical boat of the La Plata River estuarine zone between the rivers *Santa Lucia and Solís Grande*; and (d) boats in San Gregorio de Polanco village in the *Rincón del Bonete Reservoir* site

Photos courtesy of: Sebastián Horta

in 2000 constitute a national policy that prioritizes biodiversity conservation. While SNAP has advanced in the implementation of protected areas in mainland and marine coastal areas, the development of conservation measures for aquatic ecosystems, and in particular fishing practices, is still in its infancy. In this regard, it is intended that the experiences developed within the GEF-DINARA-FAO project serve as pilot cases for integrating biodiversity conservation goals into fisheries management.

The overarching environmental objective of the Project is to shift management of coastal fisheries from one based on a single-species approach towards one that reflects EAF principles (FAO Uruguay Project Plan, 2007). This shift aims to reduce impacts on ecosystem "health" and support biodiversity conservation while promoting the sustainability of fisheries and relevant national socio-economic objectives. Many of the objectives and principles for implementing the EAF in Uruguay are mentioned in the responsible fisheries and aquaculture development law approved by National Parliament (Dec/2013), among which the most innovative for Uruguayan fisheries is: the adoption of an ecosystem approach to management and co-management as alternatives to centralized management of fishery resources, as presented here.

To achieve the principal objective of the project, three strategic areas were considered:

1. Initiate an Ecosystem Approach to Fisheries that incorporates the development of broadly defined Protected Areas that preserve habitat where fish feed, reproduce, and rear offspring or seek refuge.
2. Institutionalize fisheries co-management in Uruguay, whereby users participate in resource management, either via consultation of fishers by competent authorities or the generation of initiatives sent by user groups to DINARA to legitimize control measures and management strategies.
3. Generate through capacity building the strengthening of institutions at multiple levels and enhancement of public awareness on responsible fishing and co-management in Uruguay.

Operationalization of the EAF into management actions

The success of the ecosystem approach to fisheries depends upon the capacity to transform this somewhat abstract concept into concrete and efficient management actions. The activities proposed within the GEF-DINARA-FAO project seek to strengthen and further develop the EAF, generating scientific knowledge, sharing experiences, and testing new institutional tools for fisheries management.

The following steps were considered essential goals of the project:

- Incorporation of local knowledge on fishing regulations, identification of stakeholders, and balance of representation and power between fishers and institutions
- Training of key individuals (administrators, technicians, researchers and fishers) to participate in the elaboration of practical management measures and the construction of a co-management model
- Training and capacity-building of fishers as leaders in management based on the concepts of ecosystem management
- Train leaders as communicators and interpreters among fishers, as well as interlocutors between fishers and technical-political institutions of the State with expertise in the responsible use of renewable natural resources
- Development and strengthening of grassroots organizations, enabling a serious discussion on the status of resources and their management
- Development of Management Plans for each Pilot Site
- Establishment of participatory verbal and written agreements for compliance
- Design of an effective monitoring, control and evaluation program
- Development of research applied to the conservation and/or recovery of target species, and the generation of indicators for monitoring the functioning of aquatic ecosystems and the fishery.

CASE STUDY: ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT IN THE RINCÓN DEL BONETE RESERVOIR

The Rincón del Bonete Reservoir is located on the Negro River in the center of Uruguay (Figure 1). The total area of the Negro River Basin is 71 400 km^2, just over one third of the country. The basin that feeds the Rincón del Bonete Reservoir Basin occupies 39 700 km^2 within Uruguay (UTE, 1989). The headwaters of the Negro River lie in Bagé, Brazil an area of agro-industrial development that has 108 562 inhabitants (IBGE 2007; censos2007.ibge.gov.br/). The basin of the reservoir is comprised of plains and hills covered by natural grasslands, patches of tree plantations, and to a lesser extent native forests.

The hydroelectric potential of the Negro River was estimated by the German engineer Adolfo Lüding, who designed four dams for the region, later reduced to three (the fourth was planned for the Malo Creek within the pilot study area). The first dam, "Gabriel Terra" was built in 1937-1948, forming the Rincón del Bonete Reservoir extending 1 070 km^2 in area (dam elevation 80 m; volume 8 863 hm^3) with the capacity to generate 160 MW (0.15 MW km^{-2}). The reservoir has an average depth of 7.76 m, with a maximum of 30 m near the dam and a water residence time of 150 days. The water reserve calculated by the National Administration of Power Plants and Electrical Transmission (UTE) is 135 days for levels between 71 and 80 m. Currently, the reservoir serves to ensure the generation of the two most potential hydropower dams downstream. All three hydroelectric dams operate in function of the availability and demand of the National Power Grid, which incorporates other energy sources based on fuel, wind power and biomass.

Characterization of the fishery in Rincón del Bonete

The interconnected nature of the main channel (previously the riverbed of the Negro River) with its major tributaries, lakes and marshes in the upper section of the reservoir requires fisheries management at the ecosystem scale. Hydrological changes, forms of use of the reservoir, and human activities modify the patterns of movement and distribution of the principle species in the littoral region, which ultimately determine fishery dynamics. The movements of fish, whether reproductive, trophic or simply the colonization of vacant niches may be associated with variation in reservoir water levels. The use of the reservoir for hydroelectric purposes affects the occurrence and abundance of fish between the headwaters and the lower sections of tributaries that feed into the reservoir, as well as between the marginal and central regions of the lake itself.

Before the construction of the Gabriel Terra Dam, the migratory fish species of economic and ecological interest were: *sábalo* (*Prochilodus lineatus; English: shad*), *boga* (*Leporinus obtusidens*), *dorado* (*Salminus brasiliensis*), *salmón criollo* (*Brycon orbignyanus*) and catfishes (*Pseudoplatystoma coruscans; P. fasciatum*), the abundance of which were reduced to the upper Negro River and tributaries after dam construction. Given that this stretch of the Negro River, a previously lotic environment, was replaced by a lake (lentic environment), these migratory species were replaced by sedentary species such as *tararira* (*Hoplias* spp.*;* English: wolf fish), catfish (*Rhamdia* sp. and *Pimelodus* sp.) and armored catfishes (Loricariidae Fam.; Spanish: *vieja del agua*). Historical landing data indicate that the volume of *tararira* (*Hoplias* spp.) harvested from the reservoir increased from 40 tons in 1986 to 210 tons in 1996, but declined to 160 tons in 1999. Catches of Siluriformes in the same period were estimated at 30% of the catch of tararira (Crossa & Petrere, 2001).

Fishing in the Rincón del Bonete Reservoir is an important source of income and food for local people. There are 61 fishers in the reservoir with permits for commercial fishing, but only 46 were active year-round in 2012, as economic alternatives to fishing influence effort in terms of number of fishers. Some fishers and other low-income residents in the area perform multiple economic activities including vegetable gardening, hunting, wood harvesting from forests, sand and stone excavation, animal husbandry, and in a few cases work as employees in local enterprises. As of 2009/2010 many families (> 50%) joined social programs provided by the Ministry of Social Development (MIDES). Over the past decade other production-based activities have thrived in the area, in particular livestock ranching, agriculture (soybean), forestry, fish culture (sturgeon) and social and cultural tourism (San Gregorio de Polanco is the first National Outdoor Museum with over 150 painted murals), but fishers were not formally integrated into these activities.

Fishers use passive gear, such as nylon nets (60-70 m long and 1-2 m high) with mesh sizes varying 5.5 to 7.5 cm between adjacent nodes for tararira, and up to 9 cm for armored catfishes. By law, each fisher is allowed a total length of nets < 500 m (lengths generally range 430-590 m). Between harvest seasons fishers use longlines, which may be used at different depths depending upon the target species and the time of year. Each fisher uses between 271 and 364 hooks, depending upon available hands and bait.

Management in data-poor fisheries

To understand ecosystem processes and manage target species as indicators of management performance, baseline information is needed on the biology, ecology, composition and structure of communities. Such updated and detailed information was only partially available in one of the four pilot sites (Site *Coronilla - Barra del Chuy*; Defeo, 2003). In Rincón del Bonete, the studies Amestoy *et al.* (1993, 1999), Amestoy (2001), Crossa (1994) and Crossa & Petrere (2001) were the only source of quality information on the biomass of principle species as well as on species zonation in the reservoir according to their abundance and stock structure (Amestoy, 2001) and estimation of population parameters (Crossa, 1994). In these studies, taxonomic identification was limited to genus with no deposition of specimens in scientific collections, making impossible their use in the calculation of biodiversity indices. In general, the information collected in these studies was not applied to fisheries management in the reservoir, which at the onset of the Project showed symptoms of overfishing according to catch sizes, production and social conflicts.

The Rincón del Bonete Site was an exception to other sites in that its integration into the project was demanded by fishers themselves, who had organized into cooperatives in order to organize fishing activities and access markets, but were requesting greater state intervention in the management of the fishery. This demand by fishers was based on past experience in organization and participatory research.

METHODS AND RESULTS

The project activities were implemented over three years (2010-2014). During this period the project worked closely with leaders and user groups, institutions and local partners. This approach consolidated fisheries management activities at a local level, including local assessment, participatory research, workshops and various means to disseminate information and address user needs, always considering the status of target resources and the ecosystem.

Activities conducted with fishers of the Rincón del Bonete Reservoir

1. **Promotion of Local Fisheries Organization and inter-institutional collaboration**
    - Exchange of information between direct resource users and the technical team of the project
    - Project development with local authorities and users of the ecosystem (e.g. anglers, kayak club, fishermen, and the electrical company - UTE).
    - Formation of a Advisory Council of fishers, comprising five elected members from the fishers' general assembly. The Advisory Council met independently on the first Saturday of each month through the end of the project.

- Coordination of activities with local authorities, municipalities, state government (*Intendencias*), Ministry of Livestock, Agriculture and Fisheries (MGAP in Spanish), and the National Coastguards (PNN in Spanish). Local government supported the project in terms of distribution of information and logistics (courses, availability of premises for meetings, sign posts, etc.). The local representatives of MGAP provided logistical support via a local office and human resources. In the vicinity, an infrastructure was built to support DINARA and other fishing-related projects, as well as provide a suitable meeting location for fishers. From the onset of the project, activities were coordinated with the PNN of San Gregorio and Paso de los Toros for the collection and divulgation of fisheries information, educational field visits to fishing zones, and monitoring of existing regulations or those generated by the fishers.
- A socio-economic census was conducted in collaboration with MIDES of Paso de lo Toros with fishers from San Gregorio. This census later contributed data to a study conducted under the Agreement with the Social Sciences Foundation of UDELAR to develop multi-criteria analysis for evaluation of the fishery and new projects.

2. Workshops on fishing, organization and impacts of other activities on the reservoir ecosystem

Resources: Existing information on fisheries resources in the Rincón del Bonete Reservoir was systematized and key aspects regarding stock assessment, status indicators and points of reference were presented for discussion at meetings that often included at least 50-70% of active fishers. Overall, the meetings sought to generate mutual agreement, broad goals, and hypotheses, as well as to discuss mitigation measures for recovery of both the fishery and the productive capacity of the reservoir. The systematic presentation of information aimed to socialize and validate information and also to create a framework for input, strengthening the capacity for exchange of information and knowledge.

Environment: The concept of permanent and/or temporary protected breeding and nursery areas for target species was not a subject of discussion raised in meetings at the onset of the Project. It was brought up later by one fisher as an extreme measure - complete ban on fishing in the entire reservoir - in exchange for state subsidies, a request that was impossible to meet at the time. Nonetheless, this opened the door for the topic of experimental preservation areas and the most successful fishers started an initiative for a closed season during peak spawning within their areas of operation with the provision of exclusive rights (i.e. once the area re-opened other fishers were prohibited from entering).

Society: Workshops also aimed to identify the socio-economic situation of fishery as well as fishers and their families in order to increase participation and social inclusion of fishers in the new co-management governance scheme. In order to do so, the information from the aforementioned census conducted with MIDES was presented and discussed among users.

Economic: Workshops also discussed data on fishery production and infrastructure. Using qualified local informants a flowchart of the production chain was constructed that included fishers from Paso de los Toros and San Gregorio. The project also identified factors limiting the operation of local infrastructure for ice and cold storage of fish in San Gregorio in order to promote their repair and proper operation.

3. Participatory research

Participatory research activities aimed to generate basic fisheries data applicable to management under an EAF. The research themes to be addressed emerged from various activities within the project as areas of interest proposed by fishers and technicians. These themes comprised what users perceive as the information necessary to efficiently improve the fishery and maintain fisher participation (e.g. net mesh size, minimum size of entire and processed fish, fishing effort, distribution of fishing camps and fishing spots, reproductive closures or fishing bans, and catch data).

Below we describe four participatory studies conducted during the project.

1. Participatory mapping - The objective of the participatory mapping activity was to identify the spatial distribution of areas of use, fish species, fishing effort, and habitat types (Figure 3). Meetings were a joint effort among fishers to zone the area by creating maps with information on land use (e.g. homes, ports, fishing areas) and ecological processes (e.g. breeding areas, sites where certain target species occur) as well as areas of economic potential (e.g. areas for tourism or sites of interest, Figure 4). These maps provided information that could then be updated over time.

2. *Participatory mark-recapture study* - This second study aimed to address what fishers, technicians and researchers needed to know about the biology and ecology of key species. This study was key to motivating inclusion and knowledge sharing among participants. We conducted a mark and recapture study of four commercial species to provide important information on fish behavior and population dynamics to apply to management.

Participatory research using the mark-recapture method with fishers aimed to understand:

- Spatial and temporal distribution
- Growth rates (age, length, weight)
- Natural mortality rates
- Mortality attributed to fishing
- Management impacts

3. *Participatory Elaboration of Fisheries Agreements* - This activity focused on the development of Fisheries Agreements with fishers and the preparation of fisher leaders to participate in Regional Fisheries Council. Fisheries Agreements aimed to reach a consensus among local users on criteria for resource use that can be modified according to the results expected by users. These results may be linked directly to fisheries resources, ecosystem services provided by the reservoir, the socio-economic needs of the group, or a combination thereof. Among the topics discussed with fishers of San Gregorio de Polanco and Paso de los Toros, were:

- Fishing equipment (mesh type, forms of use, use of hooks, selectivity)
- Fishing effort (number of nets and hooks per fisher)
- Conditions for the allocation of fishing permits (historic fishing data)
- Duration and location of fishing bans (start and end dates; closed areas)
- Minimum catch size of commercial species (full size, butterfly filet and filet)
- Responsible bodies for monitoring and surveillance
- Control measures and penalties for infringements
- Access to resources and/or fishing zones
- Dissemination of resolutions and agreements to the community
- "Baseline" conditions of the reservoir, based upon which the state of the fishery and ecosystem can be diagnosed, evaluated and monitored under future management plan.

4. *Participation in taxonomic studies* - The final study addressed system biodiversity, including additional bio-ecological information for the EAF. In conjunction with previous data from museums and other documented records it was possible to generate a list of species and biodiversity indicators. The participation of fishers in sampling efforts for biodiversity consisted in the use of nets and electric fishing in coastal areas of the reservoir, branches, and coastal lagoons. This study resulted in the publication of a guidebook on fishes of the Negro River (Serra *et al*., 2013).

FIGURE 3

Relevant environments identified by fishers from San Gregorio de Polanco and Paso de los Toros during participatory mapping activities for the Rincón del Bonete Reservoir site

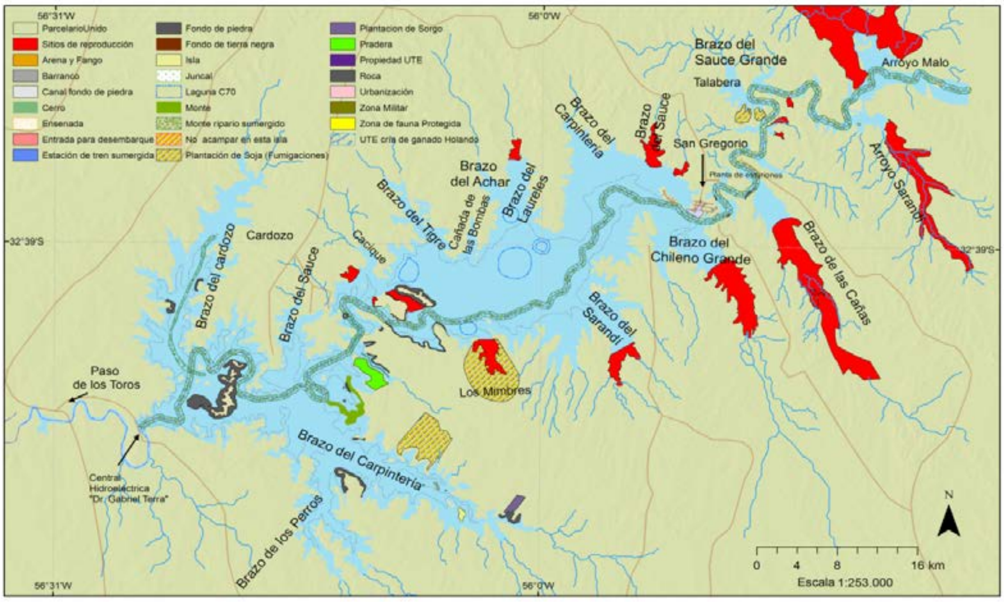
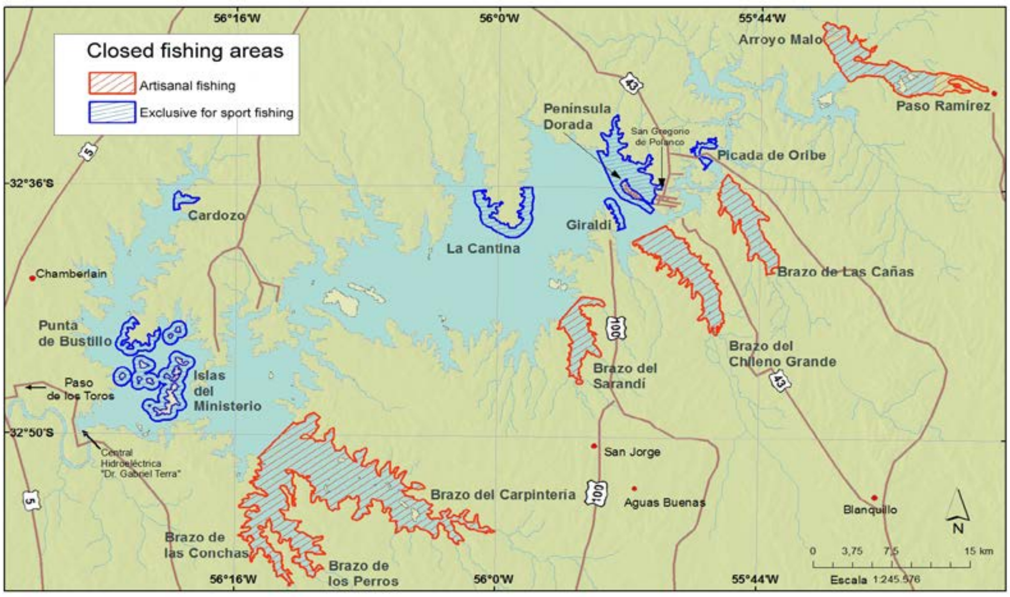


FIGURE 4

Closed fishing areas and exclusive zones for sport fishing established in agreement with the fishers in San Gregorio de Polanco and Paso de los Toros villages on the Rincón del Bonete Reservoir



Elaboration of a management plan

One of the major objectives of the Project was to elaborate a management plan for the Rincón del Bonete Site. While a draft document outlining management guidelines based on Project activities was elaborated, the internalization of the document by users did not occur. As such, this document is still considered in-process, requiring feedback by DINARA and fishers to create ownership of the plan. The importance of fishers' and institutional participation in the elaboration and approval of a management plan is elaborated by Hindson et al. (2005):

> *"Writing a management plan is not a one man show but requires enthusiasm, commitment and practical support both from the senior management levels and from the grassroots...You won't know if you are making the most of your fishery until you have a management plan that defines its goals and guides how they are to be achieved" (p. 11-12, Hindson et al., 2005).*
>
> *"A fishery management plan is a document that:*
> - *Analyzes the current situation in a fishery;*
> - *Sets out some principles that should be followed in management;*
> - *Details goals and objectives for the fishery;*
> - *Says how they are to be achieved; and*
> - *Says how they are to be monitored.*
>
> *The best management plans follow the KISS principle - Keep It Short and Simple!" (p.10, Hindson et al., 2005)*

A management plan is not a finished document but rather a guide to the elements of the fishery that can be elaborated based on emerging information from the systematization of fishers' knowledge (social capital) and the outcomes of participatory research on managed resources that may result in additional formal or informal management measures. The participation of fishers in the preparation of the Management Plan is essential for creating a sense of ownership, as well as facilitating the monitoring and adaptation of fishing activities and selected performance indicators.

The following specific objectives were proposed for the development of a Site Management Plan:

- Resources - Define in a participatory manner operational points of reference (e.g. capture average landing sizes and biomass of target fish);
- Environment - Incorporate the concept of preservation areas as well as permanent and/or temporary breeding and rearing grounds of target species. Generate agreements with artisanal fishermen in this regard;
- Social - Increase participation and social inclusion of fishermen in the new scheme of governance (co-management);
- Economic - Set in a participatory manner operational points of reference (e.g. prices, higher revenues, added value of catch, etc.).

Highlighted project achievements

The project obtained important achievements in a short time period and initiated a series of processes that together can enable the sustainability of fisheries and ecosystem services in the Rincón del Bonete Reservoir. Here we list the products and processes that facilitated ecosystem management at this site.

PRODUCTS

- Organization of an illegal and unregulated fishery (90% of fishermen were legalized)

- Institutionalization of filling logbooks, recovering quality information on production per fisher and per fishing operation (fishing zones, landing, effort, bait, commercialization)
- Strengthening of fishers' organizations such that there are now representatives of fishers in the Zonal Fisheries Council and other institutional bodies
- Support for low-income families and social facilities for producers provided by the MIDES intervention program.
- Fishers and intermediaries put back into operation the ice maker and cold storage room for fish
- Replacement of 10.000 meters of illegal nets with mesh for legal meshes, under common agreement with fishers
- Agreement between intermediaries about minimum size of fish to be marketed
- Development of a proposal for organizational strengthening (capacity building) among fishers, financed by the 'Rural Development' Program of MGAP
- Publication of a guidebook to fish species of the Rio Negro www.dinara.gub.uy/files/Publicaciones/Pesca/Guia_de_Peces_de_Rio_Negro.pdf;
- Generation of background information on fish diversity for the site
- Publication of a guide for co-management and EAF implementation www.dinara.gub.uy/files/marco%20normativo/veda_rincon_bonete_2014.pdf
- Logistical support of local monitoring and control institutions via equipment and materials
- Recycling a MGAP building for a DINARA office in San Gregorio de Polanco to enhance government support for monitoring of fishing activities and management
- Participation by indirect means in the development of a proposal for a preserved area in the National System of Protected Area (SNAP), conducted by the University (Rivera city University Center-CUR group) in Rincón del Bonete
- Development of a methodology (multi-criteria analysis) to assist fisheries managers in analyzing factors that may be considered in ecosystem management
- Establishment of fishing closures by area and periods to protect the reproduction of target species, and indirectly protect habitats www.dinara.gub.uy/files/marco%20normativo/veda_rincn_bonete_2014.pdf
- Establishment of communication channels with the local population through signage, radio and print media. Promotion of the issue of responsible fisheries and ecosystems through a drawing competition among local school children www.pescaresponsable.gub.uy/
- Draft of a Fisheries Management Plan for Rincón del Bonete Reservoir to protect and conserve aquatic resources, biodiversity and function of the site in a holistic and participatory manner and under EAF principles for the sustainable development of local communities.

PROCESSES

- Strengthening the link between institutions and local fishers (as an organization);
- Integration of other resource users in the system (sand harvesters, sport fishers and sturgeon culture farm) into the discussion on use and management planning of the reservoir resources;
- Establishment of lines of communication with the main user of water in the reservoir, the national electrical company UTE;
- Systematization of information about fishers and training of fishers in order to consolidate a representative group and develop a project submitted to MGAP
- Contribution to the issue as to whether or not to impose spatial-temporal closures on the fishery during reproductive periods of the target species;
- Initiation of participatory research (e.g. mark-recapture studies), strengthening the process of changing small nets for larger mesh sizes to prevent overfishing on

smaller size classes; validation of the importance of the rotary management areas (reservoir "arms") to maintain individual or group production; strengthening of participatory research as a source of knowledge and encouragement in fisheries co-management.

CONCLUSIONS AND GENERAL RECOMMENDATIONS.

It is a novelty in Latin America that a government implements EAF principles including the integration of fishers' knowledge as a national policy. However, compulsory (top-down) participatory management is an exception to general trends whereby participation is generally bottom-up and only time can tell whether the structures created during the Project will be stable or not. While there is government support for fishers' participation in assessment and management within the framework of an ecosystem approach, the top-down enforcement of participation and the uncertainty of newly created institutional structures are potential challenges to the long-term sustainability of fisheries co-management in Uruguay. Many activities and arrangements are still informal as the new fisheries law - which included the formation of regional advisory council, management plans, and the concept of ecosystem management – was only approved in December 2013 during the final months of the three-year project.

Challenges to implementing the EAF in Uruguayan artisanal fisheries remain:

- Institutional challenges within the government aquatic resources agency, DINARA;
- Environmental threats to aquatic resources (e.g. eutrophication, introduced exotic species, non-source pollutants, impacts of new cultures in the Basin as afforestation and soybean);
- Continual challenges for organization among fishers;
- Low importance of fish as a product in comparison to meat and dairy;
- Need for increasing government presence;
- Adjustment of administrative structures for new policies;
- Maintaining fishers' motivation to participate;
- The fishery management authority has to be convinced that having a management plan is important and that it will improve the management of the fishery. Management plans should be actively used documents, and are not only just for fisheries that are in trouble.

The inclusion of fishers in the development of management and research proposals and **capacity-building of fishers, technicians and administrators for co-management** in each pilot site were key factors contributing to the achievement of this project. One of the strategic activities was participatory mapping, through which the exchange of fishers' traditional knowledge and scientific knowledge was promoted.

Another successful approach to knowledge generation was the establishment of **letters of agreement** with various research institutions. We collaborated with the University of the Republic of Uruguay to elaborate draft use plans for some of the marine and inland water areas included in the project. These plans provide valuable input for defining public policies for ecosystem management in pilot sites.

A strategy to socialize the available information on ecosystem management for different sectors of the general public is through open seminars, workshops, educational activities in schools and universities, and traveling exhibitions on local ecosystems.

In addition, **assessment and participatory research tasks** were performed by integrating local users. An example is the mark-recapture study held in Rincón del Bonete, to understand the migratory behavior and habitat use of the fishery resource. Closed seasons established by consensus of local fishers were imposed to ensure the reproduction of fishery resources, particularly in the site San Gregorio de

Polanco. This knowledge was essential for the management of fisheries. Moreover, in accordance with local fishermen, fishing has been closed during the spawning period of the wolf fish (*tararira*, one of the main commercial species in the area) covering various tributaries of the Río Negro.

In the context of the GEF-DINARA-FAO project, alternative management strategies that incorporate the principles of ecosystem management (Shepherd, 2004) have been raised and implemented in four pilot sites. Within these sites, fishers have participated in research and management-oriented activities as well as enhanced their organizational capacity to generate proposals (fisheries use and conservation) for local and zonal Fisheries Councils. Key institutional partnerships were made at each site that facilitated the implementation of the Project and ownership of results by individual users, user groups and institutions.

Furthermore, the legal framework to support the sustainability of many of the actions initiated by the project in the four pilot sites was provided by the new Law on Fisheries and Aquaculture adopted in December 2013. The law incorporates several principles of the EAF and establishes fishery Advisory Councils as a reference tool for promoting co-management of artisanal fisheries in Uruguay. Through the creation of Fisheries Councils, human rights principles seeking participation, consensus, organization and empowerment of management were promoted through the project. The Project also supported participatory initiatives to improve the quality of life of fishing communities, including the development of seafood production systems and functioning infrastructure to support supply chains; and also promotes increased consumption of fish among the Uruguayan population. Finally, scientific knowledge was enhanced by with traditional ecological knowledge of fishermen in order to assess fisheries and the ecosystems affected by the activity.

The results achieved here were made possible due to the participation of fishers in both the preparation and implementation of the Project, as well as the financial and technical support of DINARA and FAO; and by the methods developed by the Project Management Unit that emphasized integration of fishers' knowledge and user participation in research, socialization of information and analysis, generating in each pilot site management measures designed for each individual fishery.

The continuity and further development of actions initiated by the project will depend on the ability of managers to commit human resources to continue and improve upon previous initiatives, which to our knowledge has shown promising results in the generation of knowledge applied to fisheries management and the promotion of governance of artisanal fisheries in Uruguay.

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2.3
Methods to use fishers' knowledge for fisheries assessment and management

Integrating traditional and scientific knowledge for the management of small scale fisheries: an example from Costa Rica

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ABSTRACT

Small scale fishing is not only a productive activity of great importance for food and economic security of most coastal and marine communities, but also a way of life from which a lot of experience and knowledge has derived. Some countries are starting to think about the importance and value of not only biological knowledge, but also traditional and community knowledge, utilizing them as a means to advance towards more integral marine conservation strategies. This model is shaped by a human rights approach, which in practice improves the livelihoods of these communities, reducing poverty levels and strengthening social resilience to changes (e.g. climate change). A small-scale fishing cooperative in Costa Rica, CoopeTárcoles R.L., is a good example of fisherfolk taking this matter of knowledge generation in their own hands and then setting an example of low-impact sustainable use of fisheries. This concrete example challenges our views on how to advance, via the bridging of traditional and scientific knowledge, towards more equitable and fair schemes that promote sustainable use, an ecosystem approach and the improvement of the livelihoods of coastal and marine fisherfolk communities.

INTRODUCTION

Traditionally in Central America, research related to fisheries has been characterized by three attributes: first, the research has principally been directed towards medium to large scale fisheries; second, it has been conducted mainly via academic initiative; and third, it is generally comprised of short-term research projects that include little to no

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traditional knowledge nor have promoted the participation of local actors. This occurs, for among other reasons, due to a lack of appreciation for local knowledge, as well as economic factors and a general lack of recognition of the artisanal fishing sector as a productive stakeholder with environmental, social and economic importance for the region.

This situation has not promoted, from our perspective, a positive impact on the development of knowledge regarding the management of small-scale fisheries nor on the strengthening of community governance schemes that also permit the incorporation of human well-being into efforts towards conservation of the marine environments as one of its objectives.

The management of small-scale fisheries should increasingly consider human rights, eradication of poverty and the strengthening of food security and sovereignty as objectives of equal value to those geared towards the protection and preservation of the marine environment. These issues are central and have contributed to global discussions that have led to the Millennium Development Goals, which aim to recognize sustainable development as the principal hope of the people and societies of the planet Earth. In an increasingly unequal Central America, particularly among the most powerful sectors with respect to the most vulnerable, the previously mentioned issues should be at the center of debate in the government sector and civil society spaces.

From an environmental perspective, small-scale or artisanal fishing is the closest to marine conservation. The activity is characterized by the non-selective harvest of a broad range of species, its occurrence in coastal zones and, in most cases, the highly efficient use of manual fishing gear that has relatively little environmental impact.

At the local scale, the discussion around marine conservation and the quality of life of human populations in coastal and marine territories are addressed daily by practitioners of small-scale fisheries. These discussions have an important impact, particularly in those cases where the strengthening of grassroots institutions and local people has led to reflection surrounding several questions: What information do you need to make good decisions for sustainable fisheries management? In which geographic areas? What is the best way to gather this information? What are the environmental, social and economic implications, from a local perspective, of the processes oriented towards responsible development of these fisheries that ensure food security for so many people?

In this paper we share results and lessons learned from a process that has integrated the knowledge of small-scale fishers and Western science, with the aim of generating new knowledge. Among other results, we propose that the product of community-based management emerging from this knowledge has strengthened alternative management schemes for small-scale fisheries. We discuss how knowledge in local hands allows for greater advocacy and community management of marine areas, and how once local institutions and community leaders have more information, they have access to more power to make decisions about the marine resources that they have used for decades. We also analyze the incentives and bottlenecks for the responsible use of local ecological knowledge and how this has been accepted and validated by the regulatory authorities of public goods such as the marine areas of Costa Rica.

Finally, we discuss how this innovative process of knowledge generation has opened the doors for both debate and a greater awareness of the need for an ecosystem-oriented vision to address management of fishery resources.

CONTEXT

The Fishermen's Cooperative of Tárcoles R.L. (CoopeTárcoles R.L.) is a cooperative enterprise located on the Pacific coast of Costa Rica in the province of Puntarenas. It was founded on December 13, 1985 by a group of small-scale fishers.

Its founding and ongoing motivation has been the improvement of working conditions and the positioning of artisanal fisheries products in the market. This motivation, revised in 2001, is outlined in eight objectives set forth in the bylaws of the organization (CoopeTárcoles R.L., 2001):

- Improve working conditions
- Enhance incomes among group members and their families
- Eliminate the middlemen in the marketing of fish and other marine products
- Create sources of employment
- Obtain the best prices for products
- Allow rapid growth of the cooperative enterprise by opening new markets for products
- Raise the level of organization and participation of fishers
- Promote approaches to sustainable management of natural and cultural resources

The cooperative is comprised of 35[4] men and women, dedicated to different production phases of artisanal fisheries: pre-fishing, fishing and post-fishing. Most of the members are residents of the community Tárcoles, with a few fishermen from the nearby communities of Playa Azul and Tarcolitos.

In 2001 CoopeTárcoles R.L. initiated a strategic alliance with CoopeSoliDar R.L., a self-managed cooperative comprising professionals from distinct disciplines and people interested in environmental issues that in some way provide professional services regarding the conservation of natural resources, cultural identity and social solidarity. In the same year, an associative relationship was established, validated by agreements of the General Assemblies of both cooperatives, to explore innovative ways to conduct marine conservation together with people. Simultaneous with the association of these cooperatives was the development of a baseline that indicated some of the main problems facing this community of artisanal fishers.

Among the main points identified in the baseline: lack of sources of employment facing the Tárcoles population; limited opportunities for education; and the growing scarcity of marine resources, which is inherently integrated into the productive and cultural life of this small Pacific Costa Rican community.

In the midst of this process, it was generally recognized by the community that artisanal fishing was a more accessible source of work and also of great importance in the area, as it provided both food security and cultural identity. At that time, it was estimated that approximately 90% of the economically active population of the community was engaged in fishing, whether directly or indirectly.

