FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER

591

ISSN 2070-7010

Food and Agriculture Organization of the United Nations

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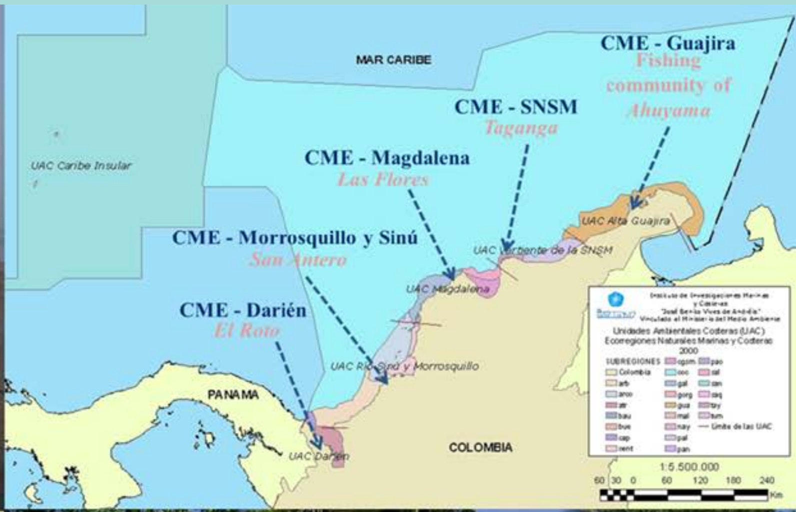
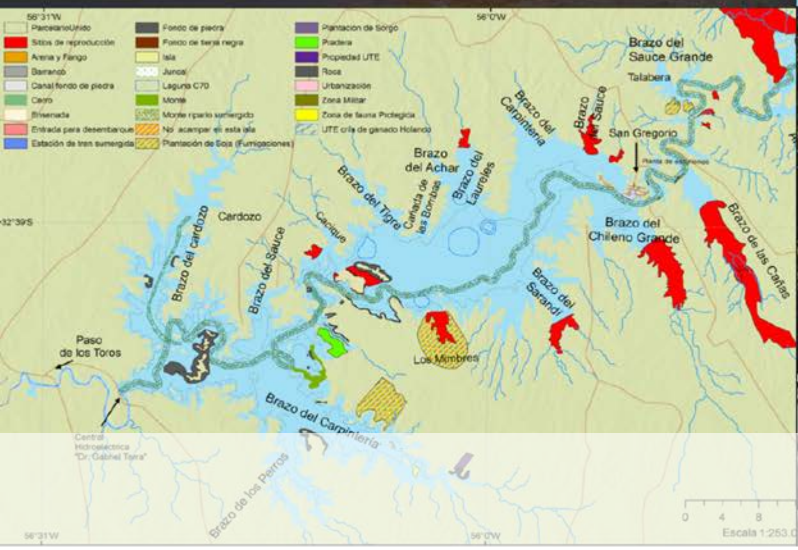
Applications, experiences and lessons in Latin America





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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2015

ISBN 978-92-5-108791-6

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).

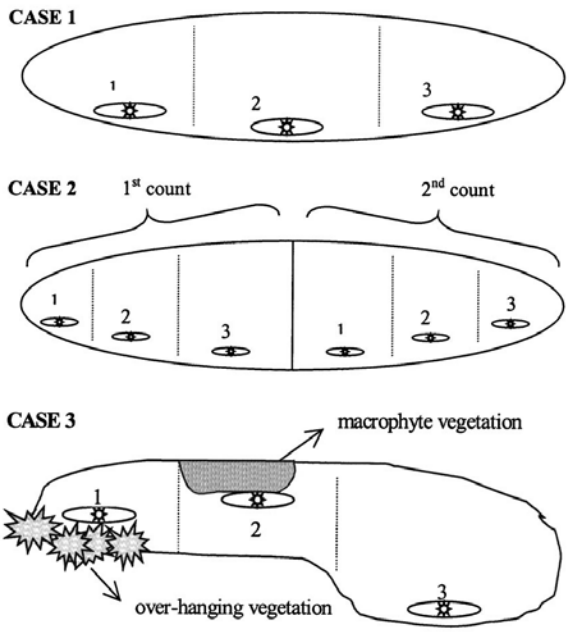
Pirarucu fishers are considered to be the most highly skilled fishers in the basin due in part to the fact that *Arapaima* have traditionally been caught with harpoons. Fishers wait silently in wooden canoes for a pirarucu to surface. When they spot a surfacing pirarucu, they throw their harpoon where 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.

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

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).

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.

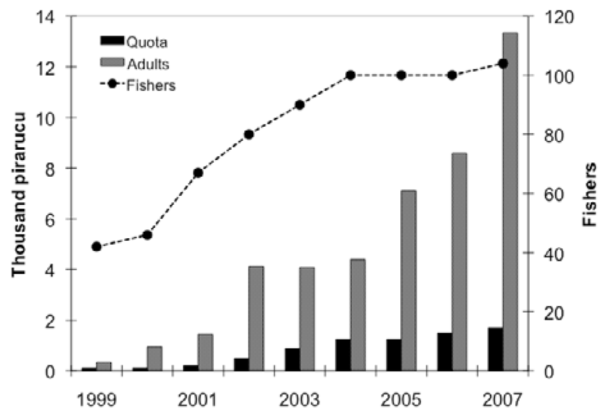
Motivation, Monitoring and Enforcement: There is no formal **monitoring** system in the Mamirauá model, although there is in many other pirarucu management systems in the Amazon where poaching is a problem. Because of the close connections between families, and the fact that members of the community 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.

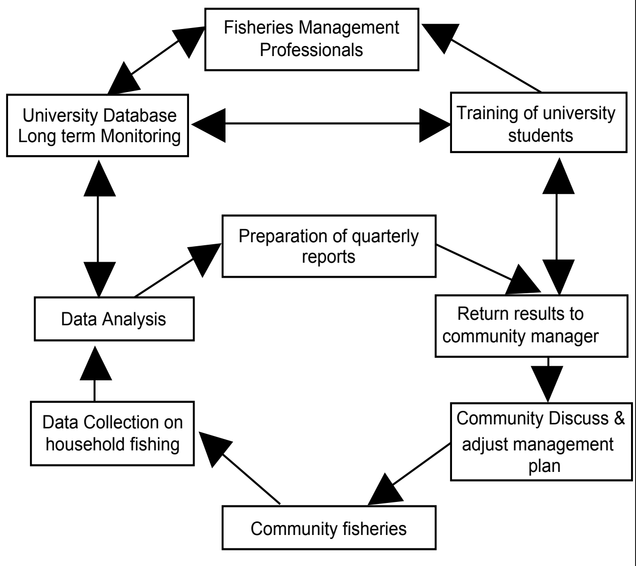
Universities have several characteristics that could enable them to provide a more stable, long-term institutional base than most government fisheries management agencies. They have the basic infrastructure needed, access to university funding sources for teaching and research, as well as research capacity 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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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.

ISBN 978-92-5-108791-6 ISSN 2070-7010

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I4664E/1/05.15