American Fisheries Society Symposium 69:741–756, 2009
© 2009 by the American Fisheries Society

Challenges and Opportunities for Co-Management of a Migratory Fish (*Prochilodus nigricans*) in the Peruvian Amazon

Elizabeth P. Anderson*,[1]
Global Water for Sustainability Program, Department of Environmental Studies
Florida International University, Miami, Florida 33199, USA

Mariana Montoya
Department of Geography and the Environment, University of Texas
1 University Station A3100, Austin, Texas 78712, USA

Aldo Soto and Hernán Flores
WWF-Peru Programme Office
Trinidad Morán 853, Lima 14 – Perú, Apartado Postal: 11-0205

Michael McClain
Global Water for Sustainability Program, Department of Environmental Studies
Florida International University, Miami, Florida 33199, USA

Abstract.—Fisheries co-management lies at the center of environmental, social, and economic issues in the lower Pastaza River basin in the Peruvian Amazon. In this remote region, the intermingling of black- and white-water systems creates unique aquatic habitats that harbor diverse assemblages of fishes, including *Prochilodus nigricans*, a migratory species of high ecological and socioeconomic importance throughout the Amazon. In the lower Pastaza basin, freshwater fishes provide a major source of food and income for indigenous communities such as the Kandozi. However, the basin's aquatic resources and the livelihoods of indigenous people are being compromised by environmentally unsound practices such as overfishing by unregulated commercial fishers and pollution from petroleum exploration and exploitation in the region. In response, there has been a concerted effort by indigenous communities, conservation organizations, and the Peruvian government to develop systems of fisheries co-management in recent years. Near Lake Rimachi, the largest lake in the Peruvian Amazon, an association of Kandozi fishermen was recently formed to oversee the management of the lake's aquatic resources. The association is working towards implementation of a newly created fisheries management plan, which includes provisions for co-management and protection of migratory species like *P. nigricans*. Although the challenges are many, the long-term objective of fisheries management around Lake Rimachi is to ensure sustainable livelihoods for indigenous communities while maintaining aquatic biodiversity. Here, we discuss the ecological and socioeconomic importance of *P. nigricans* and describe lessons learned from an ongoing process of fisheries co-management.

* Corresponding author: eanderson@fieldmuseum.org
[1] Current address: The Field Museum of Natural History, 1400 South Lake Shore Drive, Chicago, IL 60605, USA

Introduction

Tropical rivers of South America are heterogeneous systems that vary along longitudinal, lateral, and temporal scales and present an array of aquatic environments available to freshwater fishes. Migratory species, notably prochilodontid fishes, exploit this natural variation, moving between areas of distinct hydrology, soils, water quality, and vegetation at different periods in their life cycle (Winemiller and Jepsen 1998). Although not considered diadromous by the definition given by McDowall (1987), *Prochilodus* spp. exhibit complex spawning and feeding migrations spanning hundreds of kilometers and strongly influence distant ecosystems and human lives throughout the Amazon and Orinoco basins. Ecologically, *Prochilodus* play a primary role in the transfer of energy from basal resources to higher levels of the food web, and their foraging behavior shapes ecological processes in aquatic environments (Araujo-Lima et al. 1986; Flecker 1992, 1996; Forsberg et al. 1993; Winemiller 1996; Taylor et al. 2006). They are also considered one of the most important commercial and subsistence fishes in South America (Goulding 1981; Tello and Bayley 2001; Allan et al. 2005; Silva and Stewart 2006; Taylor et al. 2006; Junk et al. 2007).

Overfishing, water pollution, and dam construction threaten survival of inland water fishes worldwide, and in South America, *Prochilodus* may be particularly sensitive to the negative effects of human-induced changes to freshwater ecosystems (Allan et al. 2005). Migrations of *Prochilodus* are cued to seasonal fluctuations in water levels (Winemiller and Jepsen 1998). The presence of dams often results in hydrologic alterations and barriers to longitudinal movement that hinder the ability of *Prochilodus* and other migratory species to complete key phases of their life cycle (Ribeiro et al. 1995; Pringle et al. 2000). Some prochilodontids, such as *P. nigricans*, are known to move between white-water and black-water areas differing naturally in water chemistry (Carvalho de Lima and Araujo-Lima 2004). White-water systems are characterized by high turbidity, high oxygen, and high nutrient concentrations; conversely, black-water systems exhibit low turbidity, low oxygen, and low nutrient concentrations. Water pollution stemming from human activities like deforestation or petroleum exploitation can alter the chemistry of these systems and potentially disrupt fish movements or, in the worst cases, result in fish kills (Kimerling 2006). Overfishing of *Prochilodus* species is a pervasive problem in much of the Amazon and Orinoco basins and presents one of the greatest challenges to fisheries management. As a migratory fish, the same *Prochilodus* stocks are subject to exploitation by multiple fishing communities. Over the past 25 years, overfishing in the Orinoco drainage has substantially affected one prochilodontid species, *P. mariae*, evidenced by correlations of declining fish body mass with decreasing mesh size of fishing nets (Taylor et al. 2006). *Prochilodus* fisheries in other parts of tropical South America may mirror these conditions, but limited scientific information on their status is available (Tello and Bayley 2001).