This process allowed for the discovery that the link between the fishing community in Tárcoles and its marine resources was not limited to a dependence on them as a source of income and livelihood. Rather, it was recognized that in close relation to fishery resources underlay deep traditions and cultural ties, such that the activity of small-scale fishing represents a nucleus that binds an entire way of life and marine fishing culture. To this is linked the cultural and social dynamics as well as institutions that drive daily lives within the community.

CoopeTárcoles R.L. and CoopeSoliDar R.L. subsequently identified an initiative for responsible artisanal fishing as one of the lines of work that not only would safeguard fishery resources, but also social welfare and the cultural way of life that includes the survival and protection of local knowledge, as well as the organizational strengthening of the community and, above all, their cultural identity.

In recent years, the cooperative of artisanal fishers of Tárcoles, with the support of CoopeSoliDar R.L., has promoted a series of participatory strategies for sustainable management of fishery resources, including the generation of new knowledge. On

[4] According to the records of CoopeTárcoles R.L., the cooperative has changed its number of partners during its history from 17-50. By revision of status in the General Assembly the integration of women in the cooperative was allowed.

the basis of these strategies, the initiative for responsible artisanal fishing in the area was proposed. Among the most important results were the drafting of the Code of Responsible Fishing, participatory zoning of marine areas, the formation of the consortium By The Sea R.L. (Por La Mar R.L.) and the establishment of a fisheries data base of CoopeTárcoles R.L. A summary of the major milestones is presented in Boxes 1, 2 and 3.

BOX 1[5]

A local vision of the Community Marine Area for Responsible Fishing (Área Marina Comunitaria de Pesca Artesanal Responsable - AMPR)

Location. From a local standpoint, the community marine area of responsible artisanal fishing is considered as the zone between two fishing points locally recognized as the mouth of the Juses Maria River to the north, and Coyol Beach Point to the south.

Beneficiaries. The community marine area of responsible artisanal fishing that fishers of Tarcoles desire is that in which the rights to artisanal fishing may be exercised not only by the members of CoopeTarcoles R.L. but also all fishers committed to responsible fisheries.

Objectives. The community marine area of responsible artisanal fishing has the following objectives and these should be assumed by fishers:

- Recognize the importance of responsible artisanal fishing as a significant economic activity relevant to job creation, food security, and the eradication of poverty of coastal communities
- To conserve marine resources within the area
- Recognize the contribution made by artisanal fishermen of CoopeTárcoles R.L. to the conservation of marine biodiversity

The Costa Rican State recognized the marine area for responsible fishing of Tárcoles via the resolution PESJ 33012009 of the year 2009, by laying down the Decree that recognizes:

> "The Marine areas for responsible fishing in accordance with Executive Order No. 27919-MAG are areas of important biological, fisheries, or socio-cultural characteristics that are to be defined by geographical coordinates and other mechanisms that permit the identification of their boundaries in which fishing activity is regulated in a particular manner to ensure the exploitation of fishery resources over the long term and by which INCOPESCA can rely upon the support of coastal communities and/or other institutions for their conservation, use and management" (Executive Order 29919-MAG).

BOX 2

The general vision of the Community Marine Area of Responsible Artisanal Fishing

One-year plan

- Achieve responsible fishing
- Gain recognition of the communal marine area
- Keep the area clean and free of litter
- Inform other residents and enhance participation
- Familiarize other people with the Responsible Fisheries Code
- Ask for assistance from institutions to help homeless and alcoholics
- Involving more lujadores and lujadoras as there will be more fishing and more work for the community
- Provide more product and more work
- Strengthen CoopeTárcoles RL and encourage more participation in chores

[5] Boxes 1 and 2 are adapted from: CoopeSoliDar R.L., 2009. Tárcoles + 5

BOX 2 (CONTINUED)

Three-year plan

- Create a trademark for CoopeTárcoles R.L.
- Have a lot of fish (overstocking)
- Provide more jobs for young people
- Attract more tourists
- Promote community arts
- Achieve greater diffusion of English speaking
- Enhance visitation to the By the Sea R.L. consortium
- Ensure the establishment of a co-management committee and ensure its decision-making
- Promote increased value of the land

BOX 3

A local vision of the Community Marine Area for Responsible Fishing (Área Marina Comunitaria de Pesca Artesanal Responsable - AMPR)

The consortium For the Sea R.L. was officially initiated/launched in 2007 as an auxiliary cooperative formed from the association of CoopeSoliDar R.L. and R.L. CoopeTárcoles. Since 2004 the consortium has developed community-based marine tourism activities complementary to fishing (see the development of this process in Figures 1 and 2). The Consortium operates as a small business dedicated to community-based marine tourism, conducting guided tours of responsible artisanal fishing. Its mission is "to be an innovative and consolidated consortium, which supports the occupation of responsible artisanal fishing as a dignified way of life that contributes to the biological and cultural conservation of coastal and marine resources as a good thing for our families" (By The Mar, 2007).

For the Tárcoles community the advantage of this type of tourism is the provision of employment opportunities to local men and women of different ages and occupations while having a positive social and environmental impact. Meanwhile, the people who take the guided tours of responsible artisanal fishing have the opportunity to learn about marine biodiversity, as well as the lifestyle, culture and daily work of artisanal fishermen and other people related to this activity. For example, the work done by women in the community responsible for untangling fishing lines and collecting shellfish.

FIGURE 1

Change in visitation rates over eight years of operation of the Consorcio Porla Mar R.L., according to the number of visitors. Period 2006-2013.

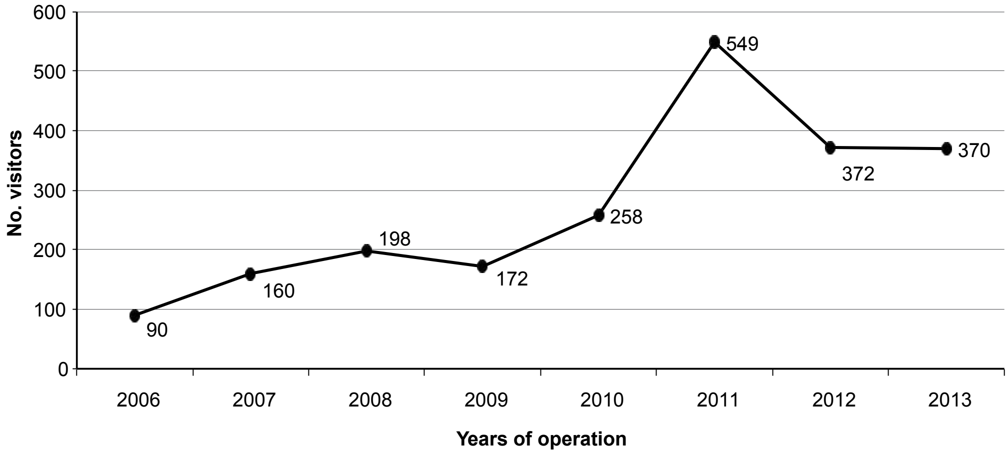
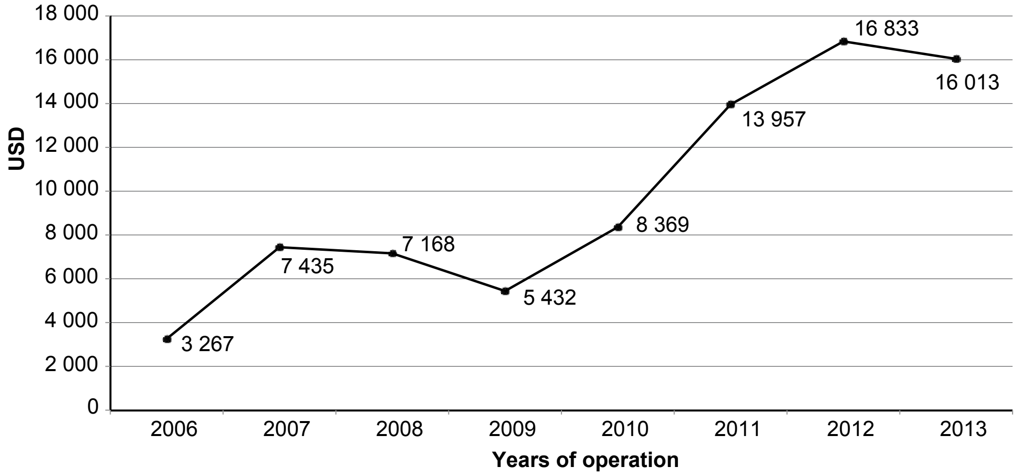


FIGURE 2
Change in income received over eight years of operation of the Consorcio Porla Mar R.L. Data in USD, 2006-2013, average exchange rate 1 USD = ₡ 505.08



GENERATING KNOWLEDGE FROM THE EXPERIENCE OF FISHERMEN AND FISHERWOMEN (FISHERY DATA BASE COOPETÁRCOLES R.L.)

Since mid-2005, CoopeTárcoles R.L. with the support of CoopeSoliDar R.L. has made an effort to collect information about the characteristics of fishing activities. Eight years later, this database constitutes a unique initiative in the region, and also serves as a concrete example of how to integrate local and traditional knowledge of fishers with scientific knowledge to guide decision-making for the management of small-scale fisheries.

This initiative, the first of its kind conducted by an organization of artisanal fishermen in the country, allows users to access valuable information and monitor the status of populations of target organisms. One of the basic indicators that fishers use to evaluate their activities is the total fish catch obtained year after year (Figure 3).

The most important indicator is the yield of fishing activities, which compares annual productivity, controlling for the effort invested in terms of time (number of fishing operations expressed as total hours spent fishing) and in terms of the amount of equipment used (number of nets used among fishers using seine nets or number of hooks for those using hook and line). This parameter permits fishers to objectively compare variation in yield from year to year and to understand the potential causes for improvements or declines in productivity in a particular year (Figure 4). These data

FIGURE 3
Total annual catch, obtained from the central database of CoopeTárcoles R.L. for 2006-2011

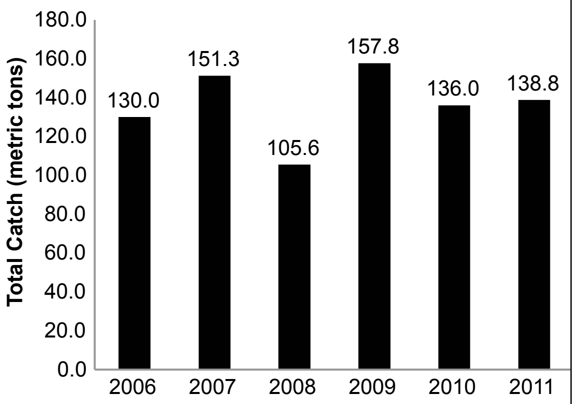
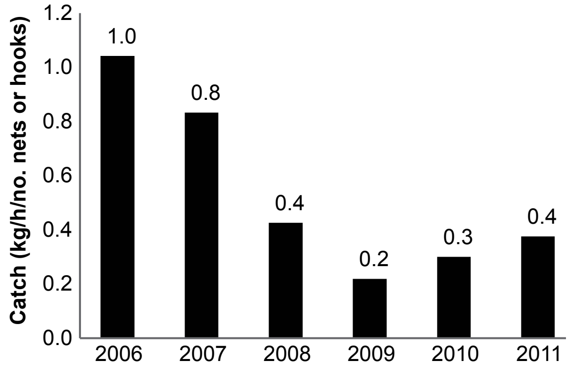


FIGURE 4
Total annual catch according to effort (kg per hour per number of nets or hooks), obtained from the central database of CoopeTárcoles R.L. for 2006-2011



thus determine the general decisions regarding the development of fishing activities in subsequent years.

The compiled information also permits the identification of fluctuation in the patterns of catch and effort in different marine and coastal locations over time, along with changes in perceived earnings from fishing. In addition, efforts have been undertaken to record developmental data (e.g. juvenile or adult) of captured individuals of spotted rose snapper (*Lutjanus guttatus*, Lutjanidae), whitefin weakfish (*Cynoscion albus*, family Sciaenidae) and white snook (*Centropomus viridis*, family Centropomidae).

A study in 2009 called attention to the size of fish of the most commercially valuable species exploited by fishers of Tárcoles and in surrounding areas. The objective of this research, developed in conjunction with fishers of CoopeTárcoles R.L., was to collect for the first time information on the number of individuals captured (Figure 5) and to determine whether fishermen were taking advantage of an adequate number of adults versus juveniles (Figure 6).

This study raised awareness regarding the exploitation of the snapper, for which fishing activity was largely based on juveniles, as well as the weakfish, of which a third of captured individuals in 2009 corresponded to juveniles (Figure 6). This information permitted the continuation of awareness building among fishers about inadequate practices and also promoted the gradual change in the use of 3-inch mesh to seine nets with larger aperture sizes.

FIGURE 5

Total number of fish caught between January and December of 2009, obtained from the central database of CoopeTárcoles R.L. for 2006-2011

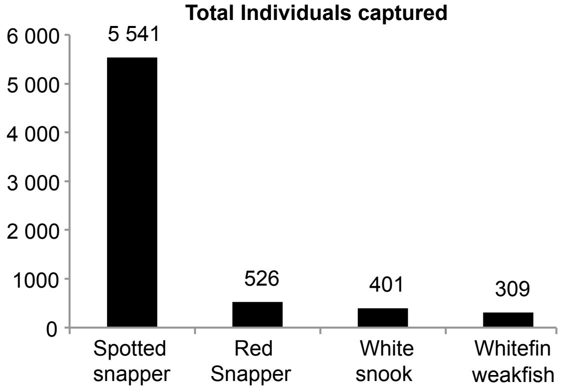
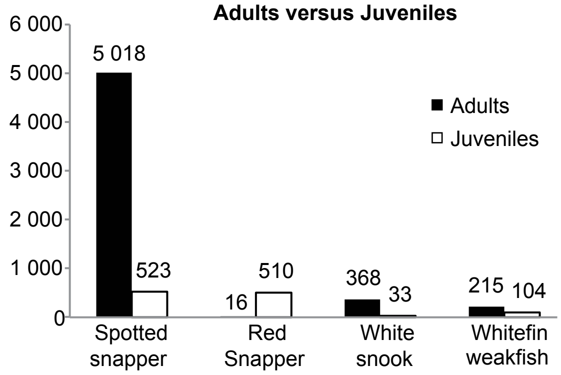


FIGURE 6

Total number of captured individuals of snapper, snook and weakfish, according to age class (juvenile vs. adult) in January to December 2009, obtained from the central database of CoopeTárcoles R.L. for 2006-2011



For other analyses, the database can also provide daily monitoring of fishing activities at different locations outside the boundaries of the marine area of responsible fishing (MARF). Such external locations are grouped into zones comparable to the area in question (Figures 7, 8).

The information generated has opened up the possibility for sustainable use of fishery resources of this small fishery and for regular monitoring of the state of the resource based on the knowledge and effort of fishermen.

As a result of the information generated by this database, it was possible to directly affect negotiations for the recognition of a Marina

FIGURE 7

Percent of total catch per zone inside and outside the MARF of Tárcoles in January to December 2011

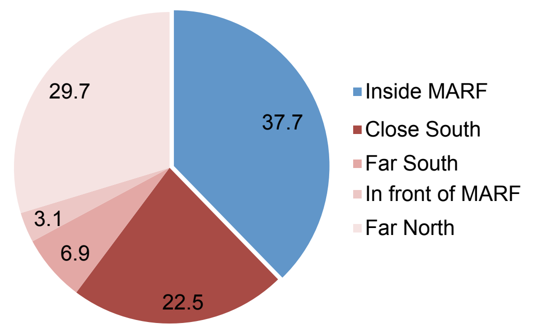


FIGURE 8
Total catch in metric tons of the ten most frequently caught species between 2006 and 2010

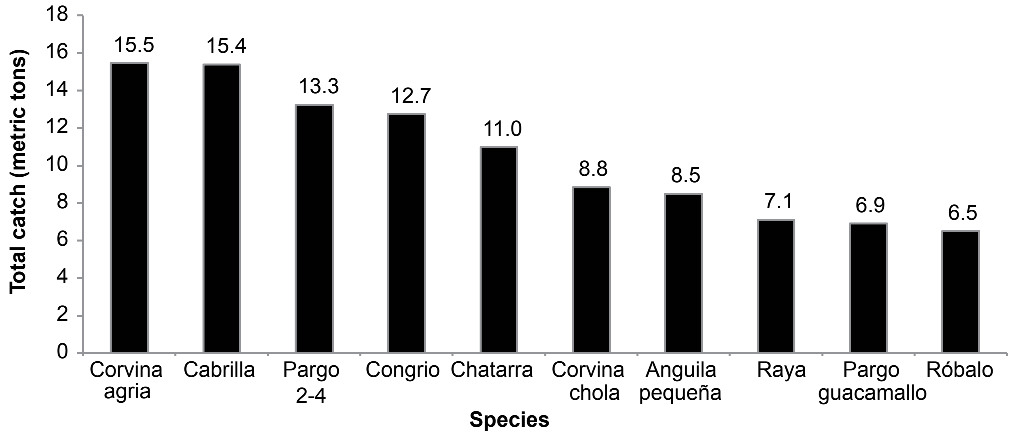
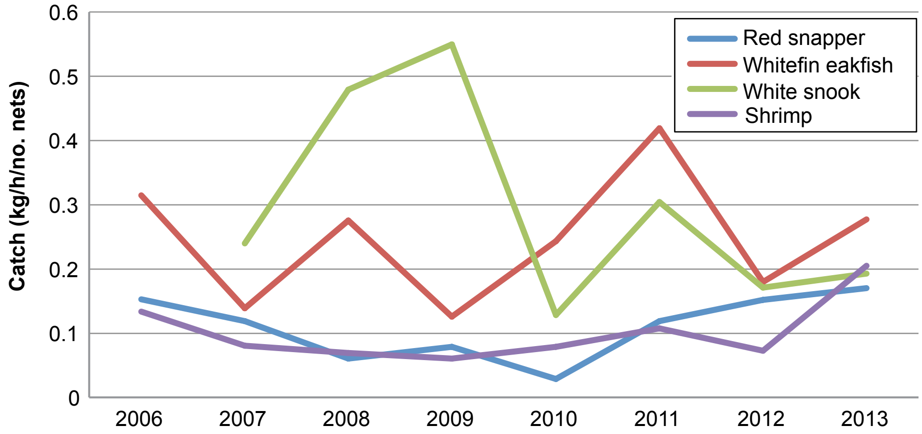


FIGURE 9
Total annual catch of the four major commercial species, obtained from the central database of CoopeTárcoles R.L. for 2006-2011



Area for Responsible Fisheries in Tárcoles. The board of INCOPESCA (National Fisheries Authority of the country) recognized, based on presented analyses of data from the database, the need to permanently remove shrimp boats from the coastal zone as requested by fishers.

The negotiations leading up to this action took several years and in 2011 INCOPESCA decided to place a temporary ban in the MARF of Tárcoles. The ban took place between 19 August 2011 and 19 August 2012. During this period shrimp boats were prohibited from entry into the MARF, and no fishing activity was allowed except for hook and line fishing. The study of the effects of the suspension of fishing operations showed recovery of snapper and shrimp in subsequent years, the two most heavily exploited species in previous years (Figure 9).

HOW IS IT DONE?

To date, more than 18 000 individual entries have been recorded in the fisheries database of CoopeTárcoles R.L., extending from January 2006 to the present. This information is periodically analyzed with the technical support of CoopeSoliDar R.L. Each entry is taken from a data sheet that the cooperative collects following the productive activities of each fisherman.

The information is entered into the database by a fisherwoman who operates a computer program specifically designed to meet the objectives of this initiative. It is a user friendly program and can handle information quickly and with fewer typing errors. Prior to using this software data was managed from an Excel spreadsheet.

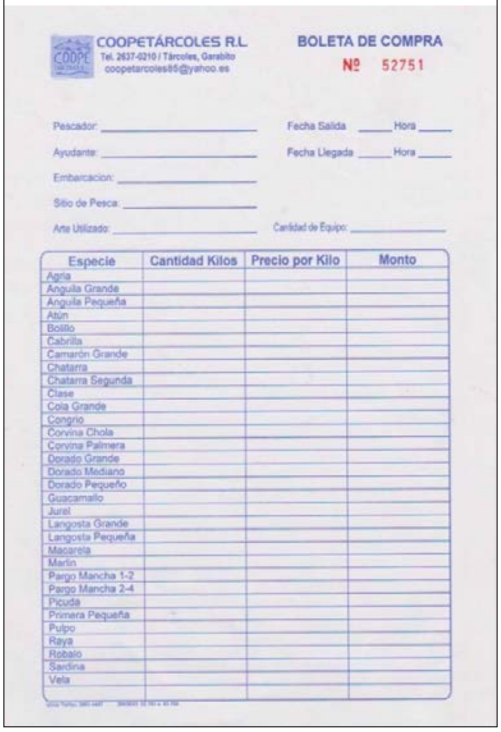
CoopeTárcoles R.L. has designed an invoice form to record revenue from products brought to the collection center by artisanal fishermen and women. The form ensures fair payment for the fishing trip and simultaneously obtains the information required for the database. These invoices immediately collect the data provided by each of the fishing trips conducted by fishers in a consistent manner, as their payment for each fishing trip depends upon their use. Subsequently, the information for each invoice is entered into the database.

The final format of the invoice that gathers this information is then transcribed into the database.

Each fishing trip includes catch information, the geographic location of the catch, the equipment used, the total time spent fishing by each fisher, and moon phase, among other data.

Each year the information derived from the database is presented and discussed with fishermen and the questions they generate based on their knowledge are analyzed, permitting validation and feedback on the system of information. Nonetheless, perhaps the most important result derived from these activities is the decision-making directly applied to the management and protection of the area through cooperative management.

FIGURE 10
Invoice form used to record the results of the fishing trips of fishermen from CoopeTárcoles R.L.



COOPETÁRCOLES R.L
Tel. 2637-0210 / Tárcoles, Garabito
coopetarcoles85@yahoo.es

BOLETA DE COMPRA
Nº 52751

Pescador: ____________ Fecha Salida ____ Hora ____
Ayudante: ____________ Fecha Llegada ____ Hora ____
Embarcacion: ____________
Sitio de Pesca: ____________
Arte Utilizado: ____________ Cantidad de Equipo: ____________

Especie	Cantidad Kilos	Precio por Kilo	Monto
Agria			
Anguila Grande			
Anguila Pequeña			
Atún			
Bolillo			
Cabrilla			
Camarón Grande			
Chatarra			
Chatarra Segunda			
Clase			
Cola Grande			
Congrio			
Corvina Chola			
Corvina Palmera			
Dorado Grande			
Dorado Mediano			
Dorado Pequeño			
Guacamallo			
Jurel			
Langosta Grande			
Langosta Pequeña			
Macarela			
Marlín			
Pargo Mancha 1-2			
Pargo Mancha 2-4			
Picuda			
Primera Pequeña			
Pulpo			
Raya			
Robalo			
Sardina			
Vela			

Each year a newsletter that simplifies the information obtained from this periodic analysis is shared with all fishers including both members and nonmembers of CoopeTárcoles R.L. This newsletter highlights some of the priority issues that require attention from the perspective of long-term sustainability of the resource. Observations of artisanal fishermen and women that have been subsequently verified in the database are presented in Box 4.

BOX 4

Impacts of the Tárcoles Marine Area for Responsible Fisheries have been evident upon analyzing the information in the database. These studies verify the following changes that fishermen have noticed during the execution of their work:

1. More fish are caught with hook and line, as reflected mainly by independent tours (guided tours of the By The Sea Consortium).
2. The anchovy (anchoita) has come back at sizes never seen before, and with it increases in catch of other types of fish.
3. Gill nets of 3 and 3.5 inches in mesh size were fishing gear that had been somewhat forgotten and today CoopeTárcoles R.L. manages a large number of requests for this gear.
4. More than 30 years have passed since the Tárcoles beach has been able to capture bass using hook and line from the beach.
5. The grouper has never come so close to the coast, especially near the site known as La Gallinera, which has meant a major reduction in fuel costs and thus the expenses of fishers.
6. Whales approached the coast as never before and were viewed on a guided tour.
7. Mussels have been collected in places for the first time in decades, as fishing vessels devastated these molluscs. Many people have come to the beach to dig up these mussels from the sand.

BOX 4 (CONTINUED)

8. The sizes achieved by many corvina and other species has surprised fishers, as these sizes demonstrate that they have developed properly. These changes also affect fishers' incomes as larger sizes imply not only increases in total kilograms delivered to CoopeTárcoles R.L., but also an increase in the commercial category of the species, which translates into more valuable fish.
9. Corvina cinchada is a species that for years had retracted from the coasts of Tárcoles. It was very common for ships to capture the species in large numbers during seasons of abundance (in the eighties and early nineties). This species has returned to the coast and is beginning to be caught again by artisanal fishermen.
10. During the final months of 2012, shrimp has been captured with cast nets, and some children could grab them with their feet from the mud. This suggests that these organisms are recovering. Participatory studies conducted between CoopeTárcoles R.L., CoopeSoliDar R.L. and INCOPESCA show that many of the jumbo shrimp females caught are carrying eggs, which is very encouraging for the future.

LESSONS LEARNED FROM THE INFORMATION DERIVED FROM ANALYSIS OF THE DATABASE:

- The information collected through the efforts of fishermen is useful and necessary for the establishment of management measures. With this important information the precedents for fisheries management can be derived. For example:
  1. Via monitoring of shrimp populations, it has been concluded that catches should be suspended between June and August, when they reproduce, and that controlled use of this resource can be employed during the months of December to March.
  2. Fishing by hook and line is more efficient, as it permits a greater total number of catch with less effort than necessary to use gillnets, and so should be supported and promoted.
  3. Most fishing within the marine area for responsible fishing is still conducted with gillnets. Gillnets as a gear used within the AMPR should be handled responsibly.
  4. The closed seasons for fishing should be used to investigate the status of fish stocks and other marine organisms, the effects of these closed seasons on fish populations and the best manner to carry out sustainable use of this resource.
- This effort necessarily involves a process of reflection, learning and trust that develops over the mid- to long-term. Fishermen must develop trust and responsibility with the facilitator / partner organization to provide information and to use it in a positive and proactive way in marine resource management. The information should be returned to fishers for use in decision-making and should belong to their organizations.
- As artisanal fishermen are involved in the generation and application of knowledge, the appropriation and use of this knowledge - once socialized and integrated - is immediate and directed towards resource management, which means that preventive measures can be taken more quickly and effectively.
- More than an academic exercise, the work of integrating scientific and traditional knowledge is a strengthening process for decision-making. It is a process that must maintain stewardship in local organizations and management must occur in this local context. Any use thereof must be analyzed by the structures of local decision-making and pass through a collective agreement to determine if information is to be shared with other actors and under what terms and conditions.
- The data collection methodology passes through phases of trial and error. This must be relaxed without underestimating the need for accuracy and reliability

of information based on scientific theory. Analysis requires data validation and continual exchange of knowledge in order to respond to such questions regarding the fisheries sector. This denotes a mid- to long-term process.

- The benefit of information is immediate. The annual patterns of fishing allow local organizations to define more effective and efficient ways to harvest resources that also save time and resources of fishers. This also shows evidence of the improvement of the surrounding environment as a result of management measures.
- The generation of information that integrates local and scientific knowledge is costly with respect to both economic and human resources, as it requires the combined willingness of many people. It remains a challenge to achieve sustainability of a process of this sort that requires support in the monitoring and validation in a comprehensive and continuous manner. To the extent that the information is for local use and management of the fishery, fishing organizations themselves can contribute to their sustainability in the long term.
- There is a lack of understanding and support by academic and government sectors regarding the value and recognition of such knowledge generation processes, the need to respect and value such initiatives.
- The process of knowledge generation provides a great opportunity for involving sectors such as women and youth, providing them with a new focus of interest and value such as Information and Communication Technologies (ICTs).
- As this process of knowledge generation recognizes the value of two types of knowledge (local and scientific), support and joint work over the mid- to long term is indispensable.
- As knowledge is consolidated at the local level and applied to decision-making, its impact transcends from the local to the national and, as in the case of CoopeTárcoles, new questions arise and give way to broader, ecosystem-based vision of factors that impact resource sustainability. For example: What other external factors beyond the local utilization of resources affect sustainability?
- An integrated approach that looks beyond the strictly environmental aspects of marine research and conservation is necessary and essential. Parallel to the objectives of conservation, other social and human welfare objectives must be integrated to identify actions that will achieve both environmental sustainability and an improved quality of life.
- The generation of knowledge in ongoing. It is a continuous learning process that strengthens the power of those actors such as artisanal fishers that prior to this process had no voice or vote in management agencies The information is rapidly transformed into power (given that the process occurs within an ethical framework and correct values), which strengthens local governance together with a fisheries management scheme oriented "in practice" towards a sustainable model.

CONCLUSIONS

Participatory research and innovative approaches to the generation of new knowledge with communities constitutes elements of enormous value to reinforce the importance of conservation and food security for the populations of artisanal fishers. The integration of traditional knowledge is reflected in the daily chores of the CoopeTárcoles R.L. fishers' productive labor. Scientific analysis was contracted to help draw conclusions and apply results to decision-making processes. Through this process, which by necessity led to a strengthening of local capacity, we found the willingness of fishers to improve activities by directing them towards a sustainable use of fisheries resources. In addition, the process allowed for the measurement of the positive results of sustainable resource use based on the local database.

As challenges, the need for local fishers to share the skills to generate new knowledge from traditional ecological knowledge with other fishing communities and to develop questions appropriate for each particular context was perceived.

Finally, it is also necessary to discuss the use of generated information by not only academic institutions but also by government and marine conservation organizations to ensure that traditional knowledge is not only respected but also valued in all its dimensions. The utilization of this knowledge should be adequately recognized, which implies the development of ethical principles for its use, and it should also be appreciated and considered in budgets that support or generate scientific information in academic and government entities.

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Conservación marina con Gente
www.youtube.com/watch?v=jS0Q0J2X-D8&feature=youtu.be

Una voz para los jóvenes pescadores y pescadoras de Mesoamérica
www.youtube.com/watch?v=EYK9j9_5Fu4&feature=context-cha

Video Incidencia Política
www.youtube.com/watch?v=nKo5SvWgBPM&feature=youtu.be

Fishers and their knowledge in Brazil: from extractive uses to collaborative exchanges

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ABSTRACT

Fishers' knowledge (FK) is the main foundation for small-scale fisheries worldwide. Fisheries management otherwise usually relies on scientific knowledge (SK) to provide information for decision-making. Efforts have been made to bridge SK and FK. In this paper, we describe an experience where FK was incorporated into decision-making within the Ecosystem Approach to Fisheries (EAF). Information was based on both secondary data from informal interviews with managers and researchers as well as primary data from a bycatch reduction device project in small-scale trawl fishing from South Brazil. The incorporation of FK into fisheries management remains a challenge and is generally more accepted in data-poor regions. Challenges include a poor understanding of alternative methods and tools, limited skills among both managers and scientists for working with FK; lack of fishers' adaptation to management arenas and miscomprehension among scientists about heterogeneity in fisherfolk. To overcome these challenges, we propose to develop the capacity to overcome limitations mentioned earlier, integrating participatory monitoring and evaluation in management, and prioritizing action-research for EAF projects.

RESUMO

O conhecimento dos pescadores é o fundamento principal para a pesca artesanal no mundo inteiro. A gestão pesqueira, por outro lado, costuma basear-se no conhecimento científico para a geração de informações para a toma de decisão. Esforços vem sendo realizados para integrar o conhecimento científico (CC) e o conhecimento dos pescadores (CP). Neste artigo, é descrita uma experiências onde o CP foi incorporado para dar suporte à tomada de decisão a partir do Enfoque Ecossistêmico Aplicado à Pesca (EAF). A informação é baseada em dados secundários, incluindo entrevistas informais com gestores e pesquisadores. Foram também revisados dados primários de um projeto desenvolvido no Brasil. A incorporação do CP na gestão pesqueira ainda permanece um desafio e é mais aceito em regiões com baixa disponibilidade de dados científicos. Desafios incluem uma baixa compreensão métodos e ferramentas alternativas, reduzidas habilidades dos gestores e cientistas para o trabalho com o CP, falta de adaptação dos pescadores às arenas de gestão e falta de compreensão sobre a heterogeneidade entre os pescadores. São propostas mudanças orientadas para: o desenvolvimento de capacidades para lidar com as limitações apresentadas, o desenho de monitoramento e avaliação participativa na gestão, e a priorização de pesquisa-ação em projetos de EAF.

INTRODUCTION

Human use of nature and its negative effects on biodiversity and ecosystems has stimulated growing concern (Chapin *et al.*, 2000). Additionally, the limitations of conventional resource management, such as, the biologically-centered information decision making, the overly centralized and technocratic management procedures, the perspective of control of nature and the treatment of people as they were separated from ecosystems (Berkes, 2003; Holling and Meffe, 1995) require new sustainability pathways[1] and management approaches (Chapin *et al.*, 2009a; 2009b; Heal and Schlenker, 2008; Rice, 2008; Slocombe, 1993; Ye *et al.*, 2013).

These approaches have been developed to broaden the scope of resource management, embracing a wide spectrum of parameters in order to better address the dynamics of social-ecological systems. Acknowledging fisheries as complex adaptive systems (Mahon *et al.*, 2008), the requirements for information in order to reduce uncertainties and surprises are relatively high (Gunderson and Holling, 2002). Information must be based upon practical experience as well as science, which are often complementary. Thereby, bridging scientific and traditional knowledge is both necessary and challenging (Berkes, 2009; Butler *et al.*, 2012; Huntington, 2000; Keen and Mahanty, 2005). Reasons for bridging knowledge include (Reid *et al.*, 2006):

- Increase the amount and quality of information available about the system
- Make findings more useful and available for different stakeholders engaged in knowledge generation
- Empower groups that hold such knowledge.

Resource users' knowledge ranges from ecologically relevant knowledge, such as target species life histories, to cultural and religious practices (Berkes, 2008; Berkes *et al.*, 2000; Grant and Berkes, 2007). Success and failure of resource management is related to the use of resource users' knowledge, with its inclusion through participation as a strong factor favoring success (G. G. M. Moura *et al.*, 2013; Walters *et al.*, 2008). Fishers' Knowledge, therefore, is not just a matter of enhanced comprehension of marine ecosystems, but also a source of social capital (Carr and Heyman, 2012; Grafton, 2005) and a conduit for fishers' participation in decision-making arenas (Medeiros, 2009). Such knowledge, obtained through dialogue and engagement, also contributes to robust governance (Ostrom, 2005; 1990).