The social and economic contexts of fisheries in South America, as well as the type of gear used in fishing, are all important factors that influence survival of *Prochilodus* spp. (Batista et al. 1998; Almeida et al. 2003). Published estimates place the potential yield of the inland food fishery of the entire Amazon River basin at 900,000 metric tons per year; in the 1990s, only about half of this potential yield was exploited by Amazonian fisheries (Bayley and Petrere 1989; Junk et al. 2007). In the Peruvian Amazon, the value of total fish capture (~80,000 metric tons/year actual yield) is estimated at US$80 million annually, shared between both commercial (25%) and subsistence (75%) based fisheries (Tello and Bayley 2001). *Prochilodus* represent a disproportionately high percentage of the number and biomass of fishes captured and sold at local and regional fish markets in the Amazon. In Manaus and Tefe, Brazil (middle Amazon), *Prochilodus* are the most important commercial species, representing 45% of market landings (Junk et al. 2007). The same is true in Iquitos and Pucallpa, Peru (upper Amazon), where *Prochilodus* spp. account for 45–55% of the commercial catch (Montreuil et al. 2001; Silva and Stewart 2006; Junk et al. 2007). These percentages are often higher for indigenous communities' fisheries; in parts of the remote northern Peruvian Amazon, *Prochilodus* represents 80% of fish capture and sale during certain times of the year (FECONAKADIP 2007). Because both artisanal and commercial fishermen target *Prochilodus*, competition for fisheries resources has resulted at times in conflicts between indigenous communities and commercial fleets over resource rights (McDaniel

1997; Almeida et al. 2003; Crampton et al. 2004b; FECONAKADIP 2007). In these situations, the response of both parties may be to increase fishing efforts or, in the case of artisanal fishermen, to adopt newer, more efficient fishing gear like gill nets. In this context, overfishing can quickly become a problem that threatens *Prochilodus* populations and the livelihoods of Amazonian people.

Studies of fishing activities and fish consumed by indigenous communities have received low priority, as most attempts to quantify importance of fishing in the Amazon have focused on commercial fisheries (Bayley 1981; Batista et al. 1998; Almeida et al. 2003). Nevertheless, indigenous fisheries deserve more attention for multiple reasons. First, indigenous communities are widespread throughout the Amazon over a large geographical area and most depend on fisheries for subsistence and income generation. Although preferences vary by region, *Prochilodus* are almost always among the most important species (Batista et al. 1998), and because *Prochilodus* are highly migratory, several different indigenous communities may harvest the same fish stocks. Second, indigenous fishermen typically harvest fish year-round and fisheries are often the primary or only source of livelihood for indigenous communities (FECONAKADIP 2007). Fishing for *Prochilodus* can intensify during migration and spawning periods or during low water, when many fish are concentrated in small areas (Batista et al. 1998; H. Flores, personal observation). Finally, although on an individual basis one indigenous community's effect on *Prochilodus* and other fish populations may be minimal, the collective influence of indigenous fishermen throughout the Amazon basin is substantial. Some authors have suggested that the amount of fish caught by subsistence and artisanal fishermen far exceeds that of commercial fisheries and may account for as much as 60% of fish landings in the Amazon (de Merona 1985; Batista et al. 1998; Maccord et al. 2007), but scant data on fish landings outside of regional markets make estimation of the quantity, value, and impact of these fisheries a challenge (Junk et al. 2007).

Effective management of *Prochilodus* and other fishes in the Amazon basin must consider the position of indigenous communities, both in terms of the pressure they exert on the resource and the integral role that fisheries play in their lives. To that end, indigenous communities are beginning to take part in fisheries co-management systems that involve a combination of traditional and modern approaches and offer a space for participation of multiple stakeholders in decision making (Dyer and McGoodwin 1994; Sen and Nielsen 1996; de Castro and McGrath 2003; Maccord et al. 2007). Fisheries co-management systems have emerged in response to several factors: failure of state-imposed restrictive regulations as a fisheries management strategy, more intense fishing pressures and more efficient gear, a desire by local communities to prevent outsiders from having access to resources (e.g., in lake settings), and a desire to regulate the distribution of benefits provided by fisheries to local communities (de Castro and McGrath 2003; Crampton et al. 2004a; Maccord et al. 2007). In some parts of Brazil and Peru, fisheries co-management systems allow rural residents and/or indigenous communities to share legal responsibility with government authorities in devising and enforcing fishing regulations (Almeida et al. 2003; Crampton et al. 2004a; FECONAKADIP 2007; Junk et al. 2007). The case of Mamirauá in Brazil provides an example: a zoned reserve was created to place fisheries resource rights in the hands of local residents with the aim of reconciling biodiversity conservation and economic growth and as a means for monitoring invasive, commercial fishing (Crampton et al. 2004b). Further, by increasing community organization, involvement in fisheries co-management systems has helped some rural and/or indigenous communities address other problems such as disease outbreaks or environmental degradation (McDaniel 1997).

The case of Lake Rimachi and the Kandozi people in the Peruvian Amazon is representative of the challenges facing management of *Prochilodus* and the opportunities for fisheries co-management in the Amazon. The Kandozi are an indigenous community that inhabits a landscape composed of interconnected black-water lakes adjacent to the turbulent, white-water Pastaza River in northern Peru. Freshwater fish provide the overwhelming majority of protein to the Kandozi diet, and the capture and sale of one species, *P. nigricans* (Spix and Agassiz 1829), provides the primary source of economic gain (FECONAKADIP 2007). Nevertheless, the long-term sustainability of Kandozi fisheries is at risk on the basis of internal threats such as overfishing within the community and external threats, including unregulated commercial fishing

and petroleum exploration. Together with local authorities, the Kandozi have recently taken steps to address these threats through a system of fisheries co-management in the lower Pastaza River basin. In this article, we briefly discuss the ecology of *P. nigricans*, describe the threats and trends that affect this and other fish species in the lower Pastaza basin, and outline the approach to fisheries co-management being implemented in Lake Rimachi, Peru.

Ecology of *Prochilodus nigricans*

Prochilodus nigricans is a potamodromous fish species that inhabits a wide range of aquatic habitats over a broad spatial area of the Amazon basin. The species is found in the main-stem Amazon River, as well as in lowland areas of Amazonian drainages in Brazil, Colombia, Ecuador, Perú, and Bolivia (Silva and Stewart 2006). It is the most widely distributed of the *Prochilodus* spp. found in the Amazon and is locally known by several common names: boquichico in Peru, curimatá in Brazil, sábalo in Bolivia, and bocachico in Colombia and Ecuador (Araujo-Lima and Ruffino 2004). In the Peruvian Amazon, *P. nigricans* reach maturation at a total length of around 25 cm and attain a maximum total length of approximately 40 cm (Montreuil et al. 2001; Escobedo et al. 2005).

In neotropical rivers, many fish species are specialized consumers of detritus; *P. nigricans* falls within this feeding group (Yossa and Araujo-Lima 1998; Taylor et al. 2006). *Prochilodus nigricans* feeds primarily on amorphous detritus that contains algae and exhibits little to no seasonal variation in diet (Bowen 1983; Bowen et al. 1984; Yossa and Araujo-Lima 1998; Oliveira et al. 2006). On the basis of their feeding behavior, *Prochilodus* spp. act as conduits of energy in aquatic food webs. As detritivores, they facilitate transfer of energy from basal resources directly to species at higher trophic levels, thus increasing the ecological efficiency of piscivore production by means of short food chains (Winemiller 1996; Winemiller and Jepsen 1998). Further, bioturbation during feeding by *Prochilodus* spp. has been shown to increase nitrogen-fixing cyanobacteria and enhance downstream transport of particulate organic carbon (Flecker 1996; Taylor et al. 2006). Recent studies suggest a lack of functional redundancy for the ecological role of *Prochilodus*, even in rivers with diverse fish assemblages (Taylor et al. 2006).

Seasonal, long-range migrations in schools are a critical component of the life history of *P. nigricans*. Although exact migratory patterns vary in different basins, in general migrations occur in response to seasonal changes in water level, food availability, reproduction, and predation risk (Araujo-Lima and Ruffino 2004; Silva and Stewart 2006; Winemiller and Jepsen 1998). *Prochilodus nigricans* moves between black-water environments, such as floodplain lakes, and white-water systems, such as main-stem rivers draining the Andes Mountains. Reproductive migrations are thought to coincide with the onset of the wet season when water levels are rising, while migrations in response to other factors occur during the receding water season (Fernándes 1997; Araujo-Lima and Ruffino 2004).