Nonetheless, integration of Fishers' Knowledge into conventional fisheries management procedures is challenging. Such integration requires, instead, an holistic approach to fisheries management that is unconventional and innovative, such as the Ecosystem Approach to Fisheries (Espinoza-Tenorio *et al.*, 2013; Kooiman *et al.*, 2005). Thereby, successful integration of Fishers' Knowledge and practical management systems into the EAF can be a matter of methods and approaches. We are not disregarding the controversies and inconsistencies in concepts and principles, which are clearly important but often overly discussed in the literature in comparison to several more practical aspects (Cochrane, 1999; Garcia and Charles, 2008; Garcia and Cochrane, 2005; Morishita, 2008; Sherman *et al.*, 2005). We consider FK as:

- The main foundation for small-scale fisheries dynamics
- Fundamental for fishers' participation in decision-making arenas
- Complementary to (and sometimes the substitute for) Scientific Knowledge to support an EAF

In this paper, methods and approaches are meant to be: i) the procedures and practices implemented to use FK in fisheries management; ii) managers' skills in decision-making arenas; iii) institutional and legal frameworks for Ecosystem Approach to Fisheries, in which configurations influence how fishers participate in decision-making

[1] Sustainability pathways could referred to a agenda for a joint achievement of ecological protection and economic development (Slocombe, 1993). It also could be defined as strategies or broader goals to overcome unsustainable pathways addressed to fisheries overexploitation (Rice, 2008).

and how knowledge flows among institutional levels and stakeholders; and iv) methods to bridge scientific and FK.

The following sections explain some of the concepts and recent developments that underpin these arguments. We then provide a case study to illustrate methods in use and lessons learned. From this case study, as well as lessons learned and the broader literature we draw conclusions and make recommendations for overcoming challenges we pointed out through methods that are more collaborative than extractive for incorporating valuable Fishers' Knowledge.

ECOSYSTEM APPROACH TO FISHERIES AND FISHERS' KNOWLEDGE: SOME DEFINITIONS

We briefly explore some definitions of the EAF and FK. In order to incorporate a broader view, management approaches are initially defined in order to stress entry points for our analysis. Complementary concepts related to this approach are also briefly defined. Fishers knowledge is defined based on the Traditional Ecological Knowledge perspective (Berkes *et al.*, 2000). We do not intend to encompass all definitions and controversies related to EAF and FK, but to some extent we use these to help bound our analysis.

Ecosystem approach to fisheries

General definitions

The ecosystem has been proposed as the main management unit since the 1930s and 1940s, although this was long limited to mean the "ecological system". The definition of ecosystem and its use as management unit were conventional both definitions. Consideration of the human dimensions of ecosystems appeared mainly after the 1980s (Grumbine, 1994). According to Grumbine, biodiversity crises, environmental policy and management failures, development of concepts in conservation biology, ecosystem appeal and rising concerns among environmentalist groups contributed to making the ecosystem a primary management unit.

The Convention of Biological Diversity (CBD) developed 12 principles for implementing ecosystem-based management (EBM) (Secretariat of the Convention on Biological Diversity, 2004), which, somehow, where also considered in scientific literature (Gelcich *et al.*, 2009). They take into account EBM elements such as: to include ecosystem dynamics (in appropriate spatial and seasonal scales); to guarantee participation in the lowest possible level; to understand management in an economic context, and others.

Fisheries overexploitation, and coastal and marine ecosystem degradation also influenced the development of more comprehensive management approaches. Marine ecosystem-based management, ecosystem-based fisheries management and the Ecosystem Approach to Fisheries are recent contributions to the growing number of similar concepts. Although overlapping at some levels and diverging at others, they converge to propose the ecosystem as a feasible composite unit for management and governance purposes. More clearly, "various expressions refer to what appear to be in practice very converging, if not totally similar, processes, aiming at largely overlapping sets of objectives." (Garcia *et al.*, 2003).

This plethora of definitions was analyzed by (Arkema *et al.*, 2006) who proposed three general criteria to classify ecosystem management definitions (sustainability, ecological health and inclusion of humans in ecosystem) and 14 specific criteria, grouped as ecological, human dimension and management criteria. The authors argue that, despite the growing consideration of the human dimension, as reflected by the literature on ecosystem goods and services, economic interests, and engaging stakeholders in management plan development, the focus is still biased towards ecological concerns.

For example, ecosystem-based fisheries management (EBFM) is said to aim to maintain system characteristics in order to support ecosystem resilience and to avoid undesirable unstable domains (Pikitch *et al.*, 2004). EBFM, also sometime treated as the Ecosystem Approach to Fisheries, takes an alternative, more effective and holistic approach to foster healthy marine ecosystems when compared to so criticized conventional management (Zhou *et al.*, 2010).

This approach attempts to reduce bycatch discards as well as manage target species within the context of overall ecosystem dynamics (Pikitch *et al.*, 2004), including issues of trophic connectivity and species interactions (Hilborn, 2011). Priority is also given to fisheries dynamics, including, *inter alia*, technical modifications and energy efficiency (Suuronen *et al.*, 2012) and changes in selective fishing philosophy (Zhou *et al.*, 2010). Nonetheless, this approach does not explicitly incorporate social dynamics, often merely considered as an external driver to ecosystem dynamics (Christie *et al.*, 2007).

One attempt to better integrate human dimensions into ecosystem-based management is the EAF. By definition "social, economic and institutional elements can be simultaneously drivers, constraints and/or supports for EAF implementation and, in addition, there can be social, economic and institutional outcomes of that implementation" (Young *et al.*, 2008).

According to the EAF definition (Garcia *et al.*., 2003), the words "Ecosystems", "Approach" and "Fisheries", when used together, "imply a process using specific means to achieve selected objectives". Also, EAF "is recognized as a form of fisheries governance framework, taking its conceptual principles and operational instruments from conventional fisheries management on the one hand, and ecosystem management on the other hand". Contributions from sustainable development and sustainability science have also helped ground perspectives on EAF and other similar concepts, taking into account principles from international conventions (FAO, 2005; Frid *et al.*, 2006; Garcia and Cochrane, 2005).

Implementing EAF is subject to several challenges yet to be better tackled. Knowledge gaps, especially are those "at the boundaries of traditional discipline areas or are in need of multidisciplinary approaches" and the prevailing of decision-making in political arena, instead of using science as a basis for management, are the main scientific challenges (Frid *et al.*, 2006). Sometimes, focus on ecosystem health indicators are unrealistic from management and socio-economic context (Christie *et al.*, 2007) where better communication between scientist and managers should be addressed.

The "problem of the fit" between ecosystem and institutions (Folke *et al.*, 2007; 1998), when mismatches between scale of ecosystem dynamics and institutional framework affect governance robustness also challenges EAF implementation. This situation is amplified in an absence of a proper institutional framework to address EAF implementation (Botsford *et al.*, 1997) as well as difficulties in connecting local and national level goals (scaling-up) (Garcia and Cochrane, 2005; Pomeroy *et al.*, 2010).

Recent contributions to EAF relevant to fishers' knowledge

Over the past decade, because of the failures of conventional fisheries management, scholars and practitioners have paid more attention to the human or social dimensions of fisheries management, especially in small-scale fisheries and EAF (Young *et al.*, 2008). The three previously mentioned main reasons for bridging knowledge – information availability, knowledge generation and empowerment – have been prominently featured. Resource user participation in the policy, planning and management phases of EAF is important for building adaptive capacity and hence fishery system resilience. EAF also encourages adaptive co-management or collaborative adaptation in association with ecosystem stewardship (Chapin *et al.*, 2009b; 2009a). The sharing of knowledge, power and responsibility for fisheries management is an essential component of these arrangements.

State agencies are learning to value FK within the context of EAF and EBM, especially in data-poor and high-uncertainty situations where the scientific production of knowledge is constrained (Fanning *et al.*, 2011). Many methods for accessing, assessing and incorporating FK into EAF are now well described (de Young *et al.*, 2008) with online tools readily available (e.g. FAO EAF Toolbox accessible at www.fao.org/fishery/eaf-net/topic/166272/en). In order to use these methods and tools it is first necessary to understand and appreciate the nature of FK.

FISHERS' KNOWLEDGE

Traditional Ecological Knowledge is used in a variety of approaches and purposes, and may be merged into two tendencies. The first proposes TEK as complementary to Scientific Knowledge, in which can contribute to improve information in ecological research. The second proposes TEK as an alternative approach to SK, "used to question it and transform it" (G. G. M. Moura *et al.*, 2013). Aspects of taxonomy (folk systematics), population ecology and ecosystems dynamics (Drew, 2005) are components to support community-based management and sustainable development (Berkes, 2008). In this paper, we assume Fishers' Knowledge as the Traditional Ecological Knowledge (TEK) relative to Fishers. It is beyond our scope to explore other definitions. The classical definition considers TEK as "cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes, 2008; Berkes *et al.*, 2000).

TEK can also be considered as an approach to sustainable management, in which case the following principles include (Whiteman, 2004):

- Humble pragmatism
- Social/ecological reciprocity – the fundamental need to give back to society and the local ecology as you take from it
- Managerial leadership based on ecological legitimacy gained through high levels of TEK
- Ecology fused with economics, business with society, and self-interest with the needs of the community and the local ecosystem.

Instead of "written knowledge" typical of western science, Traditional Ecological Knowledge relies strongly on "oral traditions" which hold emotional and personalized content from human experience (Whiteman, 2004). Additionally, TEK deals with nurturing an ecological ethics to motivate humans to show respect for nonhumans (Pierotti and Wildcat, 2000). Although emerging from the same source – the systematic observation of nature - they differ in many ways. Although TEK tends to be more qualitative and endogenous to resource users, SK tends to be quantitative and limited to a small group of professionals (Kimmerer, 2002). Furthermore, "traditional ecological knowledge is accrued through trial and error. The actions that allowed for the optimal completion of a task (in itself a culturally defined metric) are passed down from generation to generation" (Drew, 2005).

Some discrepancies arise from terminology used in association with Traditional Ecological Knowledge – traditional, local, indigenous or native knowledge. These differences in definition are mainly related to how authors deal with the temporal and spatial domains of knowledge building as well as traditional practices and social identities with the ecosystem (Berkes, 2008; Huntington, 2000).

LESSONS TO SHARE

Rede Viva: developing management tools to reduce bycatch in South Brazil

Trawl fishing is a matter of concern in terms of its impacts on marine ecosystems (Eayrs, 2007; Gillet, 2008). Small-scale trawlers targeting shrimp along the South

Brazilian coast are a valuable source of income (Andriguetto-Filho *et al.*, 2009; Bail and Branco, 2007; Branco *et al.*, 2006; Malheiros, 2008; Medeiros *et al.*, 2013), but the bycatch comprises more than 60 species of non-target marine species (Branco and Verani, 2006a; 2006b; Cattani *et al.*, 2011).

Bycatch Reduction Devices (BRD) are thought to be one set of possible solutions to bycatch problems (Broadhurst, 2000). Otherwise, BRD are not used as fishery management tool in Brazil, except for the use of Turtle Excluder Devices (TED) in industrial trawlers (boats above 11 m length), where its implementation is absent (Silva *et al.*, 2013). The National Plan for Sustainable Trawl Fishing was proposed by the Ministry of Environment (Dias Neto, 2011), including consideration to research and regulation of BRDs, but its adoption still requires technical advice and political will.

Scientific experiments have been conducted since 2008 in South Brazil by the Center for Marine Studies – Federal University of Parana (CEM/UFPR), where different technological modifications in trawl nets were shown to be effective in reducing the discards in small-scale shrimp trawl fisheries (Cattani *et al.*, 2012; Silva *et al.*, 2012a; 2011; 2012b). They are the first continued research program in Brazil on the topic, and with small-scale trawlers. Besides technological experiments, additional actions where conducted in other to provide support for the use of BRD as a management tool after 2011, by the project "Rede Viva".

The project "Rede Viva[2]" comprises collaborative research and outreach actions with Fishers (including fisherwomen, fishermen and netmakers) in South Brazilian fishing villages in the States of Santa Catarina and Paraná, under coordination of CEM/UFPR. Part of this project was to develop a framework (Figure 1) for the use of BRD as management tool in a Marine Protected Area ("Resolving environmental issues in the southern Brazilian artisanal penaeid-trawl fishery through adaptive co-management," 2013).

"Rede Viva" is not an official/government project, but Protected Area Managers collaborate with, and they have been integrated into the management Agenda. This project then explored research and outreach actions in which fishers were "partners-owners" of the objectives, method and outputs. This shift was made incorporating the following elements from adaptive co-management and EAF (Medeiros *et al.*, 2013):

- Potential for participatory process building: enabling a proper institutional environment, recognition of multiplicity of Fishers' organizations; use of participatory methods
- Knowledge bridging: use of local knowledge, fishers engagement in research and outreach
- Adaptive management: embracing surprises and uncertainties; flexibility in management tools, social and institutional learning

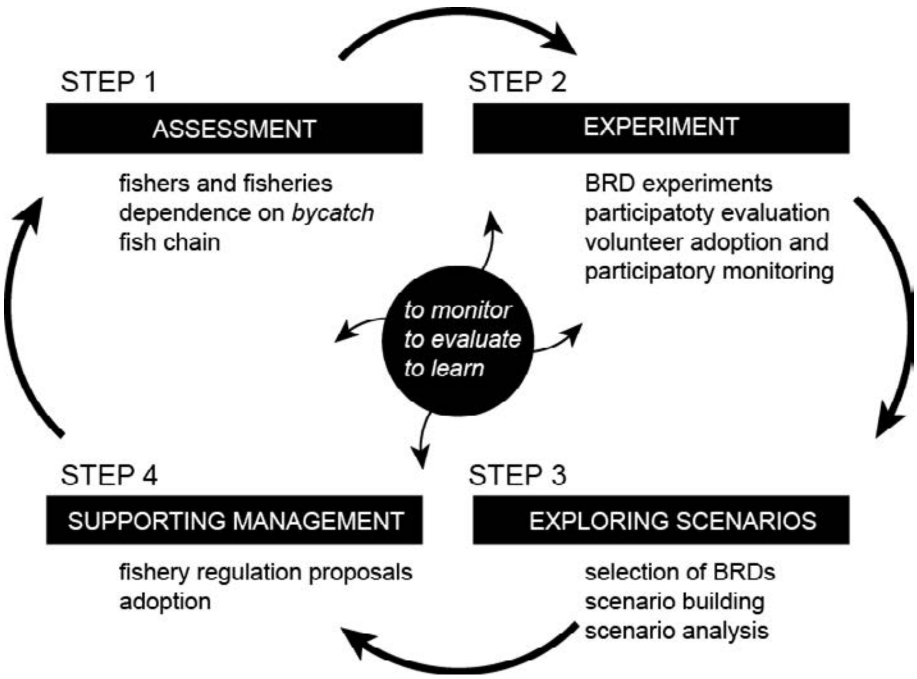
Based on these principles and concepts, the authors also suggested a few steps to empower Fishers through their engagement and incorporation of their knowledge:

- Designing of experiments with BRD
- Demonstrative workshops
- Participatory monitoring and evaluation of results
- Experimental use of BRD in fisheries management
- Knowledge sharing among researchers, Fishers and managers

This framework proposes a continuum of participatory planning, monitoring and evaluation activities where fishers are integrated in a four-step process as follows:

[2] The meaning for "Rede Viva" (translation life net) is related to the objectives of the project. Firstly, the perspective on responsible fisheries and ecosystem approach to fisheries, in order to reduce environmental impact of net, giving conditions for keeping **alive** unwanted catch after exclusion. Also, the project aims to conduct actions in order to support a social network, including fishers, managers and researches, allowing for communication, interaction and learning.

FIGURE 1
Framework proposed to BRD adoption at South Brazilian Coast



Source: "Resolving environmental issues in the southern Brazilian artisanal penaeid-trawl fishery through adaptive co-management," 2013.

1) participatory assessment of fishery systems dynamics; 2) design, volunteer adoption and participatory monitoring and evaluation or technological modifications; 3) scenario building and management options exploring; and 4) proposal and adoption of management options. A few changes in perspective were observed by researchers, according to ("Resolving environmental issues in the southern Brazilian artisanal penaeid-trawl fishery through adaptive co-management," 2013).

Before we started the project, four general conditions were found. Firstly, lack of institutional innovations and a narrowed view of fisheries management, greatly dependent on fishing restrictions (spatial and seasonal), created scepticism about a differentiated approach to management. This situation is an image representing what have been described for fisheries management in Brazil, as pointed out (Medeiros *et al*., 2013):

- Brazilian fisheries co-management policy recently created has no indication to be implemented in short-term;
- Command-and-control logic of governance still prevails in Brazilian Fisheries Management;
- Lack of consistent information about fisheries system, reducing possibility of broader scope of approaching fisheries management (e.g. Ecosystem Approach to Fisheries).

Secondly, Restrictions to research and researchers, as fishers perceive research as a way to increase restrictions to fishing via new regulations. By this, fishers quite often create an image of researchers as having the same position in rule-making and decision-making. Thirdly, net makers didn't believe that science-based net modifications would have good performance in terms of capture of shrimp. Finally, as a result from the prior conditions, fishers demonstrated unwillingness to cooperate in research and in decision-making (Table 1).

TABLE 1
Major lessons from the Rede Viva project based on fishers' perception before and after the project start

Before	After	Major lessons
Narrowed view of fisheries management	Marine zoning and experimental BRD as management tool	Fishers and manager better expectations on management
Researchers as part of the government Research enhances restrictions on fisheries.	Fishers were supportive to the collaborative research approach	Participatory research recognize fisher knowledge
Netmakers sceptical of "scientific" BRD efficiency	Netmaker proposed a "new" net modifications	Fishers participations enhance experiments design and BRD efficiency
Unwillingness to dialogue and share knowledge	Fishers engaged in experiment and curious to try BRD voluntarily	Engagement of fishers triggered initiatives on co-management

Although Fishers were sceptical of decision-making processes in Brazil (Medeiros, 2009), they have recently been given opportunities to be respected and considered (Vessaz, 2014). Since 2010, managers of Environmental Protected Area of Anhatomrim initiated the formulation of the management Plan. The Environmental Protected Area of Anhatomirim (similar to IUCN Protected Area Category VI, (Dudley, 2008) is located in Santa Catarina State, in the South-Southeast fisheries management region (Figure 2). As a national MPA, jurisdiction belongs to Instituto Chico Mendes de Conservação da Biodiversidade – ICMBIO – in the Ministry of Environment.

This MPA was created in 1992 mainly to protect the resident population of Guiana dolphins (*Sotalia guianesis*) (Floriani, 2005). Without a management plan until 2013, fishing regulations are the same inside as outside the MPA. Local problems have been amplified by existing regional problems (Diegues, 2008; Medeiros *et al.*, 2013; Silva *et al.*, 2013). An advisory board is the management arena, under coordination of local ICMBIO managers. Fishers are represented in two forms: elected community representatives and the Colônia de Pescadores – the local fisher organization.

Rede Viva project came up in the process of building the management plan. Managers created facilitation strategies where participation among fishers had been enhanced. Within a broader scope of fisheries management, managers also accepted the proposal coming from fishers – to create no-take zones based on Fishers' knowledge definition of hatchery zones.

Focus on participatory approach and adaptive learning created room for engagement of fishers in situations they were not used to be. Engagement of fishers in the design of BRD as well as experiment contributed to fishers' change of perceptions. Fishers directly contributed to BRD improvements. They gave suggestion on how tests should be performed, although positive outcomes form net modification were not clearly recognized.

When asked about relevance of bycatch reduction strategies, opinions were mostly positive with 57.1% indicating that "yes" it would be relevant, yet more than a quarter stated that "it depends" (versus "no" and "don't know"; Table 6). Supporting the idea of reducing bycatch, one fisher stated: "[Sometimes], you don't even catch one fish worth eating, and more than 100 kg is thrown away". From the small-sized fleet, all indicated that it would be worth to reduce bycatch, whereas fishers from the medium-sized fleet were more cautious, with 50% stating: "it depends" due to various factors (e.g. season, which portion of the bycatch would be reduced) (Vessaz, 2014).

The process of formulation of management plan contributed to the creation of a suitable arena for institutional innovation in the MPA Anhatomirim. Also, fishers' perception on how their knowledge was integrating in research and management highlighted possibility for change in fisheries management perspective.

Marine Protected Areas (MPAs) are thought to be one of the most effective strategies to support conservation of marine ecosystems (Agardy *et al.*, 2011; Jones, 2007). Despite of positive outcomes for marine life, the socioeconomic benefit can be fuzzy and controversial (Diegues, 2008; Jentoft *et al.*, 2012). Use of MPAs as a fisheries management tool is still recent and subject to evaluation of performance (Macedo, 2008; Macedo *et al.*, 2013; R. L. Moura *et al.*, 2009). MPA Anhatomirim is a good combination of what should be expected for an ecosystem approach to fisheries, especially:

- Acknowledgement of fishers knowledge in research and decision-making
- Adaptive management and participation as principle for conducting the management plan
- Adoption of management strategies to reduce impact of unselective fisheries

The Brazilian National System for Protected Areas (SNUC) defines two categories of MPAs: a) no-take areas where only non-extractive uses are permitted (e.g. education and visiting activities, research); and b) sustainable use where extractive uses are allowed under regulation by a management plan. Included in the latter are Marine Extractive Reserves (MERs).

With innovative institutional arrangements and positive outcomes for SSF, increased attention has been paid to MERs. They are sustainable use protected areas in which traditional use and territorial use rights are legally guaranteed. MERs were designed to modify and extend the concept of Brazilian "extractive reserves" – a conservation and sustainable development framework successfully implemented in the Western Amazonian forest economies (Allegretti, 2008) – to the coastal and marine domains of traditional fishing communities (Diegues, 2008). Although MPA Anhatomirim – as a Environmental Protected Area - is less suitable to recognize fishing livelihoods than MER, management plan offered potential for pursuing the same benefits as expected from MER.

MAIN FINDINGS OF THE CASE STUDY

A synthesis of the main findings is provided in order to help the discussion in the following sections. Our lessons indicate that success in incorporating Fishers' Knowledge is favored when:

- Fishers' engagement in outlining objectives and planning experimental design results in enhancing legitimacy and practical content for later application
- An enabling institutional environment creates identity, respect and trust as social capital among participants in decision-making arenas
- A mutually agreed trade-off between time invested by fishers and scientists or managers assists Fishers to participate in knowledge mobilization without jeopardizing their livelihood activities
- Political will, endorsement and support facilitates the mobilization and integration of knowledge types at a high decision-making levels
- Fishers are better able to contribute knowledge when the objectives are clear and practical and mechanisms for sharing are straightforward
- Fisher household, community and organization contexts and connections are taken into account rather than assuming individualism
- Scientists and managers demonstrate genuine interest in and respect for FK rather than treat it as a token input or simple tool.

CHALLENGE OF USING FK IN EAF

Knowledge bridging is crucial to EAF. Fishers' Knowledge, in combination with natural and social science, has the potential to contribute substantially significantly to sustainable fisheries. We stressed above that FK incorporation and/or recognition is not just a matter of understanding the system to be governed, but it is also a matter of self-belonging and social identity. But the following constraints on these perspectives are thought to remain challenging for effective knowledge bridging in EAF.

Alternative approaches methods and tools less well known

EAF/EBM is still relatively new, and thus shrouded in mystery to some. Broader comprehension is necessary, as well as more robust tools for its application. However, the handling of these new tools can be complicated (Garcia and Charles, 2007). Fisheries Management tools usually relies on conventional and command and control management. For example, although fishers propose a flexible regime with respect to closed seasons that relates to ecosystem dynamics, managers generally believe management without rigid/fixed times is infeasible (G. G. M. Moura *et al.*, 2013). In this case, two aspects should be pointed out:

- Managers face challenges with dialogue facilitation to bridge knowledge and build trust
- Fishery regulation tools are often too rigid and myopic for flexible mechanisms.

Efforts have been made to develop resources to overcome such barriers. Some rely on more sophisticated methodological approaches to bridge science and FK (Espinoza-Tenorio *et al.*, 2013), while others focus on developing facilitation and participatory approaches to engage stakeholders in fisheries management (Bunce *et al.*, 2000).

Nonetheless, in this information age, there is little excuse for managers and scientists especially, but also Fishers, to be ill-informed of the many tools available to enable the incorporation of Fishers' Knowledge and Scientific Knowledge for their mutual benefit. Several online toolboxes (more than those previously mentioned) provide easy access to relevant information on alternative methods and the criteria for choosing among them. In some cases internet access, education and basic literacy may be barriers, but these can be dealt with through innovative partnerships in most instances. The relative ease of access of online resources helps to level the playing field. No longer may Fishers always have to rely on external expert advice to determine methods.

Managers and scientists are usually unskilled in working with FK

Despite the ease of access to information on methods, obtaining FK, especially through dialogue and collaboration, requires social science skills that are scarce or completely lacking in many fisheries authorities. There may still be a gap, especially on the side of fisheries authorities, between knowing about methods and being able to implement them effectively. In examining this issues, the challenges addressed include (Mahon and McConney, 2004):

- Collection and management of qualitative data
- Participatory methods generally for interaction
- Decision-making through negotiation
- Appreciating social-cultural context of FK

Interdisciplinary approaches to fisheries require improved integration of social science professionals to properly address these aspects, situation emphasized after emergence of collaborative management approaches (Symes, 2006). But still, integration is "too little, too late" (Christie *et al.*, 2003).

Conventional management hardly recognizes fisher knowledge

On-going transition to alternative approaches to management is challenging and, thereby, conventional management is still the rule and Ecosystem Approach to Fisheries the exception. As a result, in top-down approaches to management the input of FK in often rare or absent (Gerhardinger *et al.*, 2009).

Reduced contribution of TEK opposes to heavy reliance on quantitative science in conventional management. Managers find it difficult to accept the value and benefits of Fishers' Knowledge in the transition to EAF. The shrimp fishery management regime in Brazil is an example, while despite a clear integration of FK and Scientific Knowledge that would support to alternative methods, managers fall into the trap of using conventional tools that are not recognized by fishers and they tend to respond by lack of compliance(Medeiros, 2009; Medeiros *et al.*, 2013).

FK incorporates views in line with the attempt to promote ecosystem-based management approached (Berkes *et al.*, 1998). This approach emphasizes systems properties, such as, nonlinearity, uncertainties and surprises, and regime shifts (Chapin *et al.*, 2009b; Charles, 1998; Folke *et al.*, 2010; Gunderson and Holling, 2002). In opposition, fallacies of certainty and illusions of controllability (Charles, 2001) typical of conventional management over-value science and under-value FK.

Fishers' Knowledge comprises a complex arrangement of understandings, perceptions and social representations of nature. Nonetheless, they are limited as well as Scientific Knowledge. Exposing the shortcomings of SK helps to prepare managers for accepting FK and EAF, but they also must realize FK is different from science.

Fishers have not adapted to management arenas

Although fishers may be willing to share knowledge, the typical management settings and systems in recently introduced EAF context may still be too formal and science-oriented. By "science" here we mean mainly ecology and economics. As Fishers' Knowledge is mainly built and transmitted by "oral traditions", fishers need to hear and to be heard in the decision-making process. The more incomprehensive the communication and decision-making for fishers' the less they will be engaged. Fishers may be more adept at observation than explanation of resource and environmental features, thus there will be a need to trust somewhat in science. Some level of trust is needed to aid fishers in connecting to scientific information and management arenas (Bodin and Crona, 2009; Matsuda *et al.*, 2010)

Fishers may not have the time to engage in protracted negotiations or decision-making of management if their livelihoods are at stake. Instead, they tend to abandon forums because they can't envision the "next steps" and connections to their livelihoods are unclear.

Management arenas are also political arenas. Fishers, who go to sea for a living, are unlikely to have the stamina for the politics of fisheries ashore. While boat owners, gear suppliers and postharvest entrepreneurs who are often also sources of FK may have more opportunities ashore, they may not have the political skills to enter the fray, such as in co-management negotiations where FK is a valuable resource and bargaining chip to obtain equitable outcomes. In cases where Fishers are adequately self-organized into interest, pressure and advocacy groups, the capacity to engage in exchange may be much higher and the methods for doing so better comprehended.

Group heterogeneity is not knowledge homogeneity

As fishers are no more a homogenous group than are scientists there will be differences in FK that will need to be resolved, tested or decided upon.

Being culturally embedded, FK is often associated with power dynamics to contend with that promote one set of knowledge or knowledge-holders over another regardless of the merit of the knowledge. Knowledge networks can form at different levels, which include family relationship, types of fisheries, community groups and others (Crona and Bodin, 2010).

Some FK may need to be actively contested if scientific evidence is contradictory, so reliance on FK is not a panacea; it may be wrong. In this sense, managers' skills are fundamental in order to create a proper environment to facilitate the de-construction and re-construction of new knowledge. This contradictions could provide insights and/or hypothesis for new research directions, based on a participatory approach, working together to solve research questions.

Changing methods: MOVING from extractive use to collaborative exchange

The information presented and arguments made in the previous sections show that Ecosystem Approach to Fisheries is based on several components in which both FK and SK are crucial. Knowledge is part of the human and social capital of fishing livelihoods. From our perspective, knowledge is not "used", but built and shared together vertically and horizontally among stakeholders in any fisheries social-ecological system. Knowledge is mobilized to negotiate and pursue goals and objectives in multi-stakeholder forums and arrangements. In this respect, we are expected to move in the direction towards "responsible fisheries", based on:

> *(..) identifying and gaining agreement on objectives that best reflect the context and the achievable desires of the key stakeholders; decisions on management measures that are well supported, reflect the objectives and clearly contribute towards attaining them; improved adherence to laws and regulations; and hence lower enforcement costs, fewer infringements, and fewer conflicts. Overall, such achievements should be reflected in greater benefits being obtained at lower cost, and both should be measurable and able to be expressed in economic terms* (Cochrane, 1999).

In terms of the bigger picture that frames the details of required fieldwork, exchanges and other interactions, we propose three main pillars to strengthen the collaborative mechanisms for incorporating FK.

Capacity development

Lack of managers' and stakeholders' skills, low awareness of tools for EAF implementation and deficiencies in the means to bridge knowledge cross all previously mentioned constraints. Therefore, developing capacity to surpass these limitations is urgent for advancement. Capacity development is demanded by managers, scientists and Fishers and, tailored to the needs of each of these groups, it should encompass several objectives:

- To reduce power asymmetries inside management arenas, especially among Fishers, managers and scientists, ultimately leveling the playing field
- To facilitate communication regarding different cultural identities (languages, cultural practices, etc.) and knowledge epistemologies
- To broaden the scope of valid knowledge and management options, in order to embrace the complex nature of fishery systems
- To build fishery social-ecological system resilience; there must be adaptive capacity to innovate collectively and transform systems
- To facilitate self-organization within the fishery system; the less external inputs required the better if collaborative knowledge exchange and integration is to be sustainable
- To address all of the dimensions of capacity such as worldview, organizational culture, adaptive strategies, networking, finances, physical resources and not just "training"

Capacity development strategies assist the empowerment of Fishers and other stakeholders. As Fishers' Knowledge is incorporated into management processes, fishers realize they are meaningful contributors, and sense of belonging can flourish. Fishers are empowered if they are able to sustainably co-manage their resources (Jentoft, 2005).

Better connection between PM&E and management in EAF

The entry point for participatory monitoring and evaluation (PM&E) as a means of inserting FK into Ecosystem Approach to Fisheries cannot be overlooked. The aspects of information exchange through collaborative evaluation provide proof of the value of FK and the benefits of adaptive management. In most fisheries, adaptive management remains more so an ideal than a reality, yet it is an important aspect of EAF. When fishers, scientists and managers gather frequently to monitor and evaluate it is likely that mutual trust and respect will be generated, although this is not inevitable. Fishers knowledge and science will both have an evidence-based platform via monitoring which is very different from trading anecdotes, theory or conjecture in a vacuum. A well-designed PM&E program aimed at institutional learning and adaptation is necessary in view of climate change. Climate change is a phenomenon that may take fisheries beyond the bounds of FK as new scenarios develop, making it more important to conduct PM&E using both science and FK. Although fishers have their own culture and mechanisms to learn and adapt to changes, collaborative approach on PM&E can enhance ability to respond.

Prioritizing Action-Research for EAF projects

Learning-by-doing and adaptation need to be promoted in EAF by the prioritization of action research that respects and uses Fishers' Knowledge as an integral part. This approach requires a reflective-practitioner, adding learning possibilities to all (Leitch and Day, 2000) engaged in EAF.

Also, action-research changes the perspective from short-term to long-term projects in which incentives for compliance and engagement are necessary when outcomes are not clear or immediate. Supported by monitoring systems and participatory approaches, engagement by all stakeholders is encouraged in the design of research and development, as well better incorporation of FK.

Action-research also promotes a collective ownership of information and management decisions, which could be challenging from the perspective of the manager, but necessary from the point of view of other stakeholders. The distinction between FK and knowledge from science becomes blurred as co-production of knowledge takes precedence. This is a clear asset for integration.

CONCLUSION

We explored some lessons from our practical experience with fisher collaborative exchanges within an analysis lightly embedded in the literature on Fishers' Knowledge and Traditional Ecological Knowledge. There is no blueprint recipe for the use of Fishers' Knowledge in Ecosystem Approach to Fisheries, but some strong principles and recommended directions for advancement are presented. There is no denying that fishers and Scientific Knowledge are both required for successful Ecosystem Approach to Fisheries. New thinking on collaborative approaches to this integration is evident. The number of participatory processes and technical tools available for this synthesis is rapidly increasing. Capacity development, participatory monitoring and evaluation, and action research frame the broad direction in which these advances are headed.

Rede Viva Project is providing insights on how to engage fishers in research and decision-making process. Considering bycatch reduction is not a clear management strategy in Brazilian fisheries management, MPA Anhatomirim is also a pilot project for new directions on Ecosystem Approach to Fisheries. Challenges as well opportunities mentioned are present, and collaborative work with fishers, researchers and manager can better address this gas we highlighted.