The Lower Pastaza River Basin, Peru

The Pastaza River is a tributary of the Marañon River, draining an Andean subcatchment of the larger Amazon River basin. Shared between Ecuador and Peru, the Pastaza River basin encompasses an area of approximately 40,000 km^2 and spans an altitudinal gradient of more than 5,000 m. This gradient has created distinct environments in the basin: páramo ecosystems and glacier-covered volcanoes characterize headwater areas, high gradient streams drain cloud forests at middle elevations (1,000–2,500 meters above sea level), and meandering rivers wind through wetlands in the lowlands. While the upper and middle parts of the Pastaza River basin are home to more than 1 million people, wilderness areas of tropical rainforest comprise the sparsely populated lower two-thirds of the basin.

In Peru, the Pastaza River basin drains an extremely heterogeneous natural landscape, dominated primarily by wetland areas. Here, the white-water Pastaza River flows adjacent to or mixes with lentic and lotic black-water systems such as Lake Rimachi and the local rivers draining into the lake. With an area of 79 km^2, Lake Rimachi is considered the largest lake in the Peruvian Amazon and forms part of a series of interconnected black-water lakes, or cochas, that integrate the lower basin of the Pastaza River with two other rivers, the Chuinda and the Chapuli (Figure 1). The intermingling of black- and white-water systems, as well as the presence of floating mats of vegetation in the lake and flooded riparian forests (varzea), have produced an array of

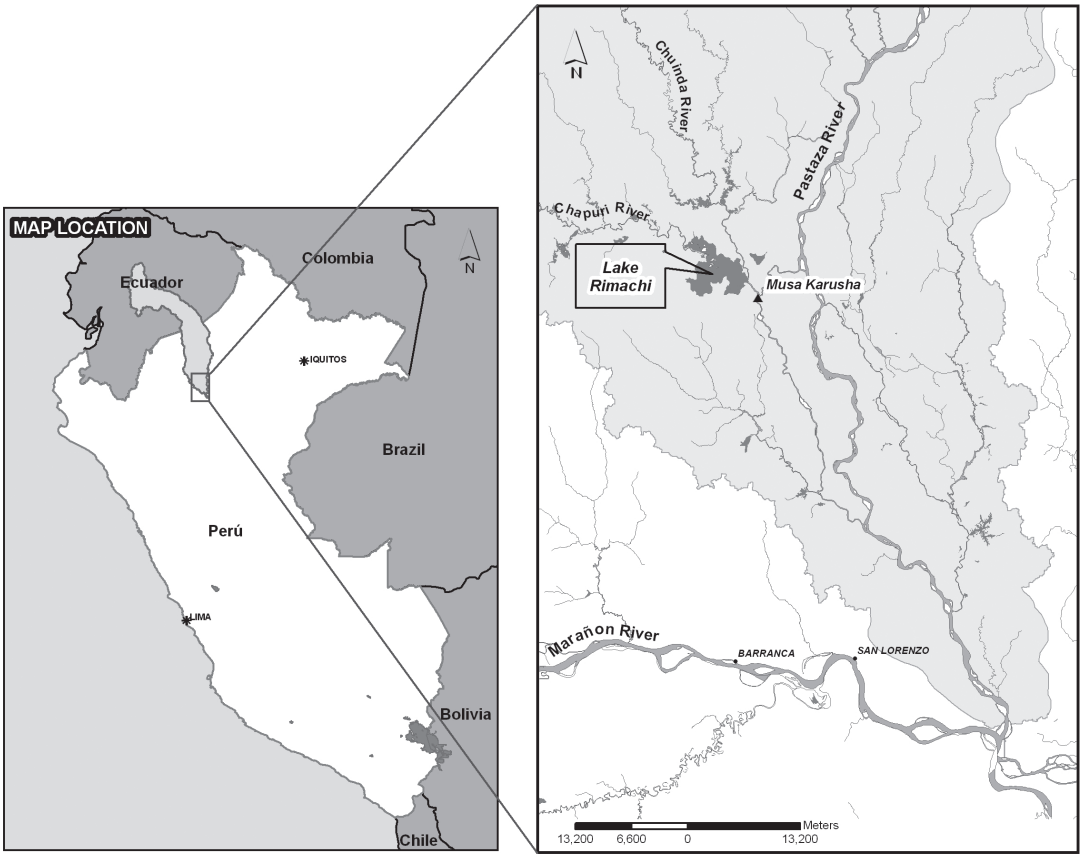

Figure 1. The Pastaza River basin is shared between Ecuador and Peru (inset). The Kandozi inhabit the area west of the Pastaza River around Lake Rimachi in the lower basin. The Kandozi village of Musa Karusha lies at the confluence of the lake near a side channel of the Pastaza River. Figure: C. Alvarez, WWF-Peru.