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A method for assessing fishers' ecological knowledge as a practical tool for ecosystem-based fisheries management: seeking consensus in southeastern Brazil

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ABSTRACT

Studies on fishers' ecological knowledge (FEK) and local ecological knowledge (LEK) have rarely been undertaken for practical application in a management context. Here, we describe a methodology to access FEK that was designed under an ecosystem-based fisheries management framework. The procedure was adapted from the Delphi technique, which seeks experts' consensus, and focused on several spatial and temporal issues related to the small-scale fisheries of the northern coast of São Paulo, Brazil (particularly, in Ubatuba, between 23°20' S and 23°35' S). Experienced fishers, considered as experts, were selected during a pilot phase to participate in two sequential rounds of semi-structured interviews at 3 main landing sites and 12 coastal fishing communities. The issues addressed were: (1) spatial and seasonal occurrence of mature females and juveniles of the main commercial species, (2) fishing grounds and bycatch species for each type of fishing gear, and (3) fishers' suggestions for local fisheries management (e.g. mesh and size of gillnets, closure seasons, gear restrictions by fishing area). It was possible to identify consensus rates on the spatial and temporal issues, as well as on fishers' management suggestions. The former allowed the construction of maps representing fishing grounds and the local spatial distribution of different fishery stocks strata. We illustrate the output by focusing on five fishery stocks: the seabobshrimp *Xiphopenaeus kroyeri*, the whitemouth croaker *Micropogonias furnieri*, the inshore squid *Loligo* spp, the white shrimp *Litopenaeus schimitti* and the blue runner *Caranx crysos*. Overall, the results provided new guidelines for future local fisheries management and conservation initiatives. The methodology proved to be useful for the definition of essential fish habitats (EFHs), suggesting their potential application in other locations.

INTRODUCTION

The rapid change in fisheries systems as a consequence of continuous population growth, globalization, improved technology, increasing fleet operations, as well as climatic and environmental changes, interfere with and threaten the dynamic interaction between humans and the natural environment. Therefore, natural resource management must be adaptive and respond quickly and efficiently to new realities (Berkes, 2010; Gasalla, 2009; Miller *et al.*, 2010).

Communities dependent on fisheries resources are often the first to perceive changes in aquatic ecosystems and in the fishery stocks with which they interact, as these affect directly their livelihoods and income (Friesinger and Bernatchez, 2010). In this sense, fishers' experience-based knowledge about marine ecosystems and resources are of great value for fisheries management (Hill *et al.*, 2010). However, while recognition of the value and significance of studies on local ecological knowledge (LEK) or fishers' ecological knowledge (FEK) has increased in recent decades (Allison and Badjeck, 2004; Begossi, 2008; Berkes *et al.*, 2001; Drew, 2005; Gasalla, 2004; Johannes, 1998; Johannes *et al.*, 2000; Neis *et al.*, 1999; Silvano *et al.*, 2008; Wilson *et al.*, 2006), resource-dependent communities have often remained politically, culturally and socioeconomically marginalized (Brook and McLachlan., 2005; Lam and Borch, 2011) such that these studies findings have rarely been used for practical application in management, especially in ecosystem-based fisheries management (EBFM) (Gasalla and Diegues, 2011; Gasalla and Tutui, 2006).

In this type of management, the focus is on an integrated vision of the ecosystem within which the fishery is placed, rather than on single target fishery stocks and fishing fleets (Murawski, 2000). Thus, it should include ecological, social and economic factors (FAO, 2003) and simultaneously consider fish, fishers, the maintenance of fishery resources and the environment (Berkes, 2010; Degnbol *et al.*, 2006; Francis *et al.*, 2007; Link, 2002; Pikitch *et al.*, 2004; Pitcher and Lam, 2010). As an integral part of EBFM, the concept of "essential fish habitats"(EFHs) has been applied, and is based on the "health" of fish habitats and their productivity (Rosenberg *et al.*, 2000). The identification of EFHs is important to protect areas that are critical to marine resources, including spawning and nursery grounds of commercially important species (Bergmann *et al.*, 2004; Conover and Coleman, 2000; Francis *et al.*, 2007).

In many developing countries, including Brazil, governments face many structural obstacles to gathering data, implementing regulations and making appropriate marine resource management decisions (Allison, 2011; Allison *et al.*, 2012; Kooiman *et al.*, 2005). In this sense, FEK can be useful to identify EFHs and other important data for EBFM (Bergmann *et al.*, 2005), particularly where detailed scientific datasets are unavailable and fishers can be the only source of information of environmental and stock conditions (Johannes *et al.*, 2000; Silvano and Begossi, 2010). Moreover, despite wide recognition of the importance of FEK studies, there are only a few studies that address methods to access this knowledge (Davis and Wagner, 2003; Huntington, 1998, 2000).

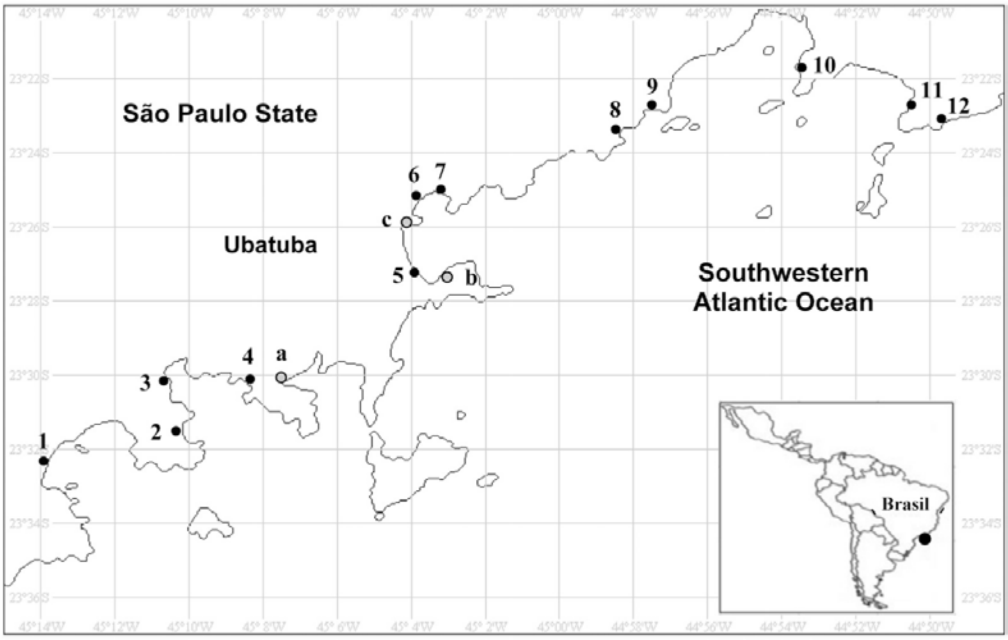
This paper aims to present a tested method, adapted from the Delphi technique, and evaluate its efficiency to assess strategic FEK with potential to provide more accurate responses to issues of importance to EBFM initiatives, including the identification of potential EFHs, fishing grounds, bycatch species per fishing gear as well as local fishers' suggestions for management in the study area.

Study area

Ubatuba is located on the north coast of São Paulo (between 23°20' S and 23°35' S), which lies in the southeastern Brazilian shelf (Figure 1). The last shelf receives seasonal upwelling and cool intrusions, resulting in moderately high productivity (Campos *et al.*, 2005; Castro and Miranda, 1998).

Hence, Ubatuba is characterized by intense fishing activity, mostly small-scale. Local commercial fishing records date from 1910, and over decades, fishing became a major source of income of the municipality, which presents many fishing communities and three main landing sites (Figure 1). Signs of overfishing and declining yields were being noted as far back as the 1970s (Diegues, 1974). Moreover, the area has been the scene of many conflicts, past and present, with regard to the use of natural resources. Nowadays, the study area is part of a recently created type of marine protected area (Área de Proteção Ambiental do Litoral Norte de São Paulo) whose management plan

FIGURE 1
Study area: Ubatuba region at São Paulo's northern coast, in southeastern Brazilian shelf. The numbers (1–12) correspond to the main fishing communities while the letters (a–c) to the main landing sites in the study area. Please see the names of fishing communities and landing sites as well as other details in Table 1



is still under development and future fishing restrictions are still unclear (SMA, 2012). So far, some fisheries are still allowed in the area, mostly small-scale, but there is a movement to promote a more restrictive protection level under the definition of that management plan.

MATERIALS AND METHODS

The adapted Delphi methodology

The methodology addressed in this study was adapted from the Delphi method. This method involves applying several rounds of consultations to a set of experts on a particular subject. After each round of consultation the results of all responses are summarized and presented individually to each participant. Participants can change their opinions and contributions, according to new general data, in the next round of consultations, which have their results represented to all involved, and so on, in the sequential rounds. The purpose of the method is to find consensus, while a key premise is the ability to maintain respondent anonymity throughout the process (Barrett, 2009; Linstone and Turoff, 1975; Zuboy, 1980).

We adapted the Delphi method in this study in the following ways. First, a pilot phase addressed the identification of key fishers (here considered as experts) through interviews, pre-structured questionnaires, and pre-established criteria. The second and third phases consisted of two rounds of interviews with the key fishers selected. All the information provided by key fishers at the first round of interviews were tabulated and presented to key fishers, individually, at the second round. We considered as consensual information/data those confirmed by more than 50% of key fishers at the second round of interviews. The methodology was previously explained to interviewees and they were kept anonymous so that individual opinions were not influenced by the opinions of specific individuals and so that the chance of conflict between stakeholders was reduced (Zuboy, 1980). Finally, we requested permission to publicize the collection of information found (Scholz *et al.*, 2004).

Pilot phase: selection of key fishers

In order to access reliable and valid data from FEK, it is essential to identify the most qualified and experienced fishers to be responding to the questionnaires (Moreno *et al.*, 2007). Thus, between April and September 2009 two fieldtrips were made, and a pilot phase was conducted in order to select key fishers. For this purpose, the researcher visited the major landing sites of Ubatuba: Saco da Ribeira, Cais do Alemão and Ilha dos Pescadores (Pincinato *et al.*, 2006; Vianna and Valentini, 2004) and 12 coastal fishing communities, including: Pinciguaba, Barra Seca, Itaguá and Maranduba, which are the communities that presented the largest number of vessels in the municipality (Vianna and Valentini, 2004). During the visits, local small-scale fishers were approached and interviewed with the use of semi-structured questionnaires.

The "snowball" methodology, also called "chain of informants", was used in this pilot phase of the project. Each interviewed fisher was thus asked to indicate the next respondent to contribute in the study, in succession (Scholz *et al.*, 2004; Silvano and Begossi, 2010). In this way, a total of 109 fishers were interviewed (Table 1).

TABLE 1
Number of interviewed fishers at coastal communities and landing sites of Ubatuba coast, southeastern Brazilian shelf

Corresponding number or letter in Figure 1	Fishing communities and landing sites	No. of interviewed fishers	Site location in Ubatuba
1	*Maranduba*	7	South
2	*Brava da Fortaleza*	2	South
3	*Fortaleza*	1	South
4	*Lázaro*	11	South
5	*Itaguá*	6	Center
6	*Perequê-açu*	9	Center
7	*Barra Seca*	10	North
8	*Félix*	2	North
9	*Promirim*	8	North
10	*Almada*	8	North
11	*Picinguaba*	10	North
12	*Camburi*	8	North
a	*Saco da Ribeira* [a]	13	Center
b	*Cais do Alemão* [a]	5	Center
c	*Ilha dos Pescadores* [a]	9	Center
-	Total: 12 coastal communities and 3 landing sites	109 fishers	-

The first criterion considered for selection was the willingness and availability of the respondent to participate in the research, since a fisher who did not present interest in sharing knowledge, even if experienced, would be of no value to the FEK investigation. However, after the study procedures were explained, including the method used and the goal of seeking consensus, many fishers were willing and enthusiastic to contribute. The second criterion adopted was the experience of the respondent in fishing, focusing on the fishers who had more time fishing, especially in the study area. The third criterion was the respondent's current regime on fishing, or dedication to fishing activity. Those with exclusive dedication or that had fishing as main occupations were given priority. Finally, the fourth and last criterion gave preference to fishers over 30 years old.

The interviews lasted an average of 45 min, totaling 82 h of interviews, distributed during 30 days (two field trips of 15 days each). In the three landing sites, it occurred in wharves or inside the anchored vessels, and in the 12 fishing communities, on ranches, beaches and fishers' houses. Sometimes more than one community or landing site was visited in the same day. The number of fishers interviewed per day varied from 6 to 12, according to the availability of the interviewees, the ability of respondents to transmit their knowledge and climatic and oceanographic conditions. For example, when there were cold fronts, fishers usually did not go to sea for fishing, making it easier to find them at the landing sites and in the fishing communities. Throughout this process, 41 small-scale key fishers (39 male and 2 female) were selected to participate in the next steps of the study, as described below.

First round of interviews with key fishers

The first round of interviews with the 41 key fishers selected occurred during the period of June–December 2009, during two field trips of 1 month each, at the landing sites and coastal communities (Table 2). The number of fishers interviewed per day varied from one to three. The interviews lasted an average of 2 h and a half, totalizing approximately 102 h of interviews.

TABLE 2
Number of interviewed key fishers in coastal communities and landing sites of Ubatuba coast, southeastern Brazilian shelf and characteristics of those communities and landing sites

Fishing communities and landing sites	N° of interviewed key fishers	Characteristic of the community or landing site
Camburi	2	Isolated and more traditional
Picinguaba	3	Isolated and more traditional
Almada	5	Touristic and traditional mix
Promirim	4	Touristic and traditional mix
Félix	2	Only a fell fishers remains
Barra Seca	4	Touristic and traditional mix
Perequê-açu	4	Very touristic and traditional mix
Itaguá	2	Very touristic and traditional mix
Lázaro	5	Very touristic and traditional mix
Brava da Fortaleza	1	Touristic and traditional mix
Fortaleza	1	Touristic and traditional mix
Maranduba	1	Touristic and traditional mix
Saco da Ribeira [a]	2	Mainly for gillnets boats and pink-shrimp and pair-bottom trawlers
Cais do Porto e Alemão [a]	2	Mainly for gillnets boats
Ilha dos Pescadores [a]	3	Mainly for seabob-shrimp trawlers
Total: 12 coastal communities and 3 landing sites	41 key fishers	-

[a] Landing sites.

The interviews were pre-scheduled with most key fishers, since most of them provided phone numbers to the researcher in the pilot stage. Only 4 of 41 fishers had no phones themselves, so they gave family members' phone numbers to facilitate contact. All key fishers were interviewed individually. However, there were cases in which the interviews of the pilot phase and the first round of interviews with key fishers occurred on the same day. This happened when a fisher interviewed met all of the required criteria and was available and willing to respond to the first round of interviews with key fishers at that time. Thus, in order to ensure that these opportunities were not lost, the two questionnaires (interviews of the pilot phase and of the first round) were applied sequentially.

The questionnaire of the first round of interviews addressed issues related to spatial and temporal patterns of local fisheries and12 commercially important species landed in the region (Instituto de Pesca, 2008). Regarding spatial issues, the key fishers pointed to their fishing areas and the main places of occurrence of juveniles and mature females of the target species. The species were identified by their common names and images of the species were presented to fishers to confirm their recognition (Silvano *et al.*, 2006; Silvano and Valbo-Joergensen, 2008). With respect to temporal matters, seasonal calendars (Berkes *et al.*, 2006) in table form were used and completed with FEK information about seasonality of occurrence of the species in different stages of life (young and mature females). Key fishers identified bycatch species associated with different fishing gear, also identified by their common names. And finally, questions were raised regarding solutions, envisioned by the key fishers, for fisheries management in the study area. All the data found in the questionnaires of the first round of interviews with key fishers were scanned, tabulated and systematized.

Second round of interviews with key fishers

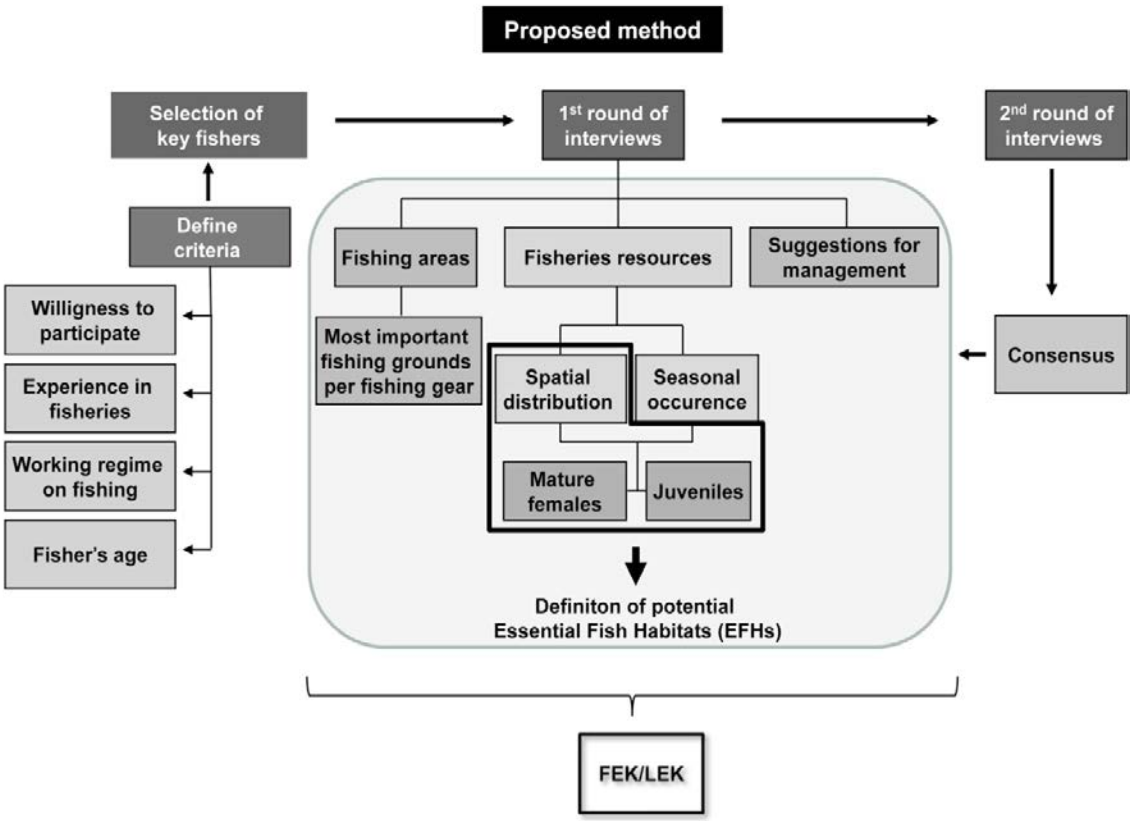
The second round of interviews took place between February and March 2010, during one fieldtrip of 45 days. The interviews lasted an average of 2 h each, totaling 74 h of interviews. The number of key fishers interviewed per day varied from two to four. Among the 41 key fishers interviewed in the first round, it was possible to locate only 37 to contribute to the second round. This was due to several factors, such as fishers' fishing trips during the field period devoted to the second round, fishers' health problems, or difficulty in locating the fishers in the landing sites.

During the second round of interviews, the information found and tabulated in the first round was presented to the 37 fishers involved in the study and they could review their responses according to the new general data. In this round of interviews we used maps of the region of Ubatuba (Nautical Chart number 1635) where the respondents pointed out their fishing areas and location of major fishing grounds, as well as where concentrations of young and mature females of the target species were located. We chose to introduce the maps during the second round of interviews assuming the fishers would be more comfortable with the researcher in that stage. In the case of fishers who were illiterate, or had difficulties reading, reference points were used, such as islands, beaches, cliffs and deep isobaths, to help interviewees to interpret the maps. Hence, fishers personally marked or pointed out to the researcher the location of these areas, in a process of participatory mapping (Berkes *et al.*, 2001). Subsequently, all maps were digitized and overlaid to identify consensus with regard to the most frequented areas according to fishing gear, or areas of higher occurrence of resources in different stages of life. For the temporal issues, the months of occurrence of young and mature females cited during both rounds of interviews were compared with respect to their percentage of citations, and the months of major significance were highlighted. The information considered consensual were those confirmed by more than 50% of key fishers. Finally, all respondents' suggestions for fisheries management made during the first round of interviews were presented to key fishers, individually, in the second round and again those suggestions that were confirmed by more than 50% of key fishers were considered consensual. The same researcher applied all the interviews and there was no field assistant or additional researches participating during the interviews. Figure 2 shows a schematic illustration of the proposed method, and its sequence.

RESULTS

The selection of "experts" allowed us to access the oldest knowledgeable fishers in the fishing communities and landing sites. Consequently 76% of the interviewees selected were over 45 years old, had at least 30 years experience in the study area, and dedicated the majority of their time to fishing activities. Moreover, the data provided by key fishers allowed the identification of consensual information regarding: (1) spatial and seasonal occurrence of mature females and juveniles of commercial species; (2) fishing areas, bycatch species and most important fishing grounds per fishing gear; (3) suggestions for local fisheries management (e.g. mesh and size of gillnets, closure seasons, gears restriction by fishing area).

FIGURE 2
Summary of the stages addressed during the process of accessing FEK/LEK to identify important issues for ecosystem-based fisheries management in Ubatuba, southeastern Brazil



Commercial species ecological data

Specific output on spatial and temporal issues are illustrated for five different fishery stocks: the croaker Micropogonias furnieri, the seabob-shrimp Xiphopenaeus kroyeri, the inshore squid *Loligo* spp., the white shrimp Litopenaeus schimitti and the blue runner Caranx crysos. The first two are species with the major landing biomasses, in kilograms, in Ubatuba, and represent fish resources of greatest commercial value in the municipality (Instituto de Pesca, 2008). The squid and the white shrimp were chosen because of their importance (in catch and income) for local communities, the squid during summer, especially from November to April (Rodrigues and Gasalla, 2008; Postuma and Gasalla, 2010), and the white shrimp during winter, especially from June to September (Costa *et al.*, 2007). Finally, the blue runner Caranx crysos was also selected because of its commercial importance and the lack of local data and knowledge regarding its ecology in the study area (and in Brazil, in general).

After the whole process, maps with spatial data (Figure 3) and tables with seasonal data (Tables 3 and 4) were developed, based on consensual FEK relating to the occurrence of mature females and juveniles. With regards to the spatial data, the maps allowed the identification of the areas, cited by more than 50% of the key fishers, which were considered as potential EFHs.

FIGURE 3

Area of occurrence of mature females (in red), juveniles (in green), and both (in blue) of: (a) *Micropogonias furnieri*, (b) *Xiphopenaeus kroyeri*, (c) *Loligo* spp., (d) *Litopenaeus schimitti* and (e) *Caranx crysos*, as indicated by the fishers; (n) corresponds to the number of fishers that provided information upon the fishing gear. The circled areas are those cited by more than 50% of interviewees. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article published in Fisheries Research Journal)

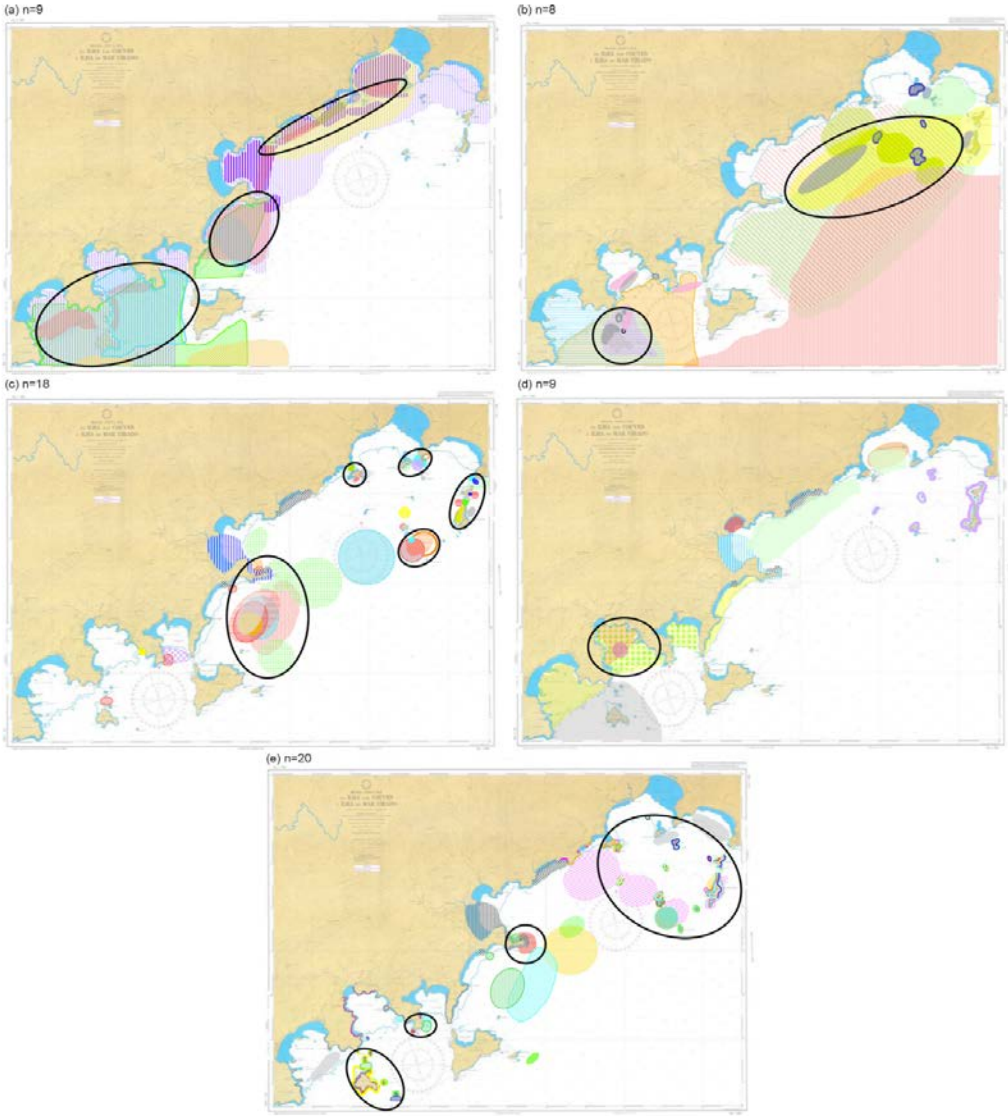


TABLE 3

Number of citations for the months of occurrence of mature females of the resources addressed in the study, during the first (1st) and second (2nd) round of interviews with key fishers in Ubatuba. The months cited by more than 50% of interviewees are boldfaced

Fishery resource	Rounds	J	F	M	A	M	J	J	A	S	O	N	D	Total number of citations
Micropogonias Furnieri	1st	**22**	**21**	10	10	12	14	14	14	12	10	**26**	**28**	33
	2nd	**22**	**19**	9	7	8	12	13	12	8	9	**20**	**22**	31
Xiphopenaeus kroyeri	1st	7	6	8	7	7	4	4	4	6	6	7	7	18
	2nd	**6**	5	**10**	**10**	**10**	**6**	**6**	4	**6**	**7**	**7**	**7**	11
Loligo spp.	1st	6	8	8	4	2	1	1	0	0	0	6	9	20
	2nd	**14**	**17**	**17**	6	3	0	0	0	1	1	4	**12**	22
Litopenaeus schimitti	1st	4	4	4	3	4	3	3	2	2	3	4	3	14
	2nd	**7**	2	4	1	1	1	0	1	2	3	**4**	**7**	11
Caranx crysos	1st	**7**	**8**	**6**	0	0	0	0	0	0	1	5	**8**	11
	2nd	**7**	**9**	**6**	1	0	0	0	1	1	1	4	**6**	9

TABLE 4

Number of citations for the months of occurrence of juveniles of the resources addressed in the study, during the first (1st) and second (2nd) round of interviews with key fishers in Ubatuba. The months cited by more than 50% of interviewees are boldfaced

Fishery resource	Round	J	F	M	A	M	J	J	A	S	O	N	D	Total number of citations
Micropogonias Furnieri	1st	6	6	5	5	6	6	4	5	7	7	7	7	17
	2nd	**22**	**24**	13	12	**14**	**17**	**17**	**17**	13	13	**22**	**21**	27
Xiphopenaeus kroyeri	1st	5	4	4	2	3	9	4	3	2	4	4	6	16
	2nd	**9**	7	1	1	1	**13**	2	1	2	5	5	4	17
Loligo spp.	1st	6	6	5	5	6	6	4	5	7	7	7	7	17
	2nd	**22**	**24**	13	12	**14**	**17**	**17**	**17**	13	13	**22**	**21**	27
Litopenaeus schimitti	1st	3	1	2	2	3	**8**	2	1	0	0	0	2	13
	2nd	**12**	**12**	**12**	**12**	**11**	**13**	4	1	0	0	0	2	20
Caranx crysos	1st	3	3	**5**	3	3	3	1	0	1	0	0	3	7
	2nd	5	6	**10**	6	5	5	4	1	1	1	4	5	16

Finally, after key fishers were confronted with the responses of the first round of interviews, the majority of them did not change their contributions, but rather, they added more information at the second round of interviews (especially by agreeing with other key fishers' contributions). For example, at the first round of interviews 60% of key fishers considered only the summer months as the spawning season of the whitemouth croaker (Micropogonias furnieri), however, after the general results of the first round were presented to them, 90% added the information that whitemouth's croaker females are also caught with eggs during the winter months, although less frequently than in summer.

Fishing gear features

Questions aimed at the fishing gear, directed for the catches of the addresses species in this study, were: (1) fishing grounds and (2) bycatch species (Table 5). The information collected regarding fishing grounds allowed the construction of general maps (Figure 4) representing the fishing grounds per type of fishing gear. Maps refer only to the information presented by the fishers that were concurrently fishing with a specific fishing gear (differently from the data regarding different species ecological data, that could be transmitted by key fishers that target that species in the past).

TABLE 5

Summary of information on the addressed fisheries: (a) target species; (b) number of bycatch species and number of those that showed more than 50% of citations, boldfaced; (c) number of fishing grounds pointed out on maps by the key fishers, and those cited by more than 50% of the interviewees, boldfaced; (d) number of management suggestions for each fishing gear and number of suggestions cited by more then 50% of interviewees, boldfaced in the table

Fishing gear	Target species	Bycatch species		Fishing grounds		Management suggestions	
		N.	>50%	N.	>50%	N.	>50%
Shrimp-trawlers	*Xiphopenaeus kroyeri*	46	**11**	9	**3**	4	**2**
Gillnets	*Micropogonias furnieri*	17	**6**	18	**2**	7	5
Hand jigs	*Loligo* spp.	0	0	17	**6**	0	0
Gillnets for white shrimp	*Litopenaeus schimitti*	30	**4**	10	**1**	2	**2**
Line and hook	*Caranx crysos*	0	0	9	**4**	0	0

Therefore, fishers did not change their contributions in the second round, although, it allowed fishers to identify them on in situ maps. Moreover, the overlapping of the digitalized cognitive maps of each fishing gear allowed the identification of the most important (or most frequent) fishing grounds per fishing gear.

Local fishers' management suggestions

The key fishers, at the first round of interviews, provide with many suggestions for local fisheries management. Table 6 presents the recommendations supported by more than 50% of the fishers at the second round of interviews (and thereby considered consensual) together with their explanations given in respect of each issue, per fishing gear. When comparing the results of the two rounds of interviews, we observed that the majority of fishers (90%) maintained their suggestions at the second round. However, 100% of the key fishers agreed with at least three suggestions of other respondents at the second round of interviews. This allowed the identification of key fishers' consensual management suggestions for local fisheries at the study area. Recommendations focused especially on the need for a reconsideration of present closing seasons' duration, new regulations and spatial zoning concerning the fishing areas of larger vessels and nets' mesh size to avoid the catch of juveniles.

FIGURE 4

Maps of the total area of fishing operations of: (a) shrimp-trawlers, (b) gillnets, and (c) hand jigs (d) Gillnets for white-shrimp and (e) Line and hook. Each deferent color refers to the fishing area of a different fisher; (n) corresponds to the number of fishers that provided information upon the fishing gear. The most significantly cited areas (by more than 50% of fishers) are circled. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article)

TABLE 6
Summary of fishers' consensual suggestions (cited by more than 50% of key fishers) for management initiatives in the study area

Fishing gear	Target species	Suggestions to management	Fisher's given reasons
Shrimp-trawlers	*Xiphopenaeus kroyeri (seabob-shrimp)*	Increase the fishing closure season from 3 to 4 months long.	After the closure season (March to May) they still catch small (juvenile) shrimps (especially during June).
		Allow only seabob-shrimp trawlers to operate up to 30m (Restrict large trawlers).	Other type of trawlers (pair-bottom trawlers and pink-shrimp trawlers) occur in deeper waters, where target species are also present, while the shrimp-seabob trawlers can not operate at depths greater than 30m.
Gillnets	*Micropogonias furnieri (whitemouth croaker)*	Prohibit mesh size smaller than 12 cm in gillnets.	The smaller the mesh more juveniles are caught. A 12cm mesh size catches good size fish and not juvenile.
		Prohibit purse-seiners of catching the white-mouth croaker.	The purse-seiners catch enormous quantities of the stock at once, reducing the stock size available to artisanal fishers.
		Define a closed season for the whitemouth croaker.	There is no closed season defined for the stock
		Prohibit boats over 11m length of fishing at depths less than 30m.	Industrial vessels catch also in shallow and coastal areas, reducing stock available for artisanal fishers.
		Define a spatial zoning for fishing with gillnets according to the size of boats.	Smaller boats do not have autonomy to operate in deeper waters; shallower depths should be guarantee and reserved for smaller boats (less than 12m length)
Gillnets for white-shrimp	*Litopenaeus schimitti (white shrimp)*	Prohibit boats larger than 11m lengths for the white-shrimp near the coast. Restrict the fishery to the smallest boats and canoes.	The white shrimp occurs in the study area only seasonally when artisanal fishers have the opportunity to catch it.

DISCUSSION

In this paper, we present a method to access FEK as a practical tool for ecosystem-based fisheries management. Here we agree with Berkes (2011) that ecosystem-based management (EBM) is not a simple exercise, as it implies uncertainties and complexity, and presupposes an interdisciplinary approach to management objectives. According to Berkes (2011), implementing EBM is more like a revolutionary, than an evolutionary process, as it requires going beyond conventional management practices. Nevertheless, we argue that the participation of fishers, and the incorporation of their ecological knowledge, is an essential part of a process that aims to implement ecosystem-based fisheries management (EBFM), especially in data-poor contexts, where FEK can be the only source of data on the resources and fleets distribution. In this sense, methods to access local and traditional ecological knowledge are of great value.