unique habitats for aquatic biota, especially fishes. Previous studies have reported 292 species of fish (33 families) from the lake and surrounding water bodies; however, these estimates are based on limited scientific information and the actual number of species may be much higher (Willink et al. 2005; FECONAKADIP 2007). A seasonal climate, with marked differences in rainfall between wet and dry seasons, characterizes the lower Pastaza River basin. Annual precipitation is estimated at 3,000 mm, and water levels in Lake Rimachi fluctuate as much as 7 m between the driest (December–February) and wettest (April–June) periods (IIAP-WWF 1999).

The lives and livelihoods of people in the Peruvian Pastaza are intimately linked to freshwater goods and services, especially fisheries. An estimated 11,600 people inhabit the Peruvian Pastaza, and most belong to one of four indigenous communities: Achuar, Kichwa, Shapra, or Kandozi. Settlements are grouped into small villages that average about 120 people and are typically located in riparian areas. In the absence of roads and other major infrastructure, waterways provide the major means of transportation and communication between villages and larger cities downstream. Fish constitute the primary source of protein for indigenous communities and fisheries drive local economies (Pinedo et al. 2000).

The importance of fisheries to indigenous communities is exemplified by the case of the Kandozi, who inhabit areas within and around Lake Rimachi. The Kandozi number about 2,500 people and are known as strong warriors that have resisted conversion by religious missionaries and enslavement by commercial resource exploitation operations. Most

Kandozi live in small villages (<25 households; average 7.5 people per household) in the lowlands of the Pastaza basin, and the majority of their diet consists of fish, yucca, and plantain (Surrallés 2007). Fisheries provide the main source of economic gain for Kandozi communities. As in many artisanal fisheries, the Kandozi harvest multiple fish species with many different kinds of fishing gear (Escobedo et al. 2005). Nevertheless, *P. nigricans* is the keystone of Kandozi fisheries and is primarily captured in lakes and connecting canals using gill nets. During the fishing period from October 2004 to February 2005, *P. nigricans* represented 78% of individuals (10,870) and 83% of biomass (10,520 kg) of fish captures by Kandozi fishermen, out of a total of 42 fish species (Escobedo et al. 2005); these data encompass just the time of year when *P. nigricans* typically spawn. Across the year, *P. nigricans* accounted for 51% of biomass of fish captures in Lake Rimachi between September 2005 and September 2006 (Figure 2). Data from 2004 to 2006 indicate that the catch per unit effort for *P. nigricans* in Lake Rimachi is significantly higher than that of other species, and capture of *P. nigricans* varies seasonally (Figures 3 and 4). When sold locally, average prices for *P. nigricans* were recently about 3.00 Peruvian soles per kilogram, just less than one U.S. dollar (Pacheco 2006).

Despite its remoteness, the Peruvian Pastaza and the area inhabited by the Kandozi has been subject to a series of human-induced threats over the past half century that have affected fishes in Lake Rimachi and surrounding environments. Petroleum production is among the most serious threats to fisheries resources and indigenous communities' livelihoods. The lower Pastaza River basin and surrounding areas are the site for major petroleum exploration and exploitation activities, and it is estimated that approximately 55% of the petroleum produced in Peru came from this region in 2008. Occasional oil spills present one form of water contamination, but a more chronic source of pollution is the failure to reinject production waters into oil wells, which leads to thermal and chemical water pollution as industrial waste waters are often released directly without treatment into rivers. Contamination events like oil spills have been linked to fish kills in the region in the past (Kimerling 2006), but it is still unclear how more chronic thermal and chemical pollution from by-waters affects fish and whether zones of degraded water quality adjacent to petroleum operations act as barriers to movement of migratory fishes like *P. nigricans*.

Additional stressors on fishes in the lower Pastaza basin have arisen from fisheries practices themselves. Commercial fishing fleets, operational

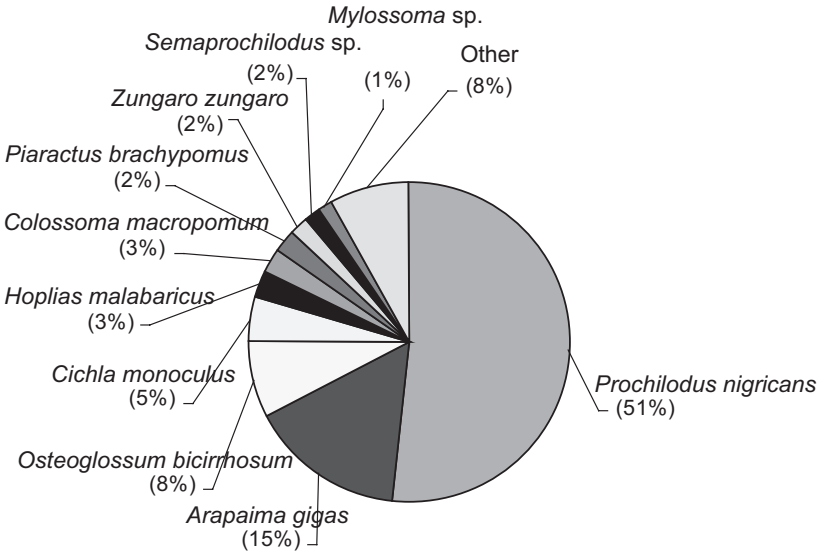

Figure 2.—Biomass of fish capture between September 2005 and September 2006 by species.

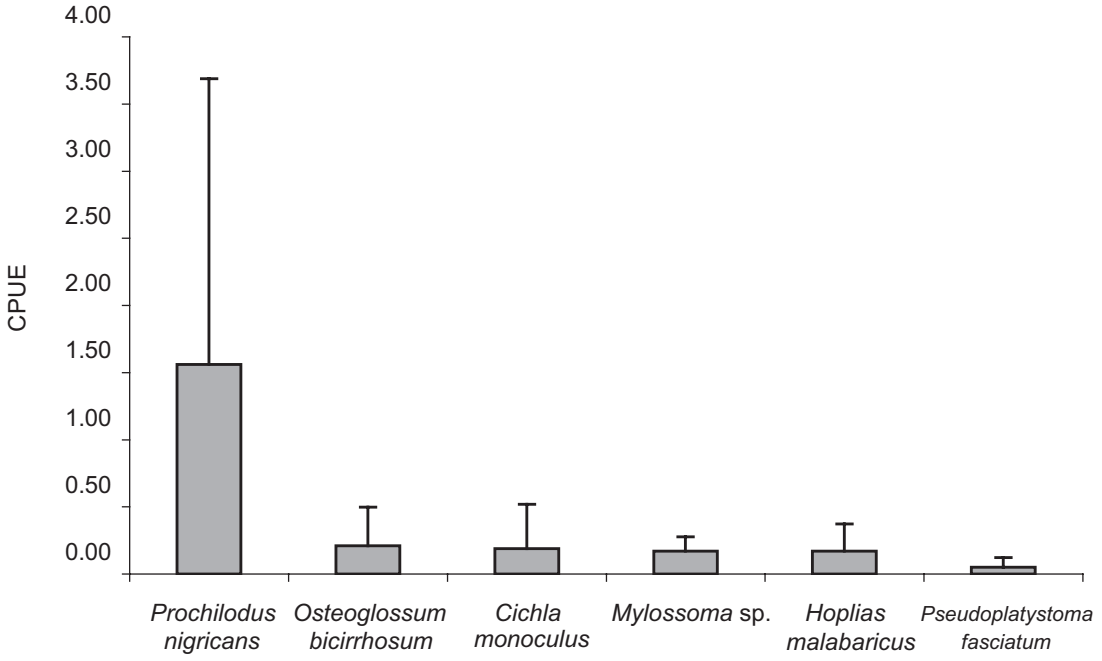

Figure 3.—Average catch per unit effort (CPUE) of the main commercial fish species in Lake Rimachi. Data cover the period from October 2004 to September 2006.