There are many studies that focus on traditional knowledge, and specifically, on fishers' ecological knowledge (FEK). Many use open or semi-structured interviews. The interviews can be applied to the maximum number of respondents as possible (Begossi and Figueiredo, 1995; Paz and Begossi, 1996; Silvano and Begossi, 2005; Silvano *et al.*, 2006, 2008), to a few select ones or to a group of interviewees (Huntington, 1998, 2000). According to Silvano *et al.* (2008), the choice of the approach will depend on the research objectives, which seems critical since it will influence directly the quality of the results.

Considering important contributions that were useful in our adaptation of the Delphi technique to approach FEK to EBFM issues, Davis and Wagner (2003) and Huntington (1998) may be highlighted. Davis and Wagner (2003) selected experts throughout solicited recommendation of local knowledgeable fishers in Nova Scotia

(Canada), while Huntington (1998) applied semi directive interviews, individually or to groups, to document TEK in a species specific research on beluga whales in Alaska (US). The method we propose somehow incorporates some considerations of both studies, among others. However, our study seems to be the first application of the Delphi method to this field, and therefore, to use rounds of interviews to find consensus. Moreover, despite extensive literature on FEK studies, and few studies on methods to access it for several purposes, there is a lack of detailed methodologies that explain how this valuable knowledge can be properly and effectively considered and incorporated into EBFM schemes. Additionally, the skills needed, the approaches, challenges, and difficulties faced by researchers who are dedicated to this field are rarely described.

Firstly, the method we describe allowed the identification of the most experienced fishers in the study area and for consensus to be reached with regards to the range of information and knowledge that these fishers hold. Overall, the second round of interviews provided an opportunity for key fishers to consider new information, and to confirm, or not, the information provided by other respondents. These data allowed important outputs such as the construction of maps with EFHs and identification of the major seasons of spawning and recruitment of important species of commercial value, which seems to be still very unclear for local science. In this sense, a consistent compatibility was found between the data transmitted by key fishers and some previous scientific studies in other regions for the: (1) white-mouth croaker Micropogonias furnieri (Menezes and Figueiredo, 1980; Robert and Chaves, 2001; Costa and Araújo, 2003; Bernardes *et al.*, 2005; Carneiro *et al.*, 2005; Carneiro, 2007; Vazzoler, 1971; Vazzoler *et al.*, 1989); (2) seabob-shrimp Xiphopenaeus kroyeri (Nakagaki and Negreiros-Fransozo, 1998; Fransozo *et al.*, 2000; Castro *et al.*, 2005; Freire, 2005); (3) inshore squid Loligo spp. (Perez *et al.*, 2002, 2005; Martins and Perez, 2006; Rodrigues and Gasalla, 2008; Gasalla *et al.*, 2010; Postuma and Gasalla, 2010); (4) white shrimp Litopenaeus schimitti (Chagas-Soares *et al.*, 1995; Costa, 2002; Castilho *et al.*, 2007; Costa *et al.*, 2007; Gonçalves *et al.*, 2009) and (5) blue runner Caranx crysos (Leak, 1981). However, these studies were conducted in other areas of the Brazilian coast, and there is no information for our study site. Nevertheless, we do believe that FEK does not necessarily need to be validated by scientific data, but rather, they can be complementary one to another. In this sense, FEK validation through scientific literature was not included as part of the proposed method.

The FEK identified may help to fill the data gap in the study area, and thus increase the potential to support ecosystem-based management of fishery resources and activities. In this sense, we found the presented method as a transparent, consensual and useful tool to assess FEK and for its inclusion in EBFM, since it revealed multispecies ecological data, fishing grounds, as well as eventually pertinent local fishers' suggestion for management. The identification of the temporal and spatial distribution of resources, including EFHs, is of great value for EBFM and for planning MPA (Marine Protected Area) management (Bergmann *et al.*, 2004, 2005). The information regarding EFHs is new, since these habitats had not been previously identified or defined at the study area for any species. Besides, mapping the most important fishing grounds and bycatch species will allow effective measures for the conservation of resources, and may simultaneously ensure specific rights for fishers themselves. The most frequented fishing ground per fishing gear were not identified and mapped in previous studies for the study area. Another important point relies on fishers' suggestions for local fisheries management, since identifying measures that are both accepted by fishers and scientifically valid is of utmost relevance for the planning and long-term success of ecosystem-based fisheries management (Himes, 2003; Bundy *et al.*, 2008; Lawson *et al.*, 2008). The data obtained were not implemented in practice so far. However, the study area is part of a recent implemented type of MPA, which the management plan is still under development. There is not any provision in the MPA management criteria for fishers knowledge to be recognized and used. Nevertheless, we expect the findings of the study may contribute, in this sense, by: (1) providing EFHs for important fisheries resources, (2) pointing the important fishing grounds that should be considered when restricting small scale fishers' rights to access specific areas, and (3) indicating areas relevant for the protection of particular fisheries/fishers and for co-management schemes.

The incorporation of LEK/FEK and fishers' participation in management plans are also important in order to decentralize government and institutional power, reduce conflicts between fishers and governmental institutions, promote community development and empowerment, and support enforcement, helping to ensure representativeness of local actors in the public policy arena (Begossi, 2008; Garcia and Charles, 2008; Gasalla, 2011; Lam and Pauly, 2010). Furthermore, in traditional fisheries management, purely biological objectives may be imposed in a top-down manner, without considering fishers' livelihoods. In this case, it is unlikely that management and enforcement will be successful, since fishers will not agree and cooperate with a non-participatory approach. In general, this form of conduct leads to more conflicts between fishers and governments (Bundy *et al.*, 2008; Lawson *et al.*, 2008). On the other hand, the objectives of fisheries management, whether social, economic or cultural, cannot be achieved in the long term. The incorporation of LEK/FEK and fishers' participation in management plans are also important in order to decentralize government and institutional power, reduce conflicts between fishers and governmental institutions, promote community development and empowerment, and support enforcement, helping to ensure representativeness of local actors in the public policy arena (Begossi, 2008; Garcia and Charles, 2008; Gasalla, 2011; Lam and Pauly, 2010). Furthermore, in traditional fisheries management, purely biological objectives may be imposed in a top-down manner, without considering fishers' livelihoods. In this case, it is unlikely that management and enforcement will be successful, since fishers will not agree and cooperate with a non-participatory approach. In general, this form of conduct leads to more conflicts between fishers and governments (Bundy *et al.*, 2008; Lawson *et al.*, 2008). On the other hand, the objectives of fisheries management, whether social, economic or cultural, cannot be achieved in the long term if there is no ecological balance and biological yields maintenance (Degnbol *et al.*, 2006).

Nevertheless, some considerations regarding the method should be made. According to Brook and McLachlan (2005), the personality of the interviewer, the level of familiarity with the interviewees, the approach and the method used, fundamentally influence the study results and the nature of the responses in LEK studies. In this study, we found that as the different steps were followed, fisher bonds/relationships were strengthened, allowing for greater reliability in the data provided, since this empirical knowledge was not disseminated quickly and accessed at once (Drew, 2005).

Such a research approach contrasted with the ongoing experiences of fisher participants with the top-down implementation of a new São Paulo's marine protected area, which at least at its foundation, threatened fishing activities as it was not based on consultations (Agardy, 2005; Mascia, 2003) with local fishing communities. Obviously, when the process started fishers found themselves apprehensive and insecure about the possible impacts on their livelihoods and incomes. However, the degree of contact and respect developed during the research described here led to fishers showing greater confidence in transmitting their knowledge. One factor in generating this level of confidence was the fact that the same researcher went to all the field trips alone and always interviewed the fishers on their own. It was important that no new actors/researchers appeared during the process, which would likely have weakened the bonds that had developed between researcher and fishers. Hence, if the researcher is not going to field alone, we suggest that it is important that the team remains the same during the whole process of interviews. Moreover, the way of approaching fishers proved to be successful in this case, but one can suggest that a gender/age reason could have contributed to the success of this interaction, since the interviewer was a young woman and the key fishers were mainly older males. However, several issues should be carefully considered significantly more relevant.

Firstly, the Adapted Delphi Methodology seems a simple exercise to be employed, but some points need to be carefully considered in order to avoid failures in the reliability of results. It seems critical that an appropriate and representative group of respondents are selected, prioritizing those with proven experience (the experts) to contribute to the research (Davis and Wagner, 2003). Secondly, during the interviews the researcher must demonstrate impartiality to the issues addressed, to exclude the possibility of imposing one's own views and preconceptions upon a subject, which could bias the results. In present study the researcher introduced herself to respondents as a student, from a oceanographic institute, with limited fishing knowledge, and as a sincere apprentice. Third, once a round of interviews was completed, these had to be summarized and presented back to the group of fishers in the most effective manner as possible. At this stage, it is essential not to ignore disagreements, which can lead to artificial consensus regarding the information provided by fishers. According to the findings of this study, when these steps are taken, the chances of success greatly increase.

However, the method also presents some constraints. It does not allow fishers to undertake real-time discussions of different points of views and possible exchange of knowledge, since the interviews are applied individually and the respondents are kept anonymous. Another constraint is that when a fisher lacks specific knowledge, he or she may speculate, as some experienced fishers may not admit to not knowing a particular answer and thus "lose face". And finally, the fisher's own interest may influence the answers, biasing the obtained results (e.g. by not pointing out the "real" spawning season of a species if it occurs during holidays, to avoid future fishing closures during an important period of income). For the reasons outlined above, a degree of subjectivity always remains and has to be considered.

In summary, our critical considerations on the proposed method seems to be in accordance with what was previously found by other authors on the Delphi technique (Linstone and Turoff, 1975; Zuboy, 1980; Drew, 2005; MacMillan and Marshall, 2006).

CONCLUSIONS

The adapted Delphi methodology proved to be useful for the identification of EFHs and EBFM issues, by providing innovative input and guidelines for decision makers. However, it has to be emphasized that as natural systems vary temporally and spatially, FEK studies need to be frequently updated.

Fishers' ecological knowledge is indeed a necessary and irreplaceable data source for fisheries management under community-based schemes in Brazil and elsewhere, but especially in data-poor environments. However, its approach and assessment is not simple or trivial, requiring effective and locally elaborated methods and communication skills (Gasalla and Diegues, 2010).

Finally, we concluded that this methodology may be of great value for assessing the traditional, many-sided and valuable knowledge of fishers, and its inclusion in EBFM and can be adapted to other fields of ethnoecology and natural resource management as well as in other locations.

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2.4
Public policy, government, and fishers' knowledge

Fisher's knowledge and the ecosystem approach to fisheries: legal instruments and lessons from five cases studies in coastal Brazil

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ABSTRACT

Fisher's knowledge may be defined broadly as fishers understanding of biological species (morphology, behavior, growth, feeding habits, reproduction, etc.), species interactions, ecosystem dynamics (including terrestrial, marine/freshwater and weather dynamics), as well as of social-ecological interactions and feedbacks dynamics. Despite the advocacy of many researchers for the use of fisher's knowledge to improve fisheries management by governments and other organizations, there is little guidance on how to use such knowledge in practice. In Brazil, we reviewed 158 federal legal documents related to environmental management, in particular coastal and fisheries management, issued between 1934 and 2012 to assess how this matter has been dealt with by the federal government. We found that the ecosystem approach to fisheries (EAF) is not yet clearly institutionalized in federal legislation; nonetheless, fisheries management via Protected Areas favors the adoption of such an approach. Additionally, we explore lessons learned regarding fisher's knowledge and its potential to improve the ecosystem approach to fisheries based on five case studies and over 15 years of research on the south and southeastern coast of Brazil. These case studies include three from the coast of Rio de Janeiro (Arraial do Cabo, Vila do Aventureiro at Ilha Grande and Trindade in Paraty), one from the coast of São Paulo (Ponta da Almada in Ubatuba) and one from the coast of Santa Catarina (Lagoa de Ibiraquera in Imbituba). We conclude that the use of fishers' knowledge within the EAF is likely to occur within the Protected Areas legal framework, but is subject to the personal values and attitudes of the Protected Area manager and the government political will to create or reclassify protected areas.

Conhecimento de pescadores e Abordagem Ecossistêmica na Pesca: Instrumentos legais e lições de cinco estudos de caso da costa do Brasil

RESUMO

O "conhecimento local de pescador" pode ser definido amplamente como o entendimento dos pescadores sobre a biologia das espécies (morfologia, comportamento, hábitos alimentares, reprodução, etc.), as interações entre espécies, a dinâmica dos ecossistemas (incluindo dinâmicas terrestres, marinhas, de água doce e climáticas), bem como sobre as interações e dinâmicas de retroalimentação (feedbacks) dos sistemas socioecológicos. Apesar de muitos pesquisadores defenderem o uso do conhecimento de pescadores para melhorar a gestão da pesca por parte dos governos e outras organizações, há pouca orientação prática sobre como utilizar tal conhecimento. Neste trabalho, revisamos todos os diplomas legais federais brasileiros relacionados a gestão ambiental, em especial, gestão pesqueira e gestão costeira, promulgados entre 1934 e 2012, dos quais selecionamos 158 documentos para avaliar como a incorporação do conhecimento de pescadores para melhorar gestão tem sido tratado pelo governo federal. Encontramos que o enfoque ecossistêmico para gestão da pesca (EAF) ainda não está claramente institucionalizado na legislação federal; porém, a gestão da pesca por meio de Áreas Protegidas favorece a adoção deste enfoque. Além disso, examinamos as lições aprendidas em relação ao uso do conhecimento do pescador e seu potencial para melhorar o enfoque ecossistêmico para gestão da pesca, com base em cinco estudos de caso e mais de 15 anos de pesquisa nas costas do sul e do sul do Brasil. Esses estudos de caso incluem três do litoral fluminense (Arraial do Cabo; Vila do Aventureiro, na Ilha Grande; e Trindade em Paraty), um do litoral paulista (Ponta da Almada, em Ubatuba), e um do litoral catarinense (Lagoa de Ibiraquera, em Imbituba). Concluímos que o uso do conhecimento dos pescadores dentro de um enfoque ecossistêmico para a gestão pesqueira é provável que ocorra dentro das estruturas legais que regulamentam as áreas protegidas, no entanto, ele fica susceptível ao perfil do gestor da Área Protegida em questão e da vontade política dos governantes para criar, implementar ou recategorizar as áreas protegidas.

INTRODUCTION

Populations that depend on natural resources for their survival develop over time a profound body of knowledge on the dynamics of the resources they exploit and of the ecosystems in which they are found (Berkes 1999). These knowledge systems have been well-documented in various fishing systems (e.g., Johannes *et al.*, 2000; Seixas and Berkes, 2003). Fishers' knowledge may be broadly defined as the understanding of biological species traits (morphology, behavior, growth, food habits, reproduction, migration, etc.), interspecific interactions, ecosystem dynamics (including marine, brackish and fresh water; terrestrial and atmospheric dynamics) as well as the dynamics and feedbacks among the components of socio-ecological fisheries systems.

The importance of considering fishers' knowledge in fisheries resource management, especially when scientific data on resource dynamics and systems to be managed is insufficient, has been recognized among many researchers (Johannes 1998, Berkes *et al.,* 2001), particularly with respect to detecting early signs of environmental change (Rochet *et al.,* 2008). This does not necessarily mean that fishers' knowledge should be considered indiscriminately. Rather, attention should be paid regarding who possesses/owns the knowledge (Davis and Wagner, 2003), as the issues of participation, representativeness and legitimacy are critical in the context of transmission of knowledge to decision-makers and the validity of knowledge at a geographic scale greater than that used by fishers. Although several researchers advocate the use of fishers' knowledge for improving the management of fisheries resources by governments and NGOs, there are few guidelines available for how to use this knowledge in a management context.

Similarly, the ecosystem approach to fisheries management (EAF) has been advocated by researchers and especially recommended by FAO to its member countries. The goals of this approach include "a balance of diverse societal objectives [regarding the use and conservation of ecosystems], by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries" (FAO, 2003). Although there are general guidelines for implementing this approach (Garcia and Cochrane, 2004) - including consultation with different stakeholders throughout the process of formulation, implementation, monitoring and evaluation of fisheries management plans - there are no clear guidelines on how this approach can integrate fishers' knowledge as a source of information during all stages of the management process.

This paper seeks to explore ways of using local ecological knowledge of small-scale fishers to improve fisheries management from an ecosystem perspective and to ensure the maintenance of artisanal fishers' livelihoods. We searched the Brazilian legislation for opportunities for the incorporation of local knowledge in fisheries management and evaluated if and how fishers' knowledge affected fishing regulation processes in five case studies from the south-southeastern Brazilian coast.

According to the Federal Constitution of Brazil of 1988, the natural resources of the continental shelf and the exclusive economic zone are properties of the Federal Union and the regulation of fishing therein is the responsibility of Federal and State Governments. Nonetheless, the State is not necessarily entitled to ownership of fisheries resources, according to Article 225:

> *"Everyone has the right to an ecologically balanced environment, for common use by the people and essential for a healthy quality of life, imposing upon the Government and society the duty to defend it and preserve it for present and future generations".*

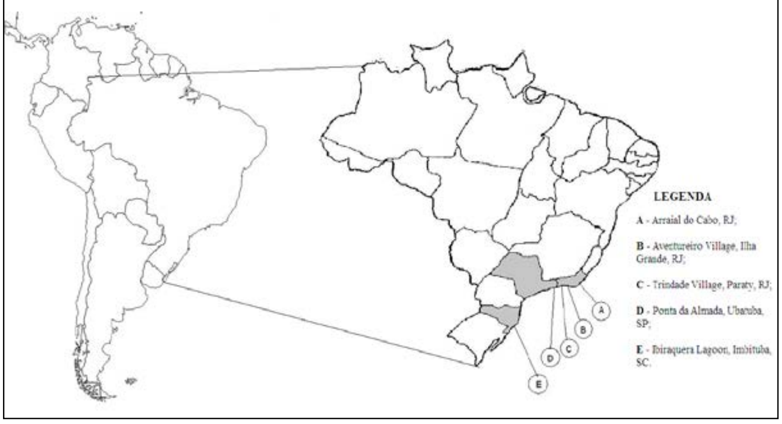
Thus, it is the responsibility of the Federal Union and the States, but also of the Brazilian population to protect and conserve the environment, including fisheries resources. This constitutional prerogative is interpreted in practice to mean that the sustainable use and conservation of natural resources is a shared responsibility between government and direct users. In this context, the ecosystem approach to fisheries should be advocated/implemented with particular consideration of fishers' knowledge.

RESEARCH METHODS

Between February of 2010 and July of 2012, we conducted a survey using online search engines of the Brazilian federal government to identify documents pertaining to legislation of: coastal fishing, fisheries resource management, vessels, fishing gear, biodiversity, conservation of natural resources, populations and traditional knowledge, wildlife protection, local and regional development, coastal administration and zoning, coastal defense, water services and protected areas, Among the legal documents found, we selected those containing the following key words: "local", "traditional", "indigenous", "native" and/or "fisher". We also searched all legal documents for the term "ecosystem approach". Within this selection, we used content analysis (Bailey, 1987) to identify how local or traditional knowledge was treated within the legislation and where opportunities exist for its incorporation into the management process.

To compare the identified opportunities within Brazilian legislation with the reality/actual management practices in distinct locations, we selected five case studies from the south-southeastern Brazilian coast based on previous experience in field research or project orientation by one of the authors (CCS). From South to North, sites include: Lagoa de Ibiraquera, Imbituba, SC (1999-2000); Ponta da Almada, Ubatuba, SP (2003-2004 e 2010-2011); Vila de Trindade, Paraty, RJ (2010-2013); Vila do Aventureiro, Ilha Grande, RJ (1995-1996 e 2011-2012); e Arraial do Cabo, RJ (2005-2007; Figure 1).

FIGURE 1
Map showing the locations of the five case studies along the southeast-southern coast of Brazil



FISHERIES MANAGEMENT IN BRAZIL

Fisheries management in Brazil, both inside and outside of Federal Protected Areas (PAs), has experienced several changes in the last 60 years. It was the responsibility of the Superintendent of Fisheries Development (SUDEPE) between 1962 and 1989, until the Brazilian Institute of Environment and Natural Renewable Resources (IBAMA) was created as an Agency within the Ministry of the Environment (MMA), which also became responsible for management of PAs. In 1998, the administration of under-explored fisheries resources was transferred to the Department of Fisheries and Aquiculture (DPA) of the Ministry of Agriculture, while over-exploited resources remained under jurisdiction of IBAMA. In 2003, the Special Secretariat of Fisheries and Aquiculture (SEAP) of the Cabinet was created in order to assume responsibilities of the then-terminated DPA. In 2007, IBAMA was branched out into the Chico Mendes Institute of Biodiversity (ICMBio), which administers all federal PAs (including no-take PAs and sustainable-use PAs). In 2009, SEAP was transformed into the Ministry of Fisheries and Aquiculture (MPA). In the same year (2009), the Decree 6981/2009 (and the MPA/MMA Ordinance No. 2/2009 that regulates this Decree) was issued regarding the shared management of all aspects related to the sustainable use of fisheries resources between MMA and the Ministry of Fisheries and Aquiculture (MPA). This brief history provides an important backdrop for understanding legal documents and case studies explored here.

BRAZILIAN LEGISLATION, COASTAL FISHING AND LOCAL/TRADITIONAL KNOWLEDGE

In our review of Brazilian federal legislation, we found 158 legal documents related in some way to coastal fisheries management between 1934 and 2012. Among them, only 15 contained the key words: "knowledge" and "know" ("conhecimento" e "saber"; Table 1). It is important to note that none of the legal documents mention "fishers' knowledge" explicitly.

Among the 15 statutes selected, only one pertains directly to fisheries: the National Plan for Sustainable Fisheries and Aquiculture (Federal Law 11959/2009), while six documents address Protected Areas: Federal Law 9985/2000, Federal Decree 5758/2006, Normative Instructions (NI) of ICMBio No. 1/2007, 2/2007, 3/2007 and 4/2008. These four NIs are specific to Sustainable Use Protected Areas, particularly Extractive Reserves (RESEX) and Sustainable Development Reserves (RDS). Four of the 15 documents guide the regulation of use and conservation of biological diversity: Legislative Decree 5092/2004, Federal Decree 4339/2002, Federal Decree 4703/2003 and Federal Decree 5092/2004. Three regulate the use of Genetic Patrimony and the protection of Associated Traditional Knowledge: Provisionary Measure 2186-14/2001, Provisionary Measure 2186-16/2001 and the Federal Decree 3945/2001. The other one is specific to Traditional People and Communities: Federal Decree 6040/2007.

It is noteworthy that only four out of the 15 statutes explicitly state the application, incorporation or involvement of local/traditional knowledge in conservation of biological diversity and management of its use. Those documents include: Convention on Biological Diversity (CDB); National Policy of Biodiversity (PNB); National Strategic Plan for Protected Areas (PNAP) and the Regulatory Instructions that regulate the creation of Management Boards of the RESEX and RDS. The remaining documents mention local, traditional or indigenous knowledge as worthy of respect, appreciation, protection and integration among other sources of knowledge, but do not specifically mention any stimulus for its application in natural resource management.

TABLE 1
List of legal documents that include at least one of the key words, indicating the context within which these words were used

Nature	No./Year	Subject	Local knowledge	Tradicional knowledge	Indigenous knowledge	Traditional wisdom (saber)
Legislative Decree	2/1992	Biological Diversity Convention (CDB)	Respect, Apply	Recognize, Protect	Integrate	0
Federal Law	9985/2000	National System of Protected Areas (SNUC)	0	Respect, Value	0	0
Provisionary Measure	2186-14/2001	Access to genetic heritage	0	Protect	0	0
Provisionary Measure	2186-16/2001	Access to genetic heritage	0	Protect	0	0
Federal Decree	3945/2001	Management Board of Genetic Heritage	0	Protect	0	0
Federal Decree	4339/2002	National Policy of Biodiversity	Involve	Involve e Protect	0	Value e Ensure participation
Federal Decree	4703/2003	PRONABIO/CONABIO	0	Protect	0	0
Federal Decree	5092/2004	Priority Conservation Areas	0	Protect	0	0
Federal Decree	5758/2006	National Strategic Plan for Protected Areas	Involve, Respect	Incorporate in PA management	Incorporate in PA management	0
Federal Decree	6040/2007	PNDS of Traditional People and Communities	0	Recognize, Protect, Garantee rights	0	Respect, Value
NI ICMBio	1/2007	Participatory Management Plan of RESEX and RDS	0	Value, Integrate	0	Value, Integrate
NI ICMBio	2/2007	Advisory Board RESEX e RDS	0	Garantee participation, Integrate	0	Integrate
NI ICMBio	3/2007	Creation of RESEX and RDS	0	Value, Integrate	0	Value, Integrate
NI ICMBio	4/2008	Research in RESEX and RDS	0	Authorization of research	0	0
Federal Law	11959/2009	PNDS Fisheries and Aquiculture	0	0	0	Protect

Legend: PRONABIO (National Program of Biodiversity); CONABIO (National Comission of Biodiversity); PNDS (National Policy of Sustainable Development); RESEX (Extractive Reserve); RDS (Sustainable Development Reserve); UC (Conservation Unit/ Protected Area); IN (Normative Instruction).

According to the Convention on Biological Diversity (CBD), discussed at the United Nations Conference on Environment and Development - UNCED in 1992, countries should:

> *"Respect, preserve and maintain knowledge, innovations and practices of local communities and indigenous populations with traditional lifestyles relevant to the conservation and sustainable use of biological diversity and promote their broad application with the approval and involvement of the holders of such knowledge, innovations and practices."*

The National Biodiversity Policy, a Brazilian law stemming directly from the CBD, encourages the involvement of local knowledge and practices and the traditional "*management* of soil, water and biological resources." In Brazil, the use of the words *manejo*, *gestão*, *ordenamento* and *administração* in Portuguese are sometimes used interchangeably referring to 'management' in English (Seixas *et al.*, 2011). In this sense, the National Biodiversity Policy can be considered as a legal instrument that stimulates the incorporation of local knowledge in natural resource management, but provides no mechanisms in how to do so.

Although there are legal incentives for the use or incorporation of local and traditional knowledge in biodiversity conservation, it is the policies of protected areas that outline specific guidelines, especially within the regulation of the Management Board of RESEX and RDS (ICMBio Regulatory Instruction 2/2007) and broadly, the National Strategic Plan for Protected Areas (PNAP). Two of the general objectives of the PNAP are: (i) ensure that scientific and traditional knowledge contribute to the effectiveness of the National System of Protected Areas (SNUC), and (ii) establish mechanisms for continual incorporation of technical and scientific knowledge and traditional knowledge in the establishment and management of protected areas.

In addition to the 15 documents listed in Table 1, other legal instruments allow for the participation of fishers in fisheries management, but usually in a advisory/consultative manner (i.e., as information providers and not as decision-makers) (Vieira and Seixas, *in review*). In addition to the Deliberative (decision-making) Boards of RESEX and RDS, only Fishing Agreements (*Acordos de Pesca*), "a set of specific measures arising from consensual treaties among various users and the governing body/management agency of fisheries resources in a given area, defined geographically" (NI IBAMA No. 29/2002) legally permit the sharing of power and use of fishers' knowledge in fisheries management. Although the Normative Instructions on Fisheries Agreements (NI IBAMA No. 29/2002) does not explicitly cite the term "knowledge" (and thus was not selected according to our criteria), it does regulate fishing agreements taking into account "the interests of the local population." In fact, this tool was created to legitimize local initiatives in fishery resources management (Castro and McGrath, 2001; Ruffino, 2005).

It is important to recognize that after the completion of data collection for this study, a new statute was published: the Normative Instruction ICMBio No. 26/2012 that "*establishes guidelines and regulates procedures for the preparation, implementation and monitoring of Terms of Agreement between the Instituto Chico Mendes and traditional populations living in protected areas where their presence is not accepted or is in disagreement with the management tools.*" According to this statute, "*The construction/elaboration of the Terms of Agreement must be based on the use of appropriate methodologies, to ensure the effective participation of the social group involved and to integrate technical and scientific knowledge with traditional wisdom (*'saberes'*), practices and knowledge*." Although this ruling represents an opportunity for using local knowledge for the creation of tools for resource management, it is only a temporary solution to the conflicts with local resident populations within unpermitted (no-take) areas. Other definitive solutions must be sought within an adequate timeframe.

With respect to the ecosystem approach to fisheries, only two documents mention this term in the selected Brazilian legislation. The National Policy on Biodiversity cites as one of two specific objectives "*to adapt to Brazilian conditions and apply the principles of the ecosystem approach to biodiversity management.*" Meanwhile, the National Strategic Plan for Protected Areas has one of its two principles as the adoption of the ecosystem approach to management of protected areas, which includes all categories of Brazil's Protected Areas. However, none of the documents defined what is understood as the "ecosystem approach."

In summary, the only regulatory mechanisms that explicitly guarantee the incorporation of local/traditional knowledge into resource management within an ecosystem-based approach are: (i) the participation of representatives of local resource users in the Deliberative Management Boards of Sustainable-Use Protected Areas, i.e., Extractive Reserves (RESEX) and Sustainable Development Reserves (RDS); and (ii) the Terms of Agreement between traditional populations and No-take Protected Areas. Fisheries Agreements, although lacking a description of ways to use local/traditional/native knowledge, can also be included here as a tool for representing local interests.

Although there are no clear guidelines for the incorporation of local/traditional knowledge from an ecosystem approach to fisheries management, except in the above-mentioned tools, some initiatives have recently used this knowledge to manage fishery resources to ensure the livelihoods of fishers. In the next section, we present some of these initiatives.

CASE STUDIES ON FISHERIES MANAGEMENT IN BRAZIL

The five case studies were classified according to community type (i.e. rural, semi-urban or urban), location of these communities with respect to Protected Areas (PA) and type of PA (i.e. marine, terrestrial or insular; Sustainable-Use or No-take PA), and opportunities for valuing and integrating local knowledge into fisheries management (Table 2). Below each of the case studies are described in detail.

Ibiraquera Lagoon, Santa Catarina (SC)

The Ibiraquera Lagoon is located within the municipalities of Imbituba and Garopaba in the State of Santa Catarina. There are eight surrounding fishing communities that, until the 1970s, relied heavily on the production of the lagoon for their livelihoods. Over the years, with the development of tourism in the region, fishing became a complementary source of food and income for most families. To our knowledge, it was in this lagoon in 1981 that the first federal statute (Ordinance SUDEPE N-027/81) was created in Brazil in response to demands of local fishers and based on their knowledge of the lagoon ecosystem dynamics and target species. In the following years two additional ordinances specific to this lagoon were created and issued (Ordinances SUDEPE N-09/86, IBAMA N-115/93), demonstrating a certain level of local organization of fishers (See Seixas and Berkes 2003b for details).

In 2000, the Transdisciplinary Center for Environment and Development (NMD) of the Federal University of Santa Catarina initiated various projects in the region of Ibiraquera within a long-term transdisciplinary research program. Based on the role/activities of the NMD a Local Agenda 21 Forum of the Ibiraquera Lagoon was created in 2002 with the participation of representatives of various communities, many of them already very active in Community Associations.

Through the work of this Forum, and the consequent creation of the Fishers' Association of the Ibiraquera Community (ASPECI), emerged the demand for creation of the Extractive Reserve (RESEX) for the Artisanal Fisheries of Imbituba and Garopaba, which was brought to the federal government (CNPT / IBAMA) in 2005 (Adriano 2011, Vivacqua, 2012). The aim of the RESEX was to create a "tool for co-management capable of dealing with problems and conflicts concerning artisanal fishing" (Vivacqua 2012). Nonetheless, many conflicts have arisen among proponents in the region (Forum and ASPECI), environmental NGOs, the federal government (ICMBio), fishers who did not support the RESEX due to mistrust and misinformation, local businesses and municipal governments. Conflicts emerged between two groups of interest: those ensuring better environmental preservation and those with economic interests in the expansion of tourism in the region (Vivacqua, 2012). Until mid-2013, the decree drafted to establish the RESEX and submitted to ICMBio had not yet been approved by the federal government (ICMBio). The ICMBio news portal reported on 06 August 2013 that ICMBio will accelerate the creation and expansion of eight protected areas, including the Ibiraquera-Encantada RESEX in Santa Catarina. It is noteworthy, however, that in recent years the federal government has prioritized the implementation of previously created PAs, i.e. the creation of management boards and management plans of PAs (ICMBio, 2013), rather than creating new ones.

Ponta da Almada and Baia de Ubatumirim, Ubatuba, SP

Ubatumirim Bay is located in the north of the municipality of Ubatuba and is mainly used by fishers of two *caiçara* communities, Ponta da Almada and Ubatumirim, which both practice artisanal fishing with multiple gears in canoes or small boats. These communities have been located on the edge of the Pincinguaba division of the Serra do Mar State Park since its expansion in 1979. Traditionally, *caiçara* communities lived off of fishing, shifting cultivation agriculture and subsistence hunting (Adams, 2000). However, due to the presence of these two communities in the Park's buffer zone and due the fact that part of their agricultural areas are inside the Park, a ban was placed on the *caiçara* plantations and subsistence hunting at the time of park implementation, increasing the dependence of these communities on fishing. Since the 1980s and more so in the 1990s, tourism began to develop in these communities, such that by the beginning of the 2010s there was virtually no fisher in the community of Ponta da Almada, which had depended exclusively on fishing for survival (Garuana 2014). This park, like many others in Brazil, was created and implemented in disregard of the existence of human populations that depended on its resources. The centralization of decision-making in environmental conservation in Brazil, especially during the military regime (mid 1960s to mid 1980s) is a historical fact. In fisheries, the situation was no different. By 2003, the fishers of Ponta da Almada confirmed that they had never been consulted about any environmental regulation.