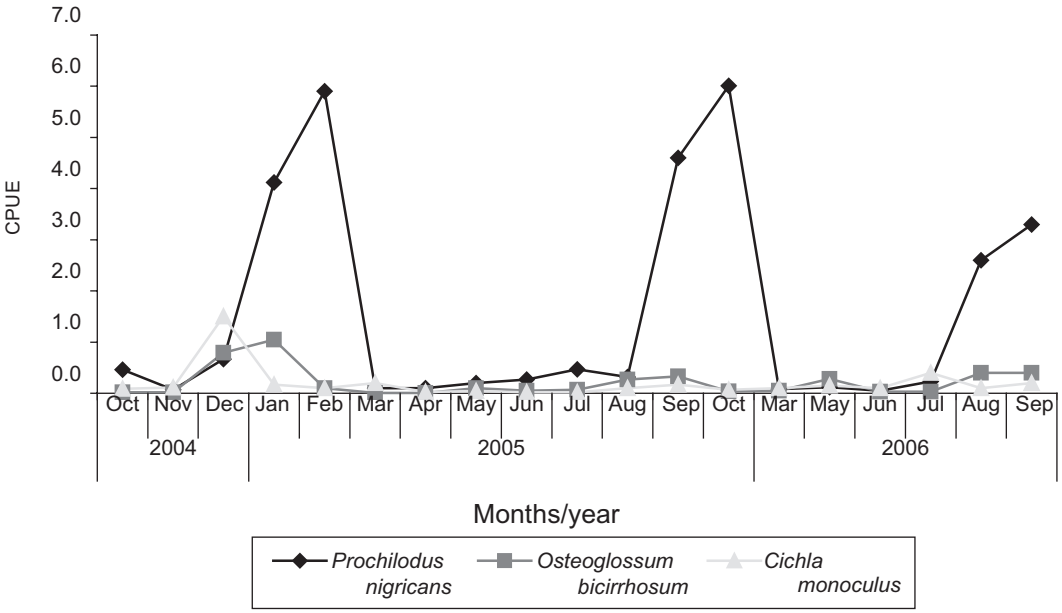

Figure 4.—Fluctuations across the year in catch per unit effort (CPUE) of three fish species in Lake Rimachi.

in Lake Rimachi since the 1970s, have been a significant source of mortality for fishes in the lower Pastaza basin. The Kandozi have perceived the commercial fleets' presence as a direct threat to their own fisheries-based livelihood. Consequently, conflicts have occurred in the past among Kandozi, commercial fishing fleets, and government fishing authorities over resource rights in Lake Rimachi. The presence of commercial fleets has also modernized fishing gear used in Lake Rimachi. Among the Kandozi, a shift from traditional fishing gear (e.g., hooks made from bird clavicle bones, wooden spears, plant-based fish poisons) to use of gill nets occurred in the mid-1990s (Bodmer et al. 2006). Changes have also occurred with respect to the primary species harvested from the lake. The focal species of fisheries in the past (1970–1990) was *Arapaima gigas*, locally known as paiche, but intense fishing pressures by commercial fleets led to depletion of *A. gigas* populations. The reduction in *A. gigas* populations and the adoption of net-based fishing techniques helped stimulate an increase in the importance of *P. nigricans* to both commercial and Kandozi fisheries. Over the past decade, the contribution of *P. nigricans* to local fisheries has only increased, in large part due to the increased efficiency of capture using nets with smaller mesh sizes. Intense exploitation of *P. nigricans* and the disproportionate contribution of this species to local and regional fisheries are topics of concern for the long-term sustainability of Kandozi fisheries. While these topics should not be overlooked, perhaps a more immediate threat to *P. nigricans* is a method practiced by both commercial and Kandozi fishermen that involves placing large gill nets (average 150 m length) in areas where migrants congregate to spawn (Pacheco 2006). Harvest of ripe individuals poses a direct threat to survival of *P. nigricans* populations in the lower Pastaza River basin.

Context for Fisheries Co-Management in Lake Rimachi

In this section, we discuss the Kandozi community's response to the threats that affect fisheries resources in Lake Rimachi and the current approach to co-management of *P. nigricans* and other economically valuable fish species. The Kandozi are one of the first indigenous communities in Peru to have legal responsibility to manage a freshwater body and its associated resources; understanding the present implications of this resource right for the Kandozi requires some appreciation of the historical context of fisheries management in Lake Rimachi. The Kandozi's response to fisheries management in Lake Rimachi has been a process-based approach, and here we provide details about that process.