In 2003, at the Ecological-Economic Zoning for Coastal Management of the north coast of the state of São Paulo, fishers from Ponta da Almada were consulted, for the first time, regarding fishing restrictions: the issue in questions was the closure of Ubatumirim Bay to shrimp trawling. As managers, fishers felt/understood that shrimp trawls captured very small fish as by-catch and also destroyed the gill nets of the local fishers. Through two meetings, a consensus was reached between parties with respect to the area proposed for closure by the government and that proposed by fishers Almada and Ubatumirim (Futemma and Seixas, 2005). Seixas and Futemma (2005) also evaluated the potential involvement of fishers in decision-making processes about fishing. This potential, however, was entirely neglected during the establishment of the Marine Environmentally Protected Area of the North Coast (APA-LN) in 2008, which encompasses the Ubatumirim Bay - another 'top -down' measure of the state government São Paulo. In 2009, fishers of Ponta da Almada were 'disgusted' by this measure and no longer wanted to collaborate with researchers because they believed we provided data to the government. This sentiment was softened through the work of the APA's Manager, who has worked within the ecosystem approach for coastal management. In 2009 the management board of APA- LN was created with 24 seats, four of which are occupied by artisanal and industrial fisheries. Although APA is considered a Sustainable-Use Protected Area in the National System of Protected Areas (SNUC), the legislation regarding the participatory nature of local representatives on the management board is unclear (Vieira and Seixas, *in review*). Although no fishers from the communities of Almada and Ubatumirim are directly involved in this board, other spaces are being created with the support of the APA to enable the use/integration of fishers' knowledge into management. Among these, we highlight: the Working Group on Fishing and the Contemporary *Caiçara* Project, aiming to value the knowledge and practices of the *caiçara* culture of northern coast of São Paulo, through the recovery of traditional knowledge and encouragement of youth participation (APA-LN, 2011). The Management Plan of the APA until the middle of 2013 was still in progress.

Vila de Trindade, Paraty, RJ

The village of Trindade is located in the municipality of Paraty, on the southern coast of Rio de Janeiro state. The whole territory of Trindade is incorporated within the Environmental Protection Area (APA) of Cairuçu (Brazil, 1983) and part of it lies within the National Park of Serra da Bocaina (PNSB) (Brazil, 2002; Conti and Antunes, 2012). Also included within the park is the Caixa D'Aço (or Cachadaço) Bay, an area heavily used by fishers and locals, besides being heavily visited by tourists.

Trindade was traditionally a *caiçara* community that was quite isolated until the early 1970s. This setting began to change with the opening of the BR-101 (Rio-Santos) Highway, which allowed men in the community to seek employment on fishing boats outside the community and boosted development in the tourism sector. In the 1970s, various conflicts arose between the local population and large tourism companies that wanted to expropriate this population. With external support, the *Trindadeiros* (people of Trindade) won the legal right to remain on their land (Lhotte, 1982; Plante and Breton 2005).

From the mid-1970s, tourism continued to increase in Trindade, becoming an important activity for the local economy (Plante and Breton, 2005). In fact, the main source of livelihood in Trindade today is related to tourism and commerce (Conti and Antunes 2012; Hanazaki *et al.,* 2013); nonetheless, fishing still represents the basis of the *caiçara* culture in the village. In the current decade, 2010, there are still families involved in small-scale fishing, especially with floating fishing traps (Begossi, 2011).

Since 2008, the Chico Mendes Institute for Biodiversity Conservation (ICMBio) has been trying to implement over Trindade lands, the National Park of the Serra da Bocaina (PNSB), created in 1971 by the federal government. Several efforts towards land planning have been made, including the prohibition of the community camping ground and of the village sewage treatment system, as well as the destruction of bars/restaurants on the beach, which has caused considerable tension between the *people of Trindade* and park managers (Conti and Antunes 2012, Bahia *et al.*, 2013). In the marine area, park managers want to regulate tourist transportation by fishers/boaters in the Caixa D'Áço Bay by requiring training courses in various areas, from first-aid to navigation skills. Fishing, though illegal inside the park area, continues to occur. The PNSB management plan was elaborated in 2002, but only in 2010 was the Advisory Management Board created. Since 2012, a monitoring process (revision) of the management plan was initiated by the park manager and his team, calling for meetings with three members of the management board representing community-based organizations in Trindade, and other local leaders. This would be a great opportunity for considering local knowledge in park planning. However, the manner in which this management plan revision is being conducted shows the unpreparedness of managers to work within an ecosystem-based approach, discouraging legitimate local participation and hence inducing an illegitimate participatory process. The following excerpt from Bahia and collaborators (2013) illustrates this case:

> *We noted that, although PNSB managers declared that the monitoring process of the Management Plan should include community participation, some attitudes of these agents have hindered the construction of a truly participatory process. Among these attitudes, we highlight the pressure to complete the process in a period that is not consistent with the possibility of effective community participation. Moreover, it is often mentioned by managers that the residents of Trindade have no right to stay in the Park, i.e., it depends on managers' goodwill to permit the community access to the Park. These situations, among others, exemplify the asymmetry in power relations between the managers and people of Trindade, which is characteristic of a preservationist view in which resource users are seen as a threat to conservation rather than as potential partners and stewards of the resources they depend on.*

Vila do Aventureiro, Ilha Grande, Angra dos Reis, RJ

The village of Aventureiro is located in the southeast of Ilha Grande on the southern coast of Rio de Janeiro State. This *caiçara* community is small and relatively isolated, comprised of approximately 20 families. Land access is enabled by trails of at least 1 hour walk from the nearest community, and as the community faces the open sea, maritime access depends on oceanographic and weather conditions. Such isolation has favored a high dependence on local natural resources via practices of shifting cultivation, fishing, hunting and plant harvesting, generating a wealth of knowledge about such resources (Seixas and Begossi, 2001; Prado, 2013).

Over the past 50 years, however, several drivers of change, mostly exogenous, have influenced the ways of life in this community. These drivers include the implementation of a national policy providing incentives for fishing development in the 1960s; the creation of a Biological Reserve (Rebio) on South Beach (Praia do Sul), comprising the village and restricting resource use / shifting cultivation within the community area in 1981; and the closing of the maximum security prison of Ilha Grande in 1994, leading to the development of tourism. In 2000, an attempt was made to withdraw the population inhabiting the Rebio (a no-take Protected Area); and in 2006, camping grounds (an important source of income for many families) were prohibited by the municipal government in the village during eight months. In response to both actions, the community self-organized and, after much negotiation, signed a Terms of Agreement (*Termo de compromisso*) with government agencies in 2006. This agreement permitted camping grounds under certain regulations and requested the reclassification of the area of the Rebio that incorporated Aventureiro as a Sustainable Development Reserve (RDS). The bill (*projeto de lei*) proposing reclassifying part of the Rebio in addition to the Marine Park of Aventureiro into a RDS was designed in 2010, pending approval in the Legislative Assembly of the State of Rio de Janeiro (Prado, 2013). Once passed, a management board will be formed and a management plan prepared that seeks to integrate the local fishers' knowledge into management of the area.

Arraial do Cabo, RJ

Arraial do Cabo is a city of approximately 27 000 inhabitants (2010 Census) located on a coastal peninsula, where artisanal fishing communities are traditionally situated on three beaches: Prainha, Praia do Anjos and Praia Grande. The sea of Arrial do Cabo is characterized by upwelling, which contributes to increased primary productivity, and ultimately, fishery resources. The sea of Arraial is also used for scuba diving, boat touring, sea transport (as there is a port in the city), for acoustic measurements of ships from Brazilian Navy, research, and until 2006 by a chemical industry/factory (Seixas and Begossi, 2008).

The Marine Extractive Reserve (RESEX-Mar) was created in 1997 on Arraial do Cabo based on the initiative of a federal environmental agency (IBAMA) employee, with the support of researchers from the Federal Fluminense University as well as fishers and local residents. At the time, an association (AREMAC) was created to co-manage the RESEX together with IBAMA. The goal was to "ensure the self-sustainable exploitation and conservation of renewable natural resources traditionally used for fishing by extractivist populations in the Municipality of Arraial do Cabo" (DECREE w/o N° of 01/03/1997). The main focus was to protect the artisanal beach seining fishery using canoes and ban large trawlers from operating within the extractive reserve. A Utilization Plan was prepared in 1999 using in part fishers' knowledge via the legitimization of locally established rules on beach seining, based on knowledge about the dynamics of schools of fish and the local coastal ecosystem, documented since 1921 . However, it was not considered when creating and producing this RESEX Utilization Plan that the sea of Arraial do Cabo is used for many other economic activities and various other forms of fishing (purse seine fishing, hook and line fishing on motor boats and canoes, scuba-diving fishing, among others). This generated over the years many conflicts between different stakeholders (Seixas and Begossi 2008).

The Association of the Arraial do Cabo Marine Extractive Reserve (AREMAC) was the local organization responsible for the co-management of the RESEX until the publication of Act 9985 in 2000 to create the National System of Protected Areas (SNUC). According to this Act, an extractive reserve should be managed by a Deliberative Management Board responsible for approving and monitoring the

RESEX management plan. This board is chaired by the agency responsible for its administration (IBAMA, replaced by ICMBio at the federal level in 2007) and consists of representatives of the traditional resident population in the area, government agencies and civil society organizations. Only by 2010, after five administrative managers with very different profiles had assumed the position of RESEX manager, was the Management Board created to meet in part the requirements of SNUC. As of 2012, the RESEX Management Plan had not been approved; nonetheless, with the existence of a Management Board, we expect that the participation of representatives of fishers on the board allow their knowledge to be considered in decision-making. Moreover, the fact that representatives of other economic activities occurring in the sea of Arraial do Cabo will also be part of this board allows an ecosystem approach to be implemented to manage this area.

TABLE 2
Case studies for fisheries management nearby or within Protected Areas (T: terrestrial, M: marine, I: island)

	Ibiraquera Lagoon	Ponta da Almada	Vila de Trindade	Vila do Aventureiro	Arraial do Cabo
Municipality, State	Imbituba/ Garopaba,SC	Ubatuba, SP	Paraty, RJ	Angra dos Reis, RJ	Arraial do Cabo, RJ
Fishing communities	Eight semiurban (~20 km from the center of Imbituba)	One semiurban (35 km from the center)	One semiurban (25 km from the center)	One rural (island)	Three urban (Praia Grande, Prainha, Praia dos Anjos)
No. fishers (year)	~350 (2000)	~40 (2004)	~50 (2010)	~ 40 (1995 e 2012)	~1 500 (2005)
Location in relation to Protected Areas: M(marine), T(Terrestrial), I(Island)					
Within No-take Protected Areas	-	-	-	Reserva Estadual Biológica da Praia do Sul (1981) (T,I)	-
Nearby No-take Protected Areas	-	Parque Estadual da Serra do Mar – Núcleo Picinguaba (1979) (T)	Parque Nacional da Serra da Bocaina (1972) (T,M,I)	Parque Estadual Marinho do Aventureiro (1990) (M)	-
Within Sustainable Use Protected Areas	-	-	APA Cairuçu (1983) (T,I)	APA Tamoios (1982) (T,M,I)	Reserva Extrativista Marinha de Arraial do Cabo (1997) (M)
Nearby Sustainable- Use Protected Areas	APA da Baleia Franca (1998) (M,T,I)	APA marinha do Litoral Norte (2008) (M)	-	-	APA da Massambaba (1986) (T)
Opportunities for valuation and integration of local knowledge in fisheries management					
Arenas/processes about artisanal fishing and/or fishers' lives	Fórum Agenda 21 Local (since 2002) – Proposal development for creating na Extractive Reserve	Consultation for Coastal ecological-economic zoning– ZEE-GERCO (2003/04)	Trindade fisheries assessment by Mosaico Bocaina (2010 -2011)	None (in 1996/1997) Proposal development for creating a Sustainable Development Reserve RDS (desde 2010)	AREMAC assemblies (1997-2010) – Elaboration of Utilization plan Deliberative management board of RESEX (since 2010)

Legend: APA (Environment Protected Areal); RESEX (Extractive Reserve); ZEE-GERCO (Ecological-Economic Zoning of Coastal Management Plan); AREMAC (Association of the Arraial do Cabo Extractive Reserve).

DISCUSSION

The use of fishers' knowledge in the elaboration of fishing regulations was observed as effective among three case studies (Arraial do Cabo, Ponta da Almada and Ibiraquera Lagoon), while in the remaining two cases we highlight the potential for such.

We have shown that Brazilian legislation merely encourages the incorporation of local knowledge in decision-making in the context of Sustainable Development Reserves, Extractive Reserves, Fisheries Agreements or Terms of Agreement for Strictly Protected Areas. Despite of that, out of the three processes that consider the use of fishers' knowledge, two initially occur outside the conservation realm: (i) the legal prohibition of certain fishing gears in Ibiraquera Lagoon in the 1980s and 1990s, and (ii) the Coastal Ecological-Economic Zoning at Ubatumirim Bay in 2003. In both cases the focus was to ensure the sustainable use of resources by fishers. It is noteworthy, however, that in neither case there were guidelines or tools to incorporate fishers' knowledge in the regulatory process. This was due to the ´profile´ (values and attitudes) of managers in charge of the processes that value the knowledge and interest of the local population. Interestingly, one of the areas (Ubatumirim Bay) has become part of a Sustainable Use PA (The Marine Protected Area of North Coast) while the other (Ibiraquera Lagoon) is pending approval to become an Extractive Reserve (RESEX) after seven years of demand for its creation. The lessons generated from past experiences can enhance resource management and ensure fishing as a livelihood within communities, especially when park managers recognize and value fishers' knowledge, as in the case of the Marine Protected Area of North Coast.

In the case of Arraial do Cabo, the extractive reserve was created to ensure the livelihoods of artisanal fishers, while banning unsustainable trawl fishing; and, as such, the locally established rules in operation for over 70 years were included in the Use Plan. Nonetheless, as the RESEX was established in an area with several other economic activities, and due to the fact that the first manager neglected to encourage dialogue with other stakeholders (Seixas and Begossi, 2008), there was a temporary impediment to implementing an ecosystem approach to fisheries management. With the creation of the Deliberative Management Board of the RESEX involving the various stakeholders, there is currently great potential for such implementation.

Extractive Reserves as well as Sustainable Development Reserves (RDS) were created in the context of common-pool resources management in the Brazilian Amazon. Extractive reserves emerged from the social organization of the *seringueiros* (Allegretti, 1989), while RDS were intentionally proposed to reconcile wildlife conservation with traditional use of natural resources (Queiroz and Peralta, 2006). Both became important tools for co-management and conflict resolution regarding natural resources use and access involving multiplicity of stakeholders in the 1990s (initially in the Amazonian states). Nonetheless, these initiatives are still incipient within the context of coastal management in the Atlantic forest biome. The Arraial do Cabo Marine RESEX is among the few along the south and southeast coast of Brazil, to this date.

Regarding the two communities where fishing areas are located within no-take Protected Areas, Vila do Aventureiro and Trindade, tourism has become the main economic activity in recent decades. Nonetheless, fishing remains an important source of food and income supplement in both communities (Hanazaki *et al.,* 2013, Prado 2013). Fishers' knowledge on the local fisheries system could be very useful for fisheries management within these areas, either via the re-categorization of the Aventureiro Marine Park as a Sustainable Development Reserve, or through Terms of Agreement signed by Trindade fishers and the manager of the National Park of Serra da Bocaina. The former has been in process for three years, while for the latter there had been little interest shown by the park manager in starting such a process during our fieldwork (Bahia *et al.,* 2013). Nevertheless, during a park management board meeting in November 2013 to discuss the monitoring of the park management plan, Trindade fishers organized themselves and pushed the Park manager to consider negotiating with them. There were already a few young leaders in Trindade, but two recent capacity-building courses provided by a university group for the Fishers and Boatmen Association of Trindade (ABAT) in September and November of 2013 motivated many fishers to engage in pushing the park manager to iniciate negotiation. The question of how open the park manager will be to a process that is participatory and welcomes different knowledge systems remains unanswered as there is no legal political guidance for this.

In considering the incorporation of fishers' knowledge in resource management, another institutional arrangement should be recognized: a Mosaic of Protected Areas composed of several PAs. A Mosaic has the objective of integrating and coordinating decisions about the activities that occur inside and on the borders of Protected Areas as well as decisions about local communities living inside the Mosaic's territory in a multiscalar perspective (Federal Law 9985/2000 - SNUC). Three of the study sites presented here (Vila do Aventureiro, Trindade and Ubatumirim Bay/Praia da Almada) are part of the Bocaina Mosaic of Protected Areas, established in 2006. This Mosaic encompasses 14 municipalities in two states (Rio de Janeiro and São Paulo) and 28 protected areas of different categories under municipal, state and federal jurisdictions. Two representatives of *caiçaras* sit on the Mosaic management board and hence have the right to participate in decision-making processes. The Bocaina Mosaic board had been quite active in its first years, including setting a Chamber of Traditional People to discuss the issue of resident communities and resource use inside the PAs. The board also demanded the assessment of Trindade fisheries inside the Serra da Bocaina National Park in 2010 in order to provide information to negotiate Terms of Agreement between the park and local fishers. Nevertheless, the park manager did not recognize the value of such an assessment and prior to November 2013 had not yet considered discussing such Terms of Agreement.

Over the last few years, this management board has become less active due to changes in the political context at national and state levels with consequences at the local level: most of the key managers involved in Mosaic management board have been replaced since 2009. Notwithstanding the institutional instability of governments, a Forum of Traditional People of Bocaina Mosaic was created (parallel to the board chamber) in 2007 by *caiçaras*, indigenous groups, and *quilombolas* (maroons), which are still very active in pushing for the recognition of traditional land, knowledge and values in different natural resource management arenas (Araujo *et al.*, 2014).

In the same sense, the demand for the creation of Sustainable Use Protected Areas such as the RDS (e.g. Vila Aventureiro) and the RESEX (e.g. Ibiraquera Lagoon), may be seen as a means to ensure the integration of local knowledge in fisheries management. Furthermore, such demand also serves to legitimize local processes that can occur prior to Protected Areas establishment, as in the case of beach seining fishing rules in Arraial do Cabo. It is noteworthy that in these three sites the proposals for RDS and RESEXs emerged in response to threats either to the resource system (as in the case of Ibiraquera and Arraial do Cabo) or to the human system (as in the case of the permanence of Aventureiro community inside the PA). In all three cases, the communities organized themselves and showed agency in dealing with governments. Also in all the three cases, in addition to the Trindade case and the Forum of Traditional People of Bocaina Mosaic, local people had support from university groups to organize themselves in order to create demand and negotiate with government staff.

CONCLUSIONS

In Brazil, the ecosystem approach to fisheries, which considers various societal goals (e.g., conservation of biodiversity and sustainable use of resources) and different knowledge systems (e.g., scientific, technical, traditional and local) is not yet clearly institutionalized in federal legislation. Nonetheless, fisheries management through Protected Areas (PAs) favors the adoption of an ecosystem approach, especially in Sustainable-Use PAs, but also in No-take Protected UCs, through Terms of Agreement. Additionally, a Mosaic of Protected Areas has the potential to advance the ecosystem approach in a multiscalar perspective.

The implementation of the ecosystem approach to fisheries in Protected Areas, however, is vulnerable to the "profile of the PA head" or "governmental political will" to create or re-categorize such areas. In fact, further research should investigate the educational and professional backgrounds of managers, such as what fields of study, the values in these fields, and prior experience in managing protected areas in the same region or elsewhere.

Fishing Agreements, on the other hand, stemming from local initiative are potentially less vulnerable to these issues. However, such agreements have emerged in the context of fishing in lakes of the Amazon Basin (Castro and McGrath, 2001; Ruffino, 2005) with little overlap of economic activities in the area and geographically fairly well defined systems. The implementation of these agreements in coastal regions with multiple economic activities and open aquatic systems have not shown promise (e.g. Araújo *et al.*, 2014). In fact, even in the Amazon region, communities that initially established fishing agreements with one government agency, while excluding other economic activities, over the years ended up creating separate agreements with another agency to address cattle conflicts; furthermore, Natural Resource Use Plans were created for some of these areas, in the context of agro-extrativist territories, which are more comprehensive than the earlier fishing agreements (McGrath, pers. comm.).

In sum, despite the lack of clear guidance in Brazilian legislation on how to incorporate fishers' knowledge into an ecosystem approach to fisheries, we point out some lessons learned that may help guide further efforts. First, fishers' knowledge is likely to be considered in management regulation depending upon a manager's 'profile' (e.g. having a more people-oriented approach rather than a strict preservationist approach and valuing different knowledge systems); hence further efforts should be made to build capacity among fisheries and protected area managers towards EAF. Second, even in arenas that consider fishers' knowledge in management (e.g. the initial phase of the RESEX in Arraial do Cabo and some Amazonian fisheries co-management agreements), if other economic activities and stakeholders are not brought into the decision-making process, resource management is likely to fail over the long-term due to competing interests. Third, institutional instability at higher political levels and frequent turnover of PA managers remains a barrier to building long-term, trustable, collaborative management agreements. In order to buffer some of these impacts, fishers and their communities need to better organize themselves to continually pressure the government to recognize their land, knowledge and value systems, such as the case of the Forum of Traditional People of Bocaina Mosaic. Fourth, university research groups can play an important role in building capacity and supporting fishers' engagement in resource management in many cases. However, research-funding agencies, particularly in Brazil, seldom cover what is considered outreach academic work. In order for academics to help build capacity both for fishers and managers to engage in negotiation processes that value different knowledge systems and acknowledge diverse societal goals, such as the EAF, research funding agencies should value and financially support such efforts – particularly considering that action-oriented research may emerge within these processes. Finally, although we observed in these cases some initiative-building arenas where fishers' knowledge can be incorporated into management decisions, this process does not guarantee effectiveness of results unless fishers are empowered and well-represented in these arenas and managers are prepared to acknowledge fishers' knowledge. In this context, all the above-mentioned lessons should be considered in future efforts to incorporate fishers' knowledge into an ecosystem approach to fisheries.

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Exploring opportunities to include local and traditional knowledge in the recently created "Marine Management Plans" policy of Chile

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ABSTRACT

Marine governance is increasingly shifting towards the development of new multilevel participatory forms. In Chile, this has manifested in a mixing of "top- down" directives with "bottom-up" approaches in which fishers participate directly in policy implementation. In accordance with this tendency, Chile has recently passed legislation to create what have been termed Management Plans (Law 20657; 2013). The Management Plan legal framework allows the fisheries agencies, in a joint process with artisanal fishers and the fishing industry, to create a multi-stakeholder management committee and a fishery management plan for what are currently *de facto* open access areas. This paper reviews this new policy with a special emphasis at identifying opportunities for the inclusion of local and traditional knowledge in fisheries management. The paper highlights opportunities for local and traditional knowledge, but calls for the need to develop knowledge integration strategies. Finally, the paper uses the example of the artisanal bull-kelp *cochayuyo* fishery, in the local council of Navidad, as a way to empirically ground the potential contribution of including fishers' local and traditional knowledge in future management plans developed through this new policy. Adaptive approaches for the inclusion of local and traditional knowledge in management plans is critical.

INTRODUCTION

Increasing concerns about the integrity of oceans in relation to anthropogenic impacts such as climate change, pollution and overfishing has prompted calls to understand the potential contribution of local and traditional knowledge as complementary approaches for the sustainable governance of resources and biodiversity in marine environments. Potential contributions of local and traditional knowledge for ecosystem research and management are increasingly recognized as a way to both inform resource management and provide local users with opportunities to participate and shape new management policies and practices (Lobe and Berkes, 2004; Thornton and Maciejewski, 2012; Bundy and Davis 2013). In particular, stakeholders' knowledge and conceptualizations of key local marine ecosystems can be critical to inform and support adaptation (Cinner *et al.*, 2005), restoration (Taylor *et al.*, 2013), sustainability targets (Bundy and Davis, 2013), fisheries (Wilson *et al.* 2006; Cinner et al 2005; Godoy et al 2010) and spatial planning initiatives (Szuster and Albasri, 2010; St Martin and Hall-Arber, 2008). Accordingly, interest in integrating local and traditional knowledge and "western science" is growing as a way to fill gaps in the understanding and management of aquatic/marine resources (Bohensky and Maru 2011; Johannes *et al.*, 2000).

If local and traditional knowledge for marine management is to be effective, fishing communities must begin to be recognized as holders of this relevant information and knowledge. Stating the need for knowledge integration as a fashionable trend in natural resource management is not enough (Wohling 2009) and will likely result in little more than a box ticking exercise (Bohensky and Maru 2011). Local and traditional knowledge could be formally recognised in decision-making processes and fishing communities should be formally empowered to play a major role in the management process. Accordingly, marine management should begin creating and implementing policy alternatives through which local and traditional knowledge can be assessed and eventually included in the sustainable governance of marine ecosystems (Berkes, 2003).

Environmental governance, the structures and processes by which people in societies make decisions and share power with respect to the environment (Folke *et al.* 2005), is currently shifting towards the development of new multilevel and participatory forms, partly through government-designed decentralization (Ostrom et al 2010). In theory, under such approaches, problems associated with non-compliance, power inequalities and inappropriate discrimination can be better addressed, and major investments made in information and innovations (Ostrom 1961; Ostrom 2006). Moving towards multilevel and participatory governance systems could also generate opportunities to institutionalize local and traditional knowledge and to develop platforms for integrating this knowledge with formal scientific understanding (Folke *et al.* 2005, Ballard *et al.*, 2008). Unfortunately, the analysis of the potential of these processes for the integration of local and traditional knowledge has not received the attention it deserves.

In Chile, the global trend towards multilevel and participatory governance has manifested in a rescaling of fisheries governance, mixing "top-down" directives from government with "bottom-up" approaches in which fishers participate directly in policy implementation (Gelcich et al 2010). Initially this trend took the form of a co-management approach, which granted exclusive territorial user rights to artisanal fishers for the management of benthic resources (San Martin et al 2010). More recently, in 2012, Chile acknowledged management of open access sites as a priority. Consequently, it recently passed legislation to create what have been termed Management Plans (*Planes de Manejo*; Fisheries and Aquaculture Law 20657 of 2013). The Management Plan legal framework allows the national and local fisheries agencies, in a joint process with artisanal fishers and the fishing industry, to create management plans which are locally agreed upon. These can operate at different scales (cove, bay, administrative region, set of regions) and for different species or multiple species in what are currently *de facto* open access areas.

In this paper, we explore the potential of the Chilean Management Plan legislative initiative as a way to include local and traditional knowledge in the management of artisanal fisheries. We assess the challenges for knowledge integration and attempt to empirically ground opportunities and challenges through the development of a case study, that could use the new policy as a way to include traditional management practices. The paper begins with a brief working definition of local and traditional knowledge, its potential and downfalls. It then reviews the articles of the Fisheries and Aquaculture Law, which relate to this new policy and its initial application process, highlighting opportunities to include local and traditional knowledge. This is followed by the empirical grounding of these opportunities through a case study.

WORKING DEFINITION, POTENTIAL AND THREATS OF LOCAL AND TRADITIONAL KNOWLEDGE

Traditional knowledge, indigenous knowledge, local knowledge and local ecological knowledge are just some of the terms which are generally used in the literature to refer to knowledge systems embedded in the cultural traditions of indigenous or local communities. It is beyond the scope of this study to review the terms and definitions used to encompass all these knowledge systems (see NOAA for a set of definitions: www.st.nmfs.noaa.gov/lfkproject/02_c.definitions.htm), however we do feel it is necessary to define the concept and scope of local and traditional knowledge as used in this paper.

Here we use "Local and Traditional Knowledge" to encompass a set of attributes regarding a knowledge system, its practices, generation and the processes through which it is transmitted. In this sense, Local and Traditional Knowledge (LTK) in this paper is understood as an integrated and situated knowledge, as opposed to an assemblage of facts (see Thorton and Maciejewski Scheer, 2012 for a review of the concept). Drawing on a broad definition provided by FAO (2004) for local knowledge, we define LTK as the knowledge that people in a given community have developed over time, and continue to develop. It is based on experience, often tested over centuries of use, adapted to the local culture and environment, embedded in community practices, institutions, relationships and rituals, held by individuals or communities. Therefore LTK is dynamic and open to change. It is not confined to tribal groups or to the original inhabitants of an area. It is not even confined to rural people. Rather, all communities possess local knowledge: rural and urban, settled and nomadic, original inhabitants and migrants (FAO, 2004). By using this combined definition of LTK, we include both the collective body of knowledge incorporating environmental, cultural and social elements that is passed on from generation to generation and continues to grow and evolve over time and the current, and experiential knowledge that is held by people in a community, which can be gained by any individual who has spent considerable time observing nature and natural processes. Putting together the local and traditional aspects of knowledge recognizes its continuity and evolution over time (BeaufortSeaPartnership, 2013).

In our opinion, operating with a broad definition of LTK in marine environments is essential. In most coastal social-ecological systems, different sources or types of knowledge coexist and interact with scientific knowledge (Folke *et al.,* 2003). Combining these types of knowledge and expanding knowledge forms is vital for understanding social-ecological interactions and shaping change (Folke *et al.* 2003 and 2005). Failure to include and understand LTK risks missing an important opportunity to build a holistic understanding of fishers local ecosystem experiences, which may prove critical to provide meaningful inputs for the management of local resources (Berkes, 2000). In essence, LTK derived from the community members can assist in management and co-management efforts, contribute to the existing knowledge of the biology of various organisms and their interactions with the environment and provide important data to help shape the decisions of policy-makers and researchers.

Fishers' LTK is not confined to the biological, ecological, or oceanographic realms; it also includes informal or traditional fishery-management systems that enjoy considerable legitimacy among user groups (Cinner *et al*., 2005). These traditional arrangements provide a repository of experiences from which many of the other actors involved in the development and implementation of natural-resource management policy could draw valuable lessons (Johannes, 2002).

Although research has shown how LTK has a huge potential to achieve sustainability, a problem has arisen in that LTK is being lost and there is a need to find ways to preserve and use this knowledge in natural resource management (Jackson, 1995). Important losses of traditional management practices have occurred as governments continue to embrace command and control "western science" ways of managing natural resources (Gupta, 1996; Chambers, 1983). Even in co-management settings, current management practices and implementation of "best practice" policies with little regard to existing LTK have eroded important local and traditional management practices due to the dependence on formal scientific research, undermining the system's overall capacity to achieve sustainability (Cinner andAswani, 2007; Gelcich *et al.*, 2006; Aburtoand Stotz, 2013). In this sense, knowledge integration and the identification of opportunities to include local and traditional management in existing policies or new policies should be a research priority.

ARTISANAL MANAGEMENT PLANS IN CHILE: OPPORTUNITIES TO INCLUDE LOCAL AND TRADITIONAL KNOWLEDGE FOR SUSTAINABILITY

Recent research shows the benefits and importance of integrating LTK in marine management (Thornton and Maciejewski Scheer, 2012). Thus, it is increasingly important for innovative marine policy approaches to consider ways to integrate LTK as parts of formal resource management legislation. However, this process must necessarily be flexible and adaptive, and be coupled with constant assessments of feedbacks to avoid the process becoming a box-ticking exercise that ultimately constrains adaptive capacity (Gelcich *et al.,* 2006). In this section, we assess the potential of a newly created policy, the Chilean Artisanal Management Plan policy, as a platform for future knowledge integration and the inclusion of LTK in marine management.

The Chilean Management Plan Policy

The management plan policy of Chile essentially allows the management of a species or group of species within an administrative region, part of a region, or a set of regions through the establishment of management committees, which include both artisanal and industrial fishers, government and private company representatives that are in charge of developing, implementing and monitoring and adapting a specific management plan. The establishment of the management plan policy in Chile draws from historical developments in local resource management, which tended towards the need for a multilevel governance approach. The main driver for the establishment of the policy was the need to formalize existing management plan initiatives that had been developing for years. Foremost among these was the Sea Urchin Artisanal Management Plan for regions X and XI of Chile, which was developed in 2005 as a result of conflict related to resource access between these two different administrative territories (Moreno *et al.,* 2007; Orensanz *et al.,* 2013). In addition, the process that led to the Bahía Chasco Artisanal Management Plan for kelp species, developed in 2010, led the way towards acknowledgement, by officials of the Undersecretary of Fisheries and Aquaculture, of the need for some type of formalization of decentralized territorial-based management and the plans in operation.

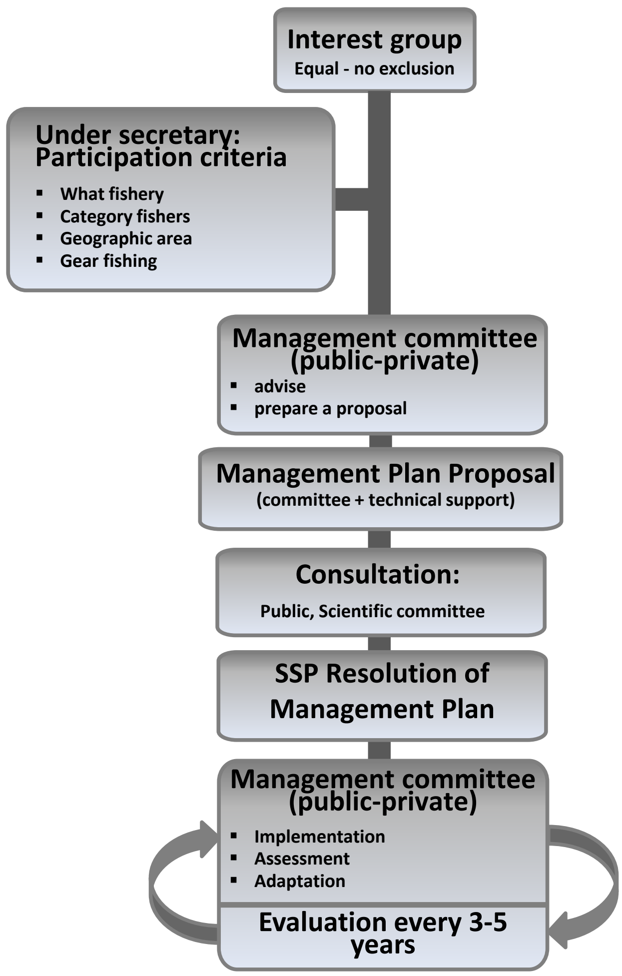
On January 3rd, 2012, Policy No. 20.560 of the Fisheries and Aquaculture Law was published. This law stated that for the management of one or more invertebrate or algae benthic fisheries, the Undersecretary of Fisheries could establish artisanal management plans. One year later, as Chile completely revised the whole fisheries legislation, article 8 of the Law No. 20.657, published on February 9th 2013, ratified the possibility to implement management plans and additionally made them available for all fisheries, including benthic and pelagic fisheries as well as those with shared stocks between industrial and artisanal fleets. In this process, artisanal management plans were re-named as simply "*Planes de Manejo*" (Management Plans). In addition, management plans were made compulsory for those fisheries with registries closed (declared in full-exploitation) and recovery plans for over-exploited fisheries became an obligation. In addition to Article 8, the Law included Article 9bis, which drew from the original Law

No. 20.560 of 2012, and specifically regards the artisanal management plans for benthic resources. Thus, benthic fisheries are now subject to Article 8 and also have specific regulations in Article 9bis of the Fisheries and Aquaculture Law N° 20.657 (2013).

Article 8 of the Fisheries and Aquaculture Law N°20.657 establishes seven minimum requirements that must be contained in any management plan: 1) general background information on the geographic area, types of resource, fishing fleets and markets; 2) clear objectives, goals and time frame to maintain fisheries at maximum sustainable yield. Importantly, other articles of the Law (e.g. Article 2 and 3) permit the focus on maximum sustainable yield to be targeted through different strategies for benthic resources with the recommendation of the scientific committee. This is due to resources specific biological and fishery characteristics; 3) strategies to achieve objectives and goals which must include conservation and management strategies and agreements between stakeholders; 4) evaluation criteria for management plans; 5) contingency strategies; 6) research and enforcement requirements; 7) other important aspects. Significant for its potential in knowledge integration, is the fact that in order to develop and implement the management plan, the undersecretary constitutes a management committee with representation from all relevant stakeholder groups (i.e. artisanal fishers, industrial fishers, processing plants, undersecretary of fisheries, direction of maritime territories and national fisheries service). The management plan must be revised and approved by established science committees (see Law Article 153 on responsibilities and establishment of these committees). Once the management plan is approved it is compulsory.

The creation of a management plan for benthic fisheries (following Articles 8 and 9bis of the Law) can be developed for one or more resources within a bay, part of a region, whole region or a set of regions; and typically follows a set of stages (Figure 1). In the first stage, an interest group must contact the Undersecretary of Fisheries. The undersecretary must convene all registered artisanal fishers and then assure no exclusion of stakeholders in the process through the establishment of participation criteria. Participation criteria are defined based on target species, fisher categories, fishing gear used and the available history of landings in the determined geographical area. Once participation criteria are established, the sub-secretary facilitates the creation of a management committee. This management committee is formed by 2-7 representatives of artisanal fishers, 1 representative of processing plants, a representative of the national direction of the maritime territories (DGTMM) and a representative of the national fisheries service. The first responsibility of the management committee is to advise the

FIGURE 1
Schematic representation of the establishment of a management committee and management plan as indicated by Articles 8 and 9bis of the Chilean Law N° 20.657 (SSP= Undersectetary of Fisheries and Aquaculture



design of a management plan proposal with the help of technicians/consultants. Once the management plan proposal is established it must be assessed by the benthic resource science committee and the general public. Once it is approved, the undersecretary of fisheries grants a management plan resolution. When the management plan is officially decreed, it becomes compulsory and only fishers who comply with the participation and operation criteria established in the management plan can continue fishing in the area. The management committee is responsible for implementing, assessing and modifying the plan. Also, this committee plays an advisory role to the Undersecretary of Fisheries and at least every three years the number of participating fishers (fishing effort) must be re-analyzed (only for benthic resources). Every five years the management plan must be assessed (Figure 1).

Currently 15 management plans which focus on artisanal fisheries are being developed. Management committees for different species are currently being formed in every administrative region of Chile, and account for whole regions, parts of regions, bays or gulfs (Subpesca, 2013). Currently most of these first management committees have been approved and are in the process of establishing the management plan proposal. The first six management plan proposals which are under consultation are all for kelp species. In a review of these six initiatives, that have a management plan currently under consultation, the words traditional and local knowledge are absent and no formal assessment of LTK has been performed. However, many of these plans have included elements of LTK obtained from stakeholder meetings. For example in Bahia Chasco, fishers are constantly participating and have guided scientists with their knowledge. In general, kelp management plans have been informed by empirical knowledge on specific harvesting territories, productivity of these territories and alternative extraction measures (participant observation, Javier Rivera).

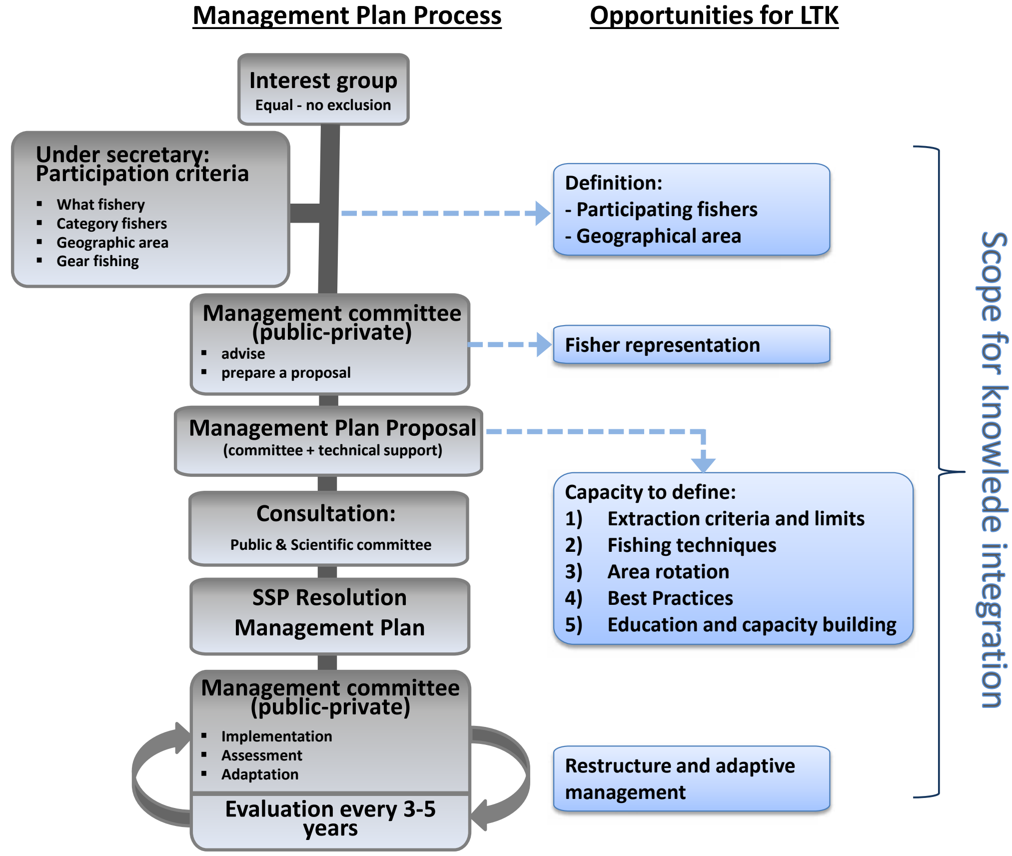
Opportunities and challenges to include Local and Traditional Knowledge in management plans

In the existing procedures to create management plans in Chile there is no legal requirement to assess or include LTK; however, the management plan design process described above and Article 9bis of the Law both provide opportunities for the inclusion of LTK that we highlight below.

The policy is emphatic in determining that management plans are applicable to all or part of an administrative region or regions in Chile. This provides opportunities to include LTK at appropriate scales. For example, it is likely easier to integrate knowledge systems when management plans operate within bays or portions of a region than when they include whole regions or sets of them. In addition, the regulation makes it possible for users to be influential actors in management committees. In fact, artisanal fishers are the stakeholder group with the greatest representation in management committees. As such, an opportunity is granted for the active participation of fishers and mobilization of management capacity for sustainable resource management. Ideally, these incentives for the inclusion of stakeholders are associated with potential reductions in transaction costs, as users can provide important information in the form of LTK, which in many instances can create new ways of approaching problems or provide information that is not available in a different form or may be costly to acquire (Figure 2).

Specific opportunities to include LTK in management plans come from a section in Article 9bis of the Law that determines possible actions that can be allowed as part of management plans and which are then formalized by the undersecretary. Actions included in this article that we feel have the potential to provide opportunities for the inclusion of LTK in management plans include: 1) the establishment of criteria and limitations for extractions; 2) determining of extraction and harvesting techniques; 3) rules for rotation of areas; 4) establishment of best practices, sustainability and restoration of ecosystems and 5) education and capacity building programs (Figure 2).

FIGURE 2
Opportunities to include Local and Traditional Knowledge within the management plan policy process of the Chilean General Fisheries and Aquaculture Law No 20657



We will explore these fivepoints further in the next section (case study). In addition to these points, management plans must be re-assessed every 3 years providing opportunities for adaptive management.

Through the establishment of management committees as the main institution through which management plans are established, the policy opens space for knowledge integration and social learning. This is important as integrating LTK with "western science" and social learning processes have been reported as key for developing new ideas and concepts for dealing with problems of natural resource governance and for expanding knowledge on ecosystem functions (Reid *et al.*, 2006; Pahl-Wostl *et al.*,. 2007).

LTK integration through the work of management committees will require support from other members; foremost among these are the representatives of the undersecretary. Fortunately, in this new policy model the role of the administrator has changed from that of an executor of to that of an autonomous agent, who has to make and manage policy decisions. As managers, heads of public offices are not merely experts in bureaucratic procedures, but are responsible for identifying policy objectives and the best organizational strategy to achieve those (Maiello *et al.*, 2013). *In this way, members of the committee will need to become what has been termed in the literature catalysts* of integration among different types of knowledge (Feldman and Khademain, 2007) and *stewards* of collective learning processes (Roberts, 1997).

For LTK to play a role in the management plan process, an important gap to address is how this knowledge will be included by fishers and scientists and under what domain. It is also important to be aware that LTK is also time sensitive and therefore changes in LTK over time must be explored (Gelcich *et al.,* 2006; Ruddleand Davis, 2011). In addition, within the context of the implementation of management plans, it will be important to relate LTK with changes in the local environment and resource availability and social, power dynamics and economic changes.

The literature is expanding on ways to systematically collect LTK and integrate it with traditional science and management of natural resources. Huntington (2000) reviewed traditional tools for including indigenous knowledge in ecological studies. Others have explored methods such as GIS mapping exercises to include LTK (Palmer, 2009; Blyth *et al.,* 2002). Reid *et al.,* (2006) have looked at how to bridge scales and knowledge systems, and more recently, Bohensky and Maru (2011) reviewed the literature on integration between indigenous and scientific knowledge. Importantly, there is a risk of inappropriate knowledge integration in which the treatment of LTK is superficial (Huntington, 2000; Bohensky and Maru, 2011) which must be considered in the inclusion of LTK in Chile.

PROPOSAL FOR A BULL-KELP MANAGEMENT PLAN IN NAVIDAD LOCAL COUNCIL AS A WAY TO EXEMPLIFY THE INCLUSION OF LOCAL AND TRADITIONAL KNOWLEDGE

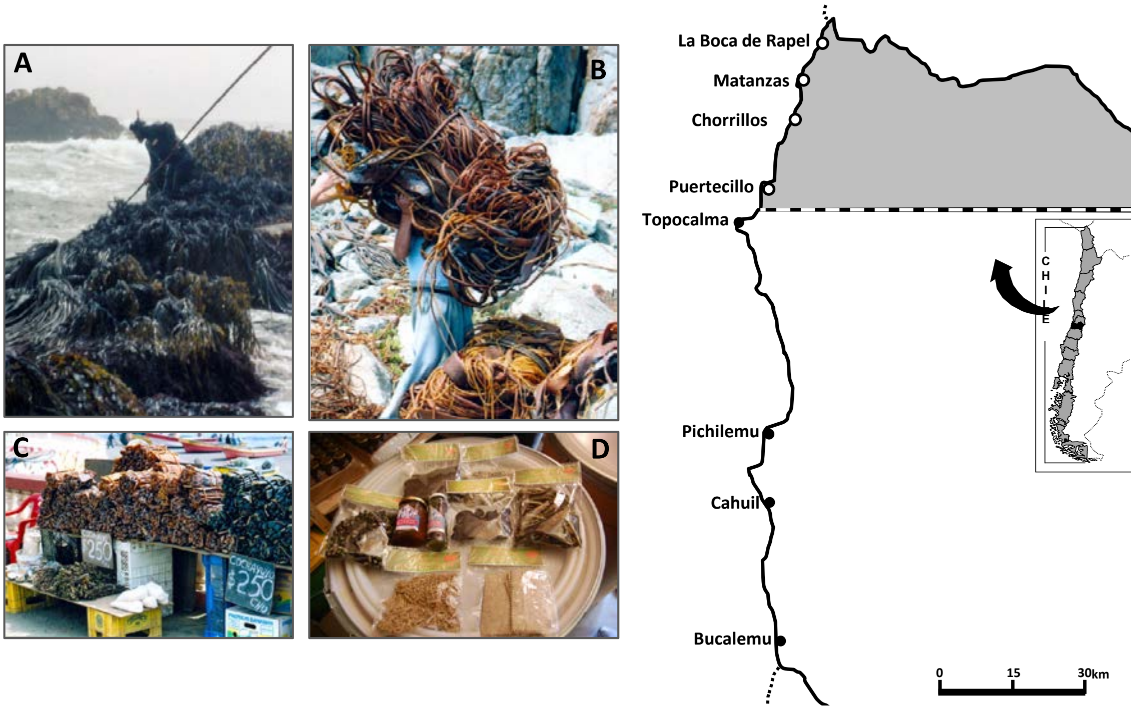
In this section, we present a case study, which has still not been applied as a management plan, as a way to illustrate how artisanal fisher communities and their knowledge might embrace the opportunity provided by the management plan regulatory framework to include LTK practices as part of a regulatory framework. We specifically refer to a traditional bull-kelp management system which is used in most of Region VI of Chile (Gelcich *et al.,* 2006) and for which a group of fishers from the north part of the region have shown interest in developing a management plan. The so-called '*parcela*' system is an informal traditional natural resource management system that is used for management of the bull-kelp '*cochayuyo*' (*Durvillaea antarctica*). The development of the system has been rooted in LTK and is based on site designation and rotational use (Gelcich *et al.,* 2006). The system gives access rights to eligible members of a particular community to undertake harvesting activities in designated grounds (a *parcela*) along the coast. These are customary property rights, legitimized by social norms and codes of behavior, and therefore illegitimate in eyes of the state (Gelcich *et al.,* 2006). Here we look into the opportunities generated by the new management plan policy for the inclusion of LTK.

Background of Navidad and the Local and Traditional Knowledge of cochayuyo harvesting

Our case study is concerned with fishers that operate in the north of Region VI in Chile, in the council of Navidad. In this location there are 6 artisanal fisher unions organized in a fisher federation named FEPANAV and four official landing ports or *caletas* (Figure 3). The bull-kelp algae *cochayuyo* is one of the main algae that is harvested in this administrative region. *Cochayuyo* extraction in Navidad is quite labor-intensive and implies a series of steps which include: extraction of the *cochayuyo* from the intertidal and shallow subtidal (1-2 m depth) zone by cutting the algae at the base of the stipe (Figure 3A), letting the *cochayuyo* drift ashore and then laying it to dry on the sides of the cliffs. Once dried *cochayuyo* are carried up cliff paths (Figure 3B) to houses or storage sheds or into a self-owned FEPANAV processing plant where it is packed into bundles of marketable units (Figure 3C) or given added value (Figure 3D), respectively. In general, *cochayuyo* is harvested and sold during the summer months (November-March) and its income used to buy basic food supplies for the winter (Gelcich *et al.,* 2006).

FIGURE 3

Map of Region VI of Chile highlighting the council of Navidad (in gray) and the official artisanal landing ports or caletas (dots). Caletas represented by white dots are part of FEPANAV and the ones interested in developing a management plan for cochayuyo for that part of the region. The photos show the cochayuyo harvesting process: A) Cutting cochayuyo on the rocks B) Carrying cochayuyo once it has dried C) Selling cochayuyo for human consumption D) Cochayuyo with added value, in form of marmalades and flours



There are 399 registered artisanal fishers in Navidad, 295 of which are intertidal gatherers/gleaners who depend on algae – mainly *cochayuyo* – for their livelihood (Table 1). This number represents around 30 percent of all the gatherers of Region VI.

TABLE 1

Number of registered artisanal fishers and their main livelihood activity for the four official caletas in Navidad. In the table the sum of the three categories does not match the total as a person can be registered in more than one main activity

Caleta	Gleaners (intertidal gathering of algae and benthic resources)	Divers (Subtidal benthic resource gathering)	Fishers (Pelagic fin-fish fishing)	TOTAL
Boca de Rapel	103	35	70	178
Matanzas	55	7	14	67
Chorrillos	90	11	3	98
Puertecillo	47	12	10	56
Total Navidad	295	65	97	399
Total Region VI	1018	121	347	1227

Source: Sernapesca.

Landings in the last five years of the fishers of FEPANAV show some heterogeneity between *caletas*, however in all *caletas* algae provide an important proportion of landings. In Puertecillo for example it reaches more than 90 percent (Table 2). Much of the income from unions in Navidad is dependent on the sale of *cochayuyo* for human consumption.

TABLE 2
Official algae and other species landings (in tons) for the official caletas of Navidad

Year	BOCA DE RAPEL			MATANZAS			CHORRILLOS			PUERTECILLO		
	Algae	Other resources	% algae	Algae	Other resources	% algae	Algae	Other resources	% algae	Algae	Other resources	% algae
2008	127,3	22,3	85,1	30,1	24,1	55,5	No Data			72,6	2,1	97,2
2009	11,7	25,7	31,3	7,7	31,1	19,9				56,2	1,4	97,6
2010	0,5	25,5	1,9	12,3	3	80,4				8,5	0,7	92,4
2011	66,9	21,5	75,7	30,2	9,4	76,3				86,6	1,8	97,9
2012	0,3	39,7	0,75	0	7,4	0				No Data		

Source: Sernapesca.

Gelcich *et al.*, (2006) have systematized the LTK of *cochayuyo* and its harvesting in Puertecillo. Similar work has been performed at the FEPANAV level, which includes all 4 *caletas* (Gelcich, unpublished data). In essence, fishers from FEPANAV extract and manage *cochayuyo* following well-defined rules based on LTK. These are voluntarily agreed upon in each union. These rules can be classified into two main groups: those providing access rights to the *cochayuyo*, and those providing effective control over or use of *cochayuyo* as a resource. Access rights to *cochayuyo* are given to each fisher in the form of a small harvesting area, or *parcela* (approximately 150 m of coastline), which consists of approximately six to eight large rocks. In general, a *parcela* produces around 1200-1800 kg of dry *cochayuyo* per season (worth five to seven times the Chilean minimum monthly wage in total for the season). It is important to note that each *parcela* is created and divided on the basis of approximate production, not on the basis of size. *Parcelas* are allocated to union members every year in August through a lottery system that awards annual rotational access to harvesting grounds. It is important to emphasize that although a *parcela* is a customary property right legitimized by social norms and codes of behavior, it is illegitimate in the eyes of the state. The only government institution that grants access to *cochayuyo* is a coastal collector permit issued by the Fisheries Department (Sernapesca).

All fishers from FEPANAV have equal rights when they receive access rights to the *parcela*; nevertheless there are differences in the way that the fishers control or harvest their *cochayuyo* based on their individual capabilities. Male fishers, especially skin-divers, generally harvest their *parcela* on their own or with their family group. Another alternative that exists is to obtain help in harvesting a *parcela* simply by requesting it from others. This form of cooperation, in exchange for a possible favor sometime in the future, is informal. Individuals associated with the union who do not qualify for this informal exchange of labor (for example, women and older men) use a process called "*mingaco*", in which the owner of a *parcela* gives food and drink to the helpers in return for their assistance. Other methods that are used to obtain benefits from access rights include the sale for one season of the *parcela* to other associates as a territorial-based transferable endowment. This system is mainly used by fishers whose physical limitations or livelihoods make it extremely difficult for them to manage their own resources. Finally, widows do not generally extract or cut algae: they collect what is washed ashore naturally by waves (normally it would be collected by the *parcela* owners). Hence, the algae in the widows' *parcelas* remain un-extracted, and no assistance for extraction needs to be found (Gelcich *et al.*, 2006).

In sum, the local rules that provide access rights over the *cochayuyo*, and those that provide the effective control or use of *cochayuyo* as a resource, which have been developed through LTK, minimize conflict. Heterogeneity in income, livelihood or capability is accounted for through a range of institutional arrangements, which seem fair to fishers and therefore do not seem to affect compliance, and provide incentives to continually build LTK (Gelcich *et al.*, 2006).

LTK is present in Navidad at three distinct levels, which are important for resource management: knowledge of the species, knowledge related to species management and knowledge of good institutions for resource management. It is beyond the scope of this paper to review all the elements of LTK present in algae gathering in Navidad, therefore in the following section we only highlight those aspects, which could easily take advantage of the opportunities provided by the management plan policy.

Opportunities for inclusion of Local and Traditional Knowledge in a Bull-kelp Management Plan in Navidad.

Certain elements of the Chilean management plan policy provide important opportunities for the inclusion of LTK in a future *cochayuyo* management plan for the council of Navidad. Essentially, these opportunities shall allow fishers to use their own knowledge, rules and regulations for resource management and maintain an adaptive learning capacity.

The opportunity in the new law allows fisher from Navidad, who already have local management rules, to select a portion of the region (in this case the north side) to develop a formalized Management Plan with support of the science committee. It is also relevant from a political and geographical perspective. The north is all one administrative council and it is geographically isolated from the south of the region due to the lack of coastal roads. In addition, FEPANAV has developed its own buying and processing plant, owned by the fishers themselves which has also helped these communities consolidate.

The fact that management committees are formed with up to seven representatives of the artisanal fisher sector provides a unique opportunity to introduce LTK into future management plans. Specific elements of the management plan which could benefit from this knowledge integration are related to: 1) the establishment of criteria and limitations for resource access, designation and monitoring, 2) the development of harvesting techniques, 3) the rotation of areas, 4) the establishment of best practice management strategies and 5) education and capacity building. We will briefly touch upon each of these opportunities with an example (Table 3).

The establishment of criteria and limitations: In Navidad every union uses the *parcela* system and has done so for more than 50 years. Determining access criteria in terms of this system is rooted in LTK. The creation of a *Cochayuyo* Management Plan in Navidad should consider this knowledge base. A systematic examination of the *parcela* system (Gelcich *et al.*, 2006) has shown how LTK associated with the *parcela* designation and monitoring criteria has enabled fishers to avoid conflict and achieve sustainable and equitable distribution of entitlements and benefits.

In addition, it is important to highlight that in these unions, once a *parcela* is granted, individual fishers decide how the *parcela* is managed and regulated for the year. Nevertheless, no *cochayuyo* extraction is permitted between April 1st and September 30th. This is a voluntary measure that was developed thanks to LTK and which relates to the biology of the algae. Local fishers perceived the period outside the closed season as the time in which algae grew faster, and therefore one or two harvests could be attained. This compares well with current scientific knowledge (Santelices *et al.*, 1980). Through the independence that the management plan policy establishes to create limitations in harvesting, the *Cochayuyo* Management Plan could find ways to include *parcelas* as the access regime and temporal bans as officially designated (Table 3).

TABLE 3
Legal opportunities and aspects of LTK generated in Navidad which could contribute to the establishment of a Cochayuyo Management Plan

Legal opportunity to include LTK in management plans	Aspects of LTK from Navidad which could be included	Level of LTK to include
Establishment of Criteria and limitations	*Parcela* access system Local banns	Institutional arrangements Species management
Establishment of harvesting techniques	Selective removal of species	Species ecology
Possibility for area rotation	Yearly lottery system Non-harvested *parcelas*	Institutional arrangements Species management
Establishment of best practice management	Yearly monitoring Yearly re-assessment of *parcelas*	Species management Institutional arrangements
Education and capacity building	Experimentation in *parcelas* Capacity building in knowledge integration	Species management Species ecology All levels

Harvesting and Management Techniques: In addition to selecting the harvesting periods, many fishers, particularly men, selectively remove species to imitate the natural disturbance associated with storms (Gelcich *et al.,* 2006). This concurs with the results of formal studies that demonstrate that *cochayuyo* persists as a result of its high rate of settlement and rapid growth (Santelices *et al.,* 1980). LTK has recognized that disturbance is a necessary part of the process that promotes ecosystem services and has developed management practices that mimic disturbance regimes in nature (Gelcich *et al.,* 2006). Management that behaves like disturbance is one of a series of practices that generates resilience (Folke *et al.,* 2003). Article 9bis of the Fisheries and Aquaculture Law (No 20.657), which establishes that management plans can propose the establishment of harvesting techniques, could provide a good opportunity to begin building and integrating knowledge on the implications of these practices as management strategies.

Possibility of area rotation: The Management Plan policy allows the implementation of rotational harvest systems. As mentioned, the concept of rotation is rooted in the LTK practices of Navidad and of many systems based on LTK globally (Berkes, 2000). In addition, it is important to consider that under the *parcela* system although widows are allocated a *parcela*, they do not harvest them. Thus, these *parcelas*, which comprise about 100 m of linear coast each, act as small reserves or buffer zones (Bustamante and Castilla, 1990; Castilla and Bustamante, 1989). Fishers regard these reserves as useful. In the words of one Puertecillo diver (2004): "it is important to maintain areas that have not been touched in order to see what happens and recuperate other sectors". These types of rotational *parcelas* have a strong potential to be now included in management plans which are sensitive to LTK (Table 3).

Best practices: The *parcela* system includes monitoring of the annual biomass yields from each individual *parcela* in the event that some produce too little and therefore the sizes or layouts may require alterations. By doing this, fishers are including monitoring and local understanding of ecosystem conditions and dynamics within their management institutions. It is interesting to note the scope of the new policy for assessment and adaptation which is in line with what local communities in Navidad have established through LTK. Monitoring and adaptation of practices will provide an important challenge for knowledge integration but has the potential to develop a unique place-based adaptive system.

In essence, an examination of the institutions that underpin the *parcela* system has enabled us to identify the "right institutions" (Cleaver 2000) – the ones that promote resilience and facilitate equal access – and the types of knowledge for resource management present in Navidad. The importance of user group experimentation for resource management has also been shown. These are the factors that can systematically be included in future management plans and which could eventually reduce unwanted effects of the policy.

DISCUSSION

In this paper, we have examined how the implementation of a policy which incentivizes multilevel and participatory governance approaches could generate the correct opportunities for the integration of LTK into resource management. Folke *et al.*, (2005) state that bringing together science and LTK can be facilitated by bridging organizations that provide an arena for knowledge coproduction, trust building, sense making, learning, vertical and horizontal collaboration, and conflict resolution. Bridging organizations should respond to opportunities, serve as catalysts and facilitators between different levels of governance, and across resource and knowledge systems (Folke *et al.,* 2005; Berkes, 2009). The management committees formed according to the management plan policy will bring together government, fishers and other stakeholders. If the committees are going to play a transformative role in natural resource management, they must aim at providing a platform for knowledge exchange and trust building, conflict resolution, and accessing different types of knowledge. Building social capital (Marin et al 2012) is one means by which the management committees will provide the necessary leadership to achieve a management vision which integrates LTK where possible.

Despite its potential for achieving sustainability, formalizing LTK must proceed with caution (Cinner and Aswani, 2007). There is an imperative need to assess, given a particular social-ecological context, what formal science and LTK can contribute to natural resource management and where there may be limitations (Wohling, 2009; Ruddle and Davis, 2011). In some cases LTK may not be appropriate or present. In others, "western science" might be the most relevant form of knowledge for a determined situation (Bohensky and Maru 2011). In this sense, it is critical to be able to examine and discuss the limitations of LTK that may emerge from field research associated with management plans, as well as to elaborate on cases exploring its usefulness in a complementary relationship with "western scientific" knowledge (Ruddle and Davis 2011). It is important to recognize that the inclusion of LTK in the Chilean management plans could in some places outweigh the benefits.

In addition, while formalizing LTK is desirable, risks associated with loss of adaptability must be constantly considered. The Chilean management plan policy could account for this risk by agreeing on a process for sharing knowledge and co-producing knowledge. Integration will probably emerge out of extensive deliberation and negotiation, as the actual arrangement itself evolves over time. In this sense, knowledge integration is path-dependent. That is, the outcome is strongly influenced by the history of the case (Gelcich *et al.,* 2010). Fortunately, the adaptive component of the policy provides an opportunity for the "co-production of knowledge", described as "Working from the premise that knowledge is a dynamic process – that knowledge is contingent upon being formed, validated and adapted to changing circumstances – opens up the possibility for researchers to establish relationships with indigenous peoples as co-producers of locally relevant knowledge" (Davidson-Hunt and O'Flaherty, 2007: 293). The co-production of knowledge and knowledge integration will probably be the greatest challenge for communities who wish to engage in the management plan policy in a way that includes LTK. The Chilean management plan policy provides a unique opportunity for empirically based knowledge integration research and practice.

Fishers from the council of Navidad are keen to see their own management schemes being recognized. Concomitantly, taking into account LTK could be useful in designing effective fishery-management arrangements. However, a note of caution is needed. These informal tenure systems based on LTK such as the one developed in Navidad are vulnerable to top-down experiments in institutional engineering (e.g., Gelcich *et al.*, 2006), a situation that may lead to reinforcement of local elite power or to strengthening of state control (Gelcich *et al.,* 2006). Also, the potential exclusion of marginal stakeholders who are often poorer and/or politically weaker may have severe implications on equity and community welfare (Gelcich *et al.,* 2005; Wilson *et al.,* 2006). Thus the definition of participation criteria, the initial step of establishing a management plan, when establishing management committees, is essential. Special attention must be paid to develop management plans in which consensus regarding knowledge systems are achieved, where fishers have the opportunity to exercise formal control over the resources on which they depend but could operate under local rules and hence maintain their local institutions and LTK adaptability (Johannes 2002). In our opinion LTK within Navidad could currently be integrated to future *cochayuyo* management plans. In fact, Navidad could become a learning platform for knowledge integration, in which traditional practices and the advice of the science committee design the system, under the enabling conditions of this new policy instrument.

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Diversity of small-scale fisheries and fishery agreements from the participatory management perspective in Colombia

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ABSTRACT

Small-scale fisheries in Colombia occur in diverse areas including river basins, estuaries, and coastlines, for both consumption-based and ornamental fisheries, and carried out by mestizo, indigenous and afro-descendant communities. These fisheries are overexploited or approach maximum sustainable yield. Meanwhile, government capacity and policies for fisheries management are weak and many fishing communities have reached a state of poverty. These conditions have generated an increased interest in the implementation of participatory fisheries management by artisanal fishermen, government and other stakeholders. We analyze 36 fisheries agreements established during the last two decades using similarity analysis, nonparametric multidimensional scaling and similarity percentages to distinguish fisheries agreements according to different management measures proposed by fishermen. Fishermen recognized similar problems despite differences in ethnicity. However, fishermen gave different priority to fisheries measures and activities to carry out their specific fisheries agreements, depending on target species. Differences in fisheries agreements were found between consumption-based and ornamental fishing ($P<0.05$), between river basin and marine fisheries ($P<0.05$), and among fisheries in lakes, lagoons, and reservoirs ($P<0.05$). Small-scale fisheries in Colombia share several fisheries conditions, but these all show differences according to the social perspective of each community to solve its specific fisheries problems. Currently, small-scale fisheries in Colombia face important challenges associated with their diversity/heterogeneity, the poor government capacity for fisheries management, the enforcement of participatory management by different stakeholders (mainly NGOs) with different approaches that respond to their own goals.

INTRODUCTION

Most of the world's fisheries are considered small-scale; however, efforts towards funding management and research have largely targeted industrial fisheries (McConney and Charles, 2008). This has led to the management of small-scale fisheries under conventional approaches, focusing on single-species fisheries with little to no consideration of the human dimension (Pomeroy, 1995) and disregarding the socio-economic needs of communities and the potential benefits of participatory governance (Berkes *et al.*, 2001).

Governments often consider community participation when there is dissatisfaction regarding the use of natural resources or to decentralize management, while encouraging the empowerment among communities (McGrath *et al.*, 2008, Pomeroy and Rivera - Guieb, 2006). This has led to a greater interaction between the State, resource users and other stakeholders in a concerted effort to solve problems and create social opportunities for the fisheries sector (Hartoto *et al.*, 2009; McConney and Charles, 2008; Symes, 2006).

Participatory management proposes shared responsibilities (Berkes *et al.*, 1991), rights and duties among the government, local users of natural resources and all parties involved in a fishery (Berkes, 2008; Carlsson and Berkes 2005, Berkes *et al.,* 2001; Pomeroy, 1995). Nonetheless, the implementation of shared management or Co-Management is complex, as the same resource can be subject to different forms of management by distinct government agencies and hold different interests within communities.

At the same time, fishing communities are heterogeneous entities that undergo constant change, implying that co-management is a state of continuous problem–solving rather than a static condition (Carlsson and Berkes, 2005). As such, Co-Management should be adaptive (Armitage *et al.*, 2007) as fishing communities tend towards resilience, given their ability to learn from previous experiences (Berkes, 2008; Salas *et al.*, 2004) and to cope with unexpected results (McConney and Charles, 2008). Nonetheless, the dynamics associated with small-scale fisheries management call for higher levels of administration, since in many cases these levels are required beyond the community level to solve the problems that need to be addressed (Nielsen *et al*., 2004). In this sense, the involvement of small-scale fishing communities in decision-making in Colombia is precarious, and only within the past few years has there been a clear interest on behalf of the government and the private sector towards the implementation of a participatory management approach. However, the Colombian government is facing several challenges in developing this type of management in the country.

Colombia, located in the equatorial zone of South America, has many marine and inland water environments where indigenous, Afro-descendant and mestizo communities develop small-scale fisheries using different methods on a variety of resources (Rueda *et al*., 2010; Lasso and Morales, 2011). Additionally, almost 90% of fisheries have reached or exceeded the maximum sustainable yield, under a governmental management scheme that is incipient and unstable (Wielgus *et al*., 2009; Gutierrez, 2010).

In order to generate baseline information for formulating legislation that provides a basis for participatory management as a formal management mechanism for small-scale fisheries in Colombia, we collected fisheries agreements elaborated in different parts of the country, all of which apply to different water bodies (marine or inland) and which comprise the participation of different ethnic groups. This paper examines and analyzes the categories of existent fisheries agreements as well as the actions for implementation proposed by fishermen within participatory processes, to identify local problems and potential solutions.

METHODS

En Colombia were identified many actions and participatory process for fishery resources management. However, just 36 of these presented into their respective public documents details about actions and participatory measures for management of fishery resources. Information was obtained from 36 participatory processes (participatory diagnosis, formulation of agreements, fishing agreements or administrative decision by the national fisheries authority) to define local fishing agreements carried out by the own communities, these helped by different stakeholders and during the last 20 years.

Each participatory process which led to some form of fishing agreement, could or not take into account the participation of the fishing national authority. In many cases the fishing agreement just involved the community and collaborating organizations like

NGOs, while in other cases, the national fishing authority was directly involved in the fishing agreements generation. In Colombia only can exercise like fishing authority the government agency created with this specific purpose, however under the current national law the local communities can be organized for finding local solutions to their own problems. This way is including the possibility of producing fishing agreements involving local management. This implies that the process carried out for obtaining each fishing agreement could be different regarding other one. For this reason the agreements considered here were restricted to those where the information leading to the definition of fisheries agreements was produced with the participation of local communities.

Each particular participatory process used in this study produced several measures for implementing and complying the specific fishing agreements, which were published like legal or informative documents (Table 1). In this sense, all measures proposed in the different fishing agreements were extracted from each document and subsequently, these were clustered in agreement categories regarding the particular focus of each one (Table 2).

We created a matrix of presence/absence data that included the agreement categories and the specific implementation actions (fishing measures) proposed by each fishing community. It incorporated as many categories of agreement and actions for implementation as were recorded in the different participatory processes. No categories of agreement or fishery measures were considered in the analysis, unless they had been explicitly described (Table 2).

TABLE 1
Fishery agreements proposed by fishermen in Colombia

State	Place	Spatial approach	Ethnic group	Water body	Communities included	Autor
Amazonas	Tarapoto lakes	Community	Indigenous	Lake-Lagoon-reservoirs group LLR	2	(Trujillo y Trujillo, 2009)
Amazonas	Yahuarcaca lagoon system	State	Indigenous	Lake-Lagoon-reservoirs group LLR	1	(Agudelo *et al.,* 2013)
Amazonas	Mid and low basin of Caquetá river	State	Indigenous and Mestizo	Lake-Lagoon-reservoirs group LLR	2	(AUNAP, 2012b)
Atlantico-Bolivar	Totumo swamp	State	Mestizo	Swamp	1	(Niño, 2011)
Bolívar	Northwest side ofr Mompox Island	Town	Mestizo	Swamp	1	(Barrero *et al.,* 2010)
Bolívar	Magangué swamp	Town	Mestizo	Swamp	1	(Niño *et al.,* 2013)
Caldas	Amaní reserviors	Town	Mestizo	Lake-Lagoon-reservoirs group LLR	1	(Fundación Humedales - AUNAP, 2013)
Caldas	Low basin of La Miel river	Town	Mestizo	River	1	(Trujillo *et al.,* 2011)
Choco	Bahia Solano Littoral	Town	Afro-descendants	Coastlines	1	(Red de Frio, 2012)
Choco	Artisanal fishing exclusive zone	Town	Afro-descendants	Coastlines	1	(AUNAP, 2013)
Choco, Valle del Cauca, Cauca y Nariño	Pacific littoral	State	Afro-descendants	Coastlines	1	(Delgado *et al.,* 2010)
Córdoba	Urrá reserviors	Town	Mestizo	Lake-Lagoon-reservoirs group LLR	1	(Fundación Humedales - AUNAP, 2012)
Cundinamarca	Tominé reserviors	Town	Mestizo	Lake-Lagoon-reservoirs group LLR	1	(AUNAP, 2012a)
Guanía	fluvial start of Inírida	Community	Indigenous	River	7	(Zuluaga & Franco-Jaramillo, 2013)
La Guajira	Mid and High Guajira	State	Indigenous	Coastlines	9	Fundación Ecosfera - AUNAP, 2013)
Nariño	Tumaco cove	Town	Afro-descendants	Coastlines	4	(López *et al.,* 2006)
Nariño	Sanquianga National Natural Park	National Park	Afro-descendants	Coastlines	1	(PNN, 2009)

TABLE 2
Categories and fishery measures from fishery agreements proposed by fishermen in Colombia

Agreement categories	Fishery measures	Agreement categories	Fishery measures
Biological controls	According to sex	Conservation	Prohibited areas for fishing
	According to size		Habitat alteration
	spawning seasons		Repopulation
	Target-species fishing		Species saving
Fishing gear controls	Prohibited fishing gear		Education
	Fishing gear specifications	Non-fishing activity controls	Looging
	Fishing Aggregating Device (FADs)		Gold mining
Fishing type controls	Consumption		Aquaculture
	Sport fishing		Agriculture
	Trade		Tourism
	Ornamental fishing	Fleet controls	Type of boat or engine
Temporary access controls	Closure period		Permited routes
	Specific fishing days		Travel speed
Area access controls	Regarding to others communities	Fishing strengthening	Fishing promotion
	Specific fishing areas		Entrepreneurship
	Rotation of fishing areas		Fishing port financial support
Trade controls	Prices		Training
	Marketing		Alternative fishing targets
	Fishing buyer		Good fishing practices
	Fair trade	Government controls	Good fishing practices
Catch controls	Catch limits		Law compliance
	Number of fishery economic units	Employment alternatives	Non-fishing programs
	Number of fishery gear units		Women participation
Research	Conservation research	Community strengthening	Strengthening of local organizations
	Fishery research		Implementation of local roles

From the presence/absence matrix, a quantitative matrix was constructed according to the number of actions proposed by fishermen for the implementation of each category of agreement identified. This allowed for the quantitative comparison under the same parameters for each of the 36 agreement proposals or fisheries agreements already in place. It was considered that information taken from the all agreements, entirely or in greater part, represented the interests and particular perspectives of the communities, as otherwise they would not have been proposed or approved by the fishing communities.

Data were analyzed using descriptive statistics to describe the trend associated with the proposals made by the fishermen regarding categories and fishery measures in fishery agreements. A management analysis using nonparametric multidimensional scaling (NMDS) was used to correlate the similarities between the categories of agreement proposed, taking into account the number of actions selected by each community to implement each category of agreement (Clarke and Warwick, 2001). Each community was assigned a category for factors; water body where the activity occurs (rivers, coastal marine, swamp and lakes, ponds, dam) basin associated to the fishery (Caribbean, Pacific and inland waters), category of catch (fish for consumption or ornamental fish) and type of aquatic environment where they develop fisheries (marine or inland waters).

To determine the factor level variation, the Bray-Curtis similarity index was used (Clarke and Warwick, 2001). The data was processed using fourth root to reduce the importance of fisheries agreements that were proposed with very low total references for the set of fishing communities studied; subsequently the results were plotted in two dimensions to the final configuration representing the lowest stress for 999 iterations. A one-way analysis of similarity (ANOSIM) was used to determine differences for the categories of each factor.

In addition to the significance level of the test, ANOSIM adds an R value to the degree of separation in terms of categories of fishing agreements ranging from 0-1. R values > 0.75 show good separation for the factors evaluated, R values < 0.50 show overlapping but with differentiation, and R values <0.25 show little or undetectable separation (Wilhelmsson., 2006). Finally, similarity percentages (SIMPER) were used to identify categories of agreement that contributed to the differentiation of factors with R > 0.25. Only agreement categories with percentage of contributions greater than 5% were considered in the SIMPER analysis to avoid interference by outliers (Burt *et al.*, 2011).

RESULTS

Of the 36 participatory process analyzed, fishing communities proposed 48 fishing measures that were grouped into 15 agreement categories (Table 2). We found that the distribution of agreements was not homogenous, but rather agreements largely grouped into 4-8 categories (Figure 1). Fishing communities of distinct regions differed in their need for agreements related to the exercise of control, conservation, development or fishing strengthening. Thereby, the categories of fishing gear controls, biological controls, conservation actions and fishing strengthening represented 50% of all agreement categories proposed by communities (Figure 2).

Taking into account the number of fishing measures within participatory process proposed by each community, different number of these were also found among communities (Figure 1). Some communities proposed approximately six measures in their fishery agreements (26%), while others considered between 9 and 11 fisheries measures (44%). Nonetheless, some participatory process proposed only two fishing measures while others reached 20 measures (Figure 1).

FIGURE 1
Average number of categories for fishing agreements (black bars) and average fishery measures of fishing agreements (gray bars) proposed by small-scale fishermen in Colombia

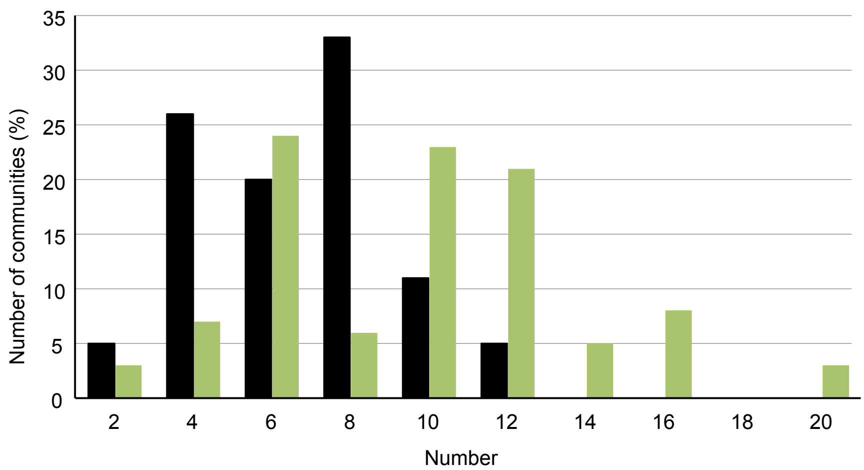


TABLE 3
One-way similarity analysis for the factors basins, ethnic groups, water bodies, type of aquatic environmental and type of fishing resource

Factor	Comparison	R Value	Significance
Tipo de ambiente acuático	Global (Aguas continentales y aguas marinas)	0.313	0.001
Tipo de recurso pesquero	Global (Ornamentales y de consumo)	0.57	0.001
Cuenca	Global	0.301	0.001
	Aguas continentales y oceáno Pacífico	0.274	0.005
	Aguas continentales y mar Caribe	0.361	0.002
	océano Pacífico y mar Caribe	0.428	0.001
Cuerpos de agua	Global	0.350	0.001
	Rios y Lagos-lagunas-embalses	0.297	0.003
	Rios y zonas costeras	0.609	0.001
	Rios y cienagas	0.164	0.152
	Lagos-lagunas-embalses y zonas costeras	0.325	0.004
	Lagos-lagunas-embalses y embalses	0.627	0.008
	Zonas costeras y cienagas	-0.145	0.719
Grupos étnicos	Global	0.054	0.217
	Indigenas y mestizo	-0.019	0.537
	Indigenas y afrodecendientes	0.081	0.161
	Mestizo y afrodecendientes	0.231	0.005

Differences between fisheries agreement categories proposed for consumption-based fisheries versus ornamental fisheries (Table 3) were found (P= 0.001, ANOSIM). Consumption-base fisheries incorporated agreements pertaining to categories such as biological controls, fishing gear controls, area access controls and conservation issues while communities working with ornamental fisheries did not (Table 4). On the other hand, for the case of ornamental fishing agreements proposals did not consider fishing strengthening, fleet controls, or government controls, as was the case of consumption-based fisheries. Differences between the categories of agreements proposed for freshwater fisheries and marine fisheries were also found (P= 0.001, ANOSIM). These differences were related to fisheries agreement categories such as fisheries promotion and research (scientific and traditional knowledge) for marine fisheries, whereas categories of agreements such as temporal access controls and area access controls were more important for freshwater fisheries.

FIGURE 2
Percentage of total number of fishing agreements proposed by fishermen

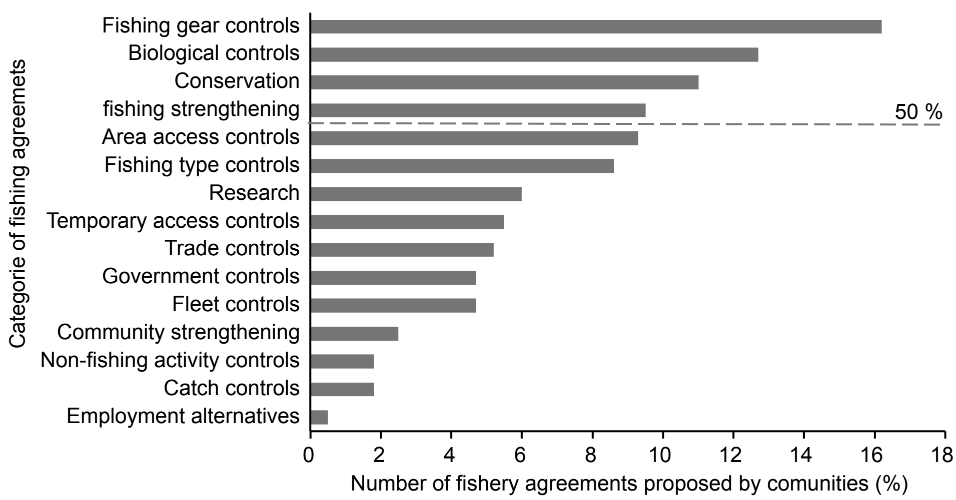


TABLE 4
Similarity percentages SIMPER for the average of fishery measures proposed for each fishing agreement category

	Basins			Water bodies				Type of fishing resources		Type of aquatic environment	
Fishing agreements categories	**Pacific**	**Caribbean**	**Continental**	**River**	**LLR**	**Coast**	**Swamp**	**Ornamental**	**Fishing-based consumption**	**Fresh waters**	**Marine waters**
Biological controls	0.63	1.80	1.12	0.50	1.86	1.24	1.33	0.57	1.33	1.11	1.25
Fishing strengthening	1.38	1.80	0.29			1.65	1.67	0.00	1.22	0.39	1.63
Fishing gear controls	0.88	1.90	1.41	1.13	1.57	1.41	2.00	1.00	1.52	1.33	1.5
Area access controls	1.13	0.00	1.12	0.50	1.86	0.53	0.67	0.43	0.93	1.22	0.38
Conservation	0.50	1.30	0.82	0.25	1.00	0.76	3.00	0.00	1.00	0.78	0.81
Fishing type controls	0.50	0.90	0.94	0.75	1.14	0.65	1.33	0.86	0.78	0.94	0.63
Trade controls	0.50	0.80	0.35	0.50	0.14	0.65	0.67	0.57	0.48	0.39	0.63
Fleet controls	0.13	0.90	0.24	0.00	0.57	0.47	0.67	0.00	0.44	0.22	0.5
Government controls	0.75	0.70	0.24			0.65	1.33	0.00	0.56	0.28	0.63
Community strengthening	0.25	0.50				0.35	0.67				
Research	0.63	1.00	0.35	0.25	0.29			0.29	0.67	0.39	0.81
Temporal access controls			0.71	0.63	0.71	0.18	1.00	0.57	0.41	0.72	0.13
Catch controls				0.00	0.57						
Non-fishing activities controls				0.25	0.14	0.00	1.00				

For the basin and water bodies factors, at least two variables were differentiated; therefore not only a global R was calculated, but also particular R for each pair of data comparisons (Table 3). Fishery agreements proposed between coastlines (Caribbean and Pacific basins) showed partial overlapping with some differences (R= 0.428, P= 0.001, ANOSIM). Fishery agreements proposed by Caribbean fishermen gave greater importance to fisheries categories such as biological controls, fishing gear controls, conservation issues and fleet controls, while Pacific Ocean fishermen gave priority to area access control.

A partial overlap in fisheries agreements for continental freshwater basins and both coastal fisheries was found (R=0.361 and R=0.274, P=0.001, ANOSIM). Area access control was important in fisheries agreements for continental freshwater basins and Pacific Ocean basin, but not for Caribbean fisheries. However, fishery categories related to fishing strengthening and government controls were low or absent in Pacific Ocean fishery agreements, but with higher relevance in continental freshwater basin fishery agreements.

On the other hand, similarity was found among fishery agreements in the Caribbean, while fishery agreements in the Pacific Ocean fell into two groups (Figure 3), whereby there were different contexts, interests and ways to face problems among small-scale fishery communities from Pacific and Caribbean basins. Fishery agreements proposed in continental freshwater basins were different from those for coastal fisheries, even though continental freshwater basin fishery agreements showed a scattered distribution (Figure 3), according with their own fishery measures. This indicated that some differences were identified in fisheries categories among freshwater fishery communities.

Categories of management proposed by fishermen for rivers and coastal areas were different (P= 0.001, ANOSIM), and both groups showed a certain dispersion

FIGURE 3
Non-parametric multidimensional scaling analysis among categories of fishing agreements proposed by fishermen. The data were separated in the basin factor for continental fresh water basin (white circles), Pacific Ocean basin (black triangles) and Caribbean basin (black squares)

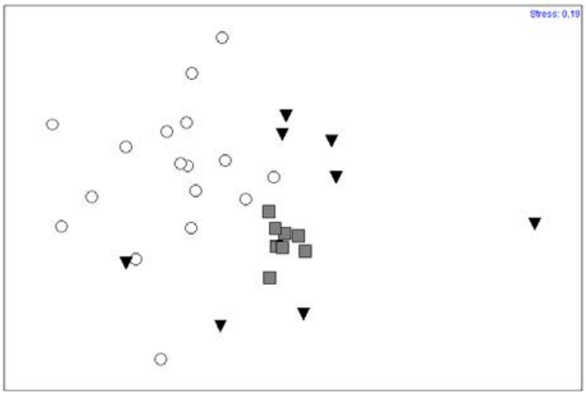
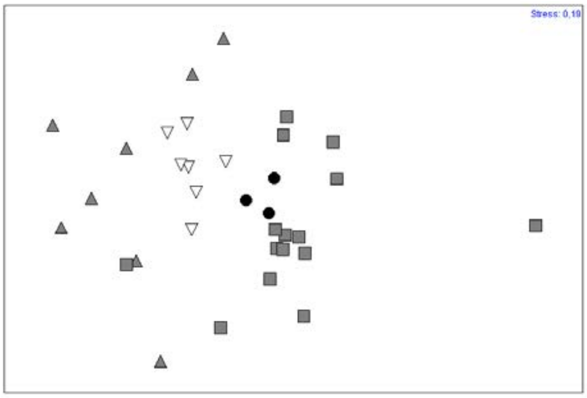


FIGURE 4
Non-parametric multidimensional scaling analysis among categories of fishery agreements proposed by fishermen. The data were separated in the water body factor for rivers (gray triangles), Lake-Lagoon-Reservoirs group LLR (white triangles), coastlines (gray squares) and swamps (black circles)



pattern (Figure 4). Fisheries measures such as government control, fleet control, fisheries promotion, and community strengthening were not considered by river fishery agreements, but were considered in coastal agreements. Alternatively, coastal fishery agreements considered biological controls and conservation issues as very important, while river agreements considered the temporary access control as one of the most important fishery categories.

Fishery agreements in swamps and other freshwater systems, such as lakes, lagoons and dams (LLR) showed results in different ways. A difference was found between fishery agreements in swamps and LLR ($R= 0.627$, $P=0.001$). Swamp fishermen preferred measures related to fishing gear controls and closures, together with measures regarding conservation issues and fishing promotion. In addition, these swamp fishery agreements considered fishery agreement categories like government controls and community strengthening, but these were not included in LLR fishery agreements. LLR agreements, however, gave priority to area access controls and catch controls.

LLR fishery agreements partially overlapped with coastal and river fishery agreements ($R=0.325$ and $R=0.297$, $P= 0.001$). Fishery agreements in these water bodies emphasized fishery measures associated with biological controls and area access controls, and gave less importance to trade controls. On the other hand, fishery agreements for swamps showed significant similarities in fisheries agreement categories such as area access controls, trade controls and catch controls, with river fishery agreements. They also showed similarities with coastal agreements in fisheries categories such as biological controls, fishing gear controls and fishing promotion. Therefore fishery agreements for swamps, coastlines and river basins showed no differences ($P>0.05$, ANOSIM). Finally, analyses for fishery agreements among ethnic groups (mestizo, indigenous and afro-descendants) showed no differences in fisheries agreement categories (Table 3).

DISCUSSION

Fishery agreements in the context of participatory management

Fishery agreements constitute the first steps for consolidating participatory management of natural resources (Graham *et al.*, 2006; Pomeroy and Rivera-Guieb, 2006). In fact, fishery agreements are not difficult to accomplish, if there is trust between local communities and the management team (De Castro *et al.*, 2000). This may explain in part the wide range of variation in the number of categories identified in fishery agreements and in the number of measures for fishery management proposed by fishermen within those agreements. However, the number of categories of fishery agreements, their method of implementation, and effectiveness depend on the particular conditions in which the small-scale fishery is developed (Haggan *et al.*, 2007). In the case of Colombian small-scale fisheries, three external factors may influence the definition of these fishery agreements.

The first external factor is related to the limited capacity of government to identify priorities and establish clear criteria for participatory management. This situation makes it difficult to obtain legal supporting for small-scale fisheries given that there are many particular conditions (Lam and Pauly, 2010), for example the poverty degree, community isolation, public order problems, etc. As a result, many small-scale fishery agreements could be starting with different points of view in accordance with the goals of those institutions that participated in or led these processes. It may appear that these fishery agreements were framed in responsible fishery agreements (Agudelo *et al.*, 2013; Fundación Ecosfera - AUNAP, 2013; Zuluaga and Franco-Jaramillo, 2013; Trujillo *et al.*, 2011; Niño, 2011; Trujillo and Trujillo, 2009), fishery management plans (Fundación Humedales - AUNAP, 2013; AUNAP, 2012a; AUNAP, 2012b; Barrero *et al.*, 2010), conservation agreements (Niño *et al.*, 2013; Delgado *et al.*, 2010; PNN SANQUIANGA, 2009), trade agreements (Red de Frio, 2012), sustainable fishery practices (Fundación Ecosfera - AUNAP, 2013; Fundación Humedales - AUNAP, 2012), and rules for fishery management (López *et al.*, 2006). Nevertheless the given name to each participatory management process by their stakeholders, included in any of above management concepts, it necessarily will not mean similar mechanisms neither way of implementation. The second external factor pertains to the different management perspectives that into the generation of fishery agreements. The participation of different stakeholders such as the government (e.g. Fisheries Authority, Environmental Authority) NGOs, research institutions, universities, and trade sector, among others, were not balanced in all 36 participatory process Most small-scale fisheries management processes have been led by private institutions; NGOs in particular have played an important role in generating ideas and methods for developing participatory management approaches (McConney and Charles, 2008; Kurien, 2003) in situations where the government has limited capacity or is entirely absent. The goals of such processes were directed by these institutions depending upon their own view of various participatory management strategies, including Community Based Management –CBM- (Graham *et al.,* 2006; De Castro *et al.*, 2000), Co-Management – CM - (Hartoto *et al.*, 2009; Berkes, 2008; Armitage *et al.*, 2007), Co-Management Based-Fishery Community Management – CBFCM; Community-Based Resource Management – CBRM- (Haggan *et al.*, 2007; Pomeroy and Rivera-Guieb, 2006), Right Based Management –RBM- (WWF, 2013), among others (McConney and Charles, 2008; Armitage *et al.*, 2007 Haggan *et al.*, 2007; Pomeroy and Rivera-Guieb, 2006; De Castro *et al.*, 2000). Although all these approaches for management are based on community participation in decision making and management, the level of participation of other stakeholders, including the government, may differ.

As a result of the first two external factors, a third external factor emerges, referred to as the lack of alignment and prioritization of category agreements and methods of enforcement. It may be possible that small-scale fishery processes transversal to social and ecologic aspects directly related to communities, as well as the role of government were not completely taken into account (Armitage *et al.*, 2007;Pomeroy and Rivera-Guieb, 2006; Carlsson and Berkes, 2005; Charles, 2005). As such, the fishery agreements that included control of fishing gear, control of biologic parameters of target species in the fishery, resource and ecosystem conservation and fishery promotion reached together a 50% prioritization over 15 total kind of fishery agreements proposed by fishermen, which is considered important. On the other hand, other kind of agreements related with area/temporary closures included the national fishery law (Law 13 of 1990) and the government participation had low priority by fishermen.

A low or limited presence of the government in fishery management proposals could be more in line with CBM, apparently for the historic absence of government for local decision-making. However switching from a model based on government management to a model with a wide range of local community autonomy may be not the best choice for small-scale fishery management in Colombia, even in protected areas such as National Parks, indigenous areas, or territories managed by afro-descendant groups.

Enforcement of participatory management in Colombia will require an improved level of community organization in order to gradually empower community members for managing fisheries resources, without overlapping with the responsibilities of national fishery authority as Pauly (2006) suggest. Different levels of co-responsibility related to fishery management participation in the fishery agreements proposed by the communities studied could due to the following reasons: i) small-scale fishermen strongly believe that the resources from the sea or river are essentially inexhaustible , ii) the historical perception based on experience, and transmitted from father to son, about fishery resources are not disappearing, but they are moving to other areas or deeper waters, as an effect of increased effort on the fishery; iii) fishermen's livelihoods are generally supported by daily catches with limited middle- to long-term planning; and iv) fishermen tend to think that fisheries-related problems are mostly caused by external factors (e.g. environmental damage) and not by their own activities.

Diversity of fishery agreements in Colombia

Small-scale fisheries in Colombia integrates many different approaches. The country has two coast lines (Pacific and Caribbean) and numerous large and small river basins, all of them with different realities. Fishermen of coastal zones prioritized fishery agreements to increase their incomes and enhance organization, but these preferably provided for agents external to their communities and fishing areas. This preference is possibly promoted by the historical interaction with actors of the government and private sectors, given the multiple economic interests associated with coastal waters (tourism, oil companies, etc.). On the other hand, fishery agreements in river systems prioritized controls for fishery access with respect to area and time, recognizing in this case, compared with marine fishermen, that fisheries management also depends upon fishermen as local users. This may be related to the recognition of a drastic reduction in fishery resources by river fishermen (Gutierrez, 2010), showing that in just few circumstances the resources may sometimes be replaced by other species not previously considered as commercials (e.g. ornamental fishery).

Coastal fishermen appear to have a more optimistic vision that inland fishers, where reductions in traditional and commercial species in recent decades have been compensated by market adaptation introducing new species into fisheries (García *et al*., 2007). New species introduced for trade partially balance the incomes lost to species that are no longer caught. Fishermen of the Pacific coast emphasized controls of area access, due to the conflicts small-scale fishermen have with industrial fleets in recent decades, especially with the shallow water shrimp fleet (Rueda *et al*., 2006) and the deep sea shrimp fleet (Díaz *et al.,* 2011), that after a five-year process finally allowed the creation of an Exclusive Small-scale Fisheries Zone (ESSFZ) and Special Zone for Fisheries Management (EZFM) in northern Pacific coasts of Colombian pacific (AUNAP, 2013). These areas point out a new legal frame to develop participatory management schemes in the country.

Fishermen that target fisheries for consumption showed a greater need for fisheries regulations and investment by fisheries authorities than fishermen targeting ornamental fishes. These results can be interpreted in different ways; the ornamental fishing is usually conducted in areas with low accessibility (Zuluaga and Franco-Jaramillo, 2013) that promotes geographical isolation for fishermen (López *et al.*, 2012). On the other hand, other phases of the fishery such as resource gathering and national and international trade require participatory management of fishery resources to be enforced at multiple geographic scales (Berkes, 2008). Ornamental fishermen and consumption-based fishermen perceive that the legal and illegal mining (e.g. gold mining in rivers) poses one of the highest risks to small-scale fisheries, including both the ecosystem and fishermen themselves. As such, ornamental fishermen are addressed to implement management measures of the kind they are able to enforce, while fishermen targeting consumption-based resources feel safe to enforce several measures, even when some of them cannot be enforced in the appropriate manner. There are many reason for an inappropriate enforcement of management measures that have been proposed by the fishermen, however appear that a community weak structure usually is related with low implementation or breach of fishery measures.

Agreements in river fisheries prioritized temporary controls such us closures, as fishermen recognized that successful catches are directly linked to the rainy season and river water levels (Hernandez, 2004; Poveda, 2004). As such, poor enforcement of fishery measures during peak fish vulnerability could ultimately have negative effects on the fishery. It is also recognized that some species are highly migratory, and fishermen take advantage of this condition by increasing fishing effort during migration. This is the case of the striped catfish *Pseudoplatystoma magdaleniatum*, which is overfished during its spawning season while performing its upstream migration known locally as "subienda" (Hernandez, 2004).

Fishery agreements in lakes, lagoons and reservoirs (LLR) or mixed waters like estuaries and swamps were different from other types of agreements. In this case, area and capture controles were, as these measures are easier to enforce in LLR than estuaries during the year. Fishery agreements in estuaries prioritized similar actions to those in rivers and coastlines. Fishermen here find the government as an important stakeholder for setting regulation measures, but also for research and fishing strengthening. They also think other activities besides fisheries should be regulated. Fishermen recognize estuaries and swamps as complex areas with diverse interests that not only include fisheries (Carlsson and Berkes, 2005), and actually increase uncertainty and fragility to fisheries (De Castro *et al.*, 2000).

Colombia is a multiethnic country comprised of indigenous and afro-descendant communities that have their own territories protected by national law (DANE, 2007). However, this analysis showed that fishermen proposed similar fishery agreements, regardless of their ethnicity. This suggests that community perception of fisheries management moves beyond the similar view point, but that each community can propose culturally-appropriate mechanisms to enforce fishery measures under a fishery agreement within their territory (Haggan *et al.*, 2007). Results showed similar factors affecting fishery communities regardless of ethnic distinction, such as overfishing (Gutierrez, 2010); limited regulatory capacity of the government (Haggan *et al.*, 2007); centralized management decision-making (Armitage *et al.*, 2007); poor link between scientific knowledge and traditional knowledge (Berkes *et al.*, 1991; Nielsen *et al.*, 2004); poor empowerment of communities for fishery management (Osorio and Betancur, 2007); diffuse mechanisms for sanctions (McGrath *et al.*, 2008); global changes in supplies, demands, value and use of fishery resources (Pomeroy, 1995) and poverty and alternatives loss (Charles, 2005).

Although similarities among fishery agreements were found among agreement categories in different regions and for different water bodies, there were different fishery measures within an area or water body. Such differences may be explained by the high variability in community organization, regardless of ethnicity. A relationship between the level of community organization and the level of fishery measures proposed was observed, implying that the more organized communities are, the more structured fishery categories people proposed.

Toward a fishery participatory management enforcement

The effective distribution of power for fisheries management should be understood as a result and not as starting point of a participatory management scheme, so that legal and formal aspects of enforcement do not displace functional aspects (Carlsson and Berkes, 2005). It is necessary to recognize that in Colombia, participatory management of natural resources is a dynamic process (McConney and Charles, 2008; Pomeroy and Rivera-Guieb, 2006) that varies with social and ecological contexts (Crowder *et al.*, 2008; Armitage *et al.*, 2007).

The definition of different fishery categories according to the conditions of small-scale fisheries make it evident that general governmental criteria to validate and allow management in all different areas such as river basins, coastlines, and between consumption-based and ornamental fisheries are needed. It is also necessary to adjust management criteria according the type of community (which are quite diverse in Colombia) to optimize the effect of fishery measures (Haggan *et al.*, 2007) as well as the role of fishermen in fishery agreements (Kurien, 2003). If small-scale fisheries are considered in an integrated management system, only then can they achieve sustainability and resilience (Charles, 2005).

Success in the enforcement of participatory management in developing countries with limited government capacity need to develop new legal and administrative baselines and institutional agreements to enhance current political, social, cultural and economic situations (Pomeroy, 1995). In order to achieve this goal, government, communities and other relevant stakeholders need to work together to ensure that data is gathered with confidence and transparency, and all stakeholders develop a sense of ownership with respect to fishery resources (Lam and Pauly, 2010; Fundación Ecosfera, 2009), as well as assume responsibilities in management process (Polanco and Rodriguez, 2013). This implies that the anthrocentric approach, whereby human beings are considered unidirectional receiver of goods and ecosystem services, must be replaced by an approach where the man is responsible for ensuring that ecosystems maintain health and integrity and thus provide requirements which we depend. Such an approach should be reflected by any participatory ecosystem-based management scheme (Bundy *et al.*, 2008).

At a national level, and more so in international conventions (WECAFC, IATTC, South Pacific RFMO, SPPC) and fishery organizations (OSPESCA) with which Colombia is involved, it is evident that participatory management is important for achieving the goals of fisheries management. Colombia has many challenges to face, due to water pollution, waste water, sedimentation, aquatic ecosystem fragmentation and deforestation (Steer *et al.*, 1997), as well as the huge challenge to regulate small-scale fisheries activities such as fishing effort, low selectivity fishing gears and methods, and low compliance of fishery measures such as closures.

For participatory management of fisheries in lakes, lagoons and reservoirs (LLR), it is important to take into account the regulation of fishing efforts at the mouths of rivers where fishes arrive or migrate to spawn, as well as the selectivity of fishing gear (INCODER, 2012; Trujillo and Trujillo, 2009). Freshwater fisheries also need to attend to issues regarding exotic invasive species establishment in rivers and dams where small-scale fisheries operate. These situations should be viewed within a participatory management framework, as these species already make up part of the capture for local communities, despite the institutional limbo between national environmental and fisheries authorities.

In conclusion, the implementation of participatory management in Colombia should include a clear government-based approach to: 1) incorporate the diversity of ways in which small-scale fisheries are developed, 2) make an effort to establish alternative and complementary policies, in addition to conventional fisheries policies, to apply participatory management according to the characteristics of fishermen in different types of communities, 3) develop mechanisms to apply adaptive participatory management, 4) consider the cost of implementation of participatory management for both government and communities, and 5) establish legal frameworks that guarantee long-term implementation of participatory management.

This analysis demonstrates the need to review and align government and community enforcement and the roles of stakeholders and NGOs together with effective and reliable data (based on traditional and scientific knowledge) to promote egalitarian negotiations adjusted to the realities of communities and fisheries, and achieve effective participatory management schemes. The comprehensive fishery dynamics analysis, allocation of rights to public lands for the purposes of fishing in rivers, lagoons, lakes, estuaries, and the sea, and the important role of socio-cultural patterns and lifestyles of fishermen are challenges facing government institutions such as the maritime, environmental, ethnic and fisheries authorities, among others. From a community perspective, the effective establishment of participatory management schemes will depend on the community's level of organization. Furthermore, their commitment to assuming co-responsibility (with rights and duties) under this system will be the real platform for the establishment of long-term participatory management.

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This FAO Fisheries Technical Paper comprises a series of reviews and case studies from eight countries in Latin America regarding fishers' knowledge and its use in ecosystem approach to fisheries. The studies are based on experience in marine and inland small-scale fisheries in Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Panama, Puerto Rico, and Uruguay. Overall, these contributions demonstrate the wealth of knowledge and experience that fishers possess and offer diverse methods and legal instruments to integrate fishers and their knowledge into fisheries management. The case studies are intended to inform and provide potential models that may be applied to other fisheries.

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