Lake Rimachi has a long history of management interventions that relate to fisheries. In 1945, the Peruvian government established a Fishery Reserve (Reserva Pesquera) in Lake Rimachi as a measure to conserve fish stocks. Nevertheless, the reserve was subject to limited management and control on the part of the Peruvian Ministry of Fisheries, and commercial fishermen were permitted to exploit the lake's resources during the 1970s and 1980s. By 1990, the populations of several fishes, including *A. gigas*, had noticeably declined (Surrallés 2007). Today, information to support this decline is anecdotal, since fisheries records for 1970–1990 were lost in a fire. Declining fish populations alarmed the Kandozi community because of their fisheries-based livelihoods, and in August 1991, Lake Rimachi became the center of a confrontation between the Kandozi and the Ministry of Fisheries. Kandozi fishermen took control of the Fishery Reserve's base office of operations at the lake, with the intent to force the Ministry of Fisheries out of the region as they were permitting commercial fishermen to exploit the lake's resources and were also suspected to be involved in illegal commercialization of fishes. Since these initial conflicts in the early 1990s, Kandozi leaders have been trying to officially include Lake Rimachi in their territory. However, Peru's constitution does not allow titling of large bodies of water such as lakes or rivers. The Kandozi have thus had to explore alternative legal frameworks to enable them to have resource rights to Lake Rimachi and to have authority to monitor the entrance of commercial fishermen to the lake.

The case of Lake Rimachi lies at the heart of two important issues in the Peruvian Amazon: (1) management and conservation of inland water fishes, and (2) indigenous peoples' rights to ancestral territories and natural resources. The case has attracted the attention of two nongovernmental organizations, WWF-Peru and Racimos de Ungurahui, which specialize in environmental conservation and indigenous rights, respectively. In 2002, these

organizations conducted an analysis of the legal and institutional frameworks in Peru that would support the Kandozi's rights to fisheries resources in Lake Rimachi. Several options were uncovered, including land title for the lake, land title for surrounding areas, or creation of a communal reserve. While the legal technicalities of these options differ, all require that the Kandozi prepare a fisheries management plan for Lake Rimachi and that this plan be approved by the Vice-Ministry of Fisheries (Ministerio de Pesquería: Ley No. 25977, D.S. 012–2001-PE and R.M. No. 147–2001-PE). To this end, a formal partnership among the Kandozi, WWF-Peru, and Racimos de Ungurahui was created in 2002 to work towards formalizing Kandozi fishing activities and protecting freshwater resources through the creation and implementation of a fisheries management plan for Lake Rimachi.

The development of a fisheries management plan for Lake Rimachi has been a multi-step process and an exercise for the Kandozi in navigating the Peruvian legal framework. According to the Reglamento de Ordenamiento Pesquero de la Amazonía Peruana (Ministerio de Pesquería R.M. No.147–2001-PE), the initiative to develop a fisheries management plan has to come from an organized group of fishermen. Therefore, the first step in the process for the Kandozi was to form an association of artisanal fishermen. In Peru, artisanal fishermen's associations are recognized through a formal process overseen by the Vice-Ministry of Fisheries that involves training and licensing of artisanal fishermen. Therefore, in November 2003, at the request of the Kandozi and WWF-Peru, the Vice-Ministry of Fisheries conducted a training course for ~150 Kandozi fishermen and subsequently issued certificates and fishing licenses. The training incorporated representatives from 28 Kandozi communities from the Chapuli, Chuinda, Huituyacu, and Ungurahui River basins (all subcatchments of the Pastaza), which primarily use resources from Lake Rimachi and surrounding bodies of water, and included information on Peruvian fisheries legislation, responsibilities of artisanal fishermen's associations, and basic concepts of fisheries management (Flores, personal communication). Following the training, Racimos de Urgurahui prepared a series of legal statutes based on Peruvian laws that were revised by the Kandozi and then presented to the Vice-Ministry of Fisheries. The purpose of these statutes was to legalize the authority of the Kandozi association of artisanal fishermen that was being created over activities in all bodies of water within Kandozi territories, including Lake Rimachi. Care was taken to ensure that the Vice-Ministry of Fisheries' proposed statutes did not interfere with the statutes of the Kandozi Federation, FECONAKADIP. The negotiation of the statutes by both Kandozi fishermen and Vice-Ministry of Fisheries merits discussion because these statutes were among the first of their kind in Peru and they could provide an innovative example of aquatic resource regulation by indigenous communities.

Yungani and the Lake Rimachi Fisheries Management Plan

The Kandozi association of artisanal fishermen, known as Yungani, was officially constituted in September 2004 following the processes outlined in Peru's General Fishing Law (Ministerio de Pesqueria Ley No 25977) and as a result of the technical assistance provided by the Vice-Ministry of Fisheries. Yungani counts 115 members, all Kandozi fishermen, and it is now legally responsible for the administration and control of fisheries in Lake Rimachi. Members are required to develop and implement activities that support co-management and conservation of freshwater resources of the lake and surrounding areas. These activities include managing fisheries within the lake and surrounding water bodies and signing agreements with other civil and governmental organizations that are compatible with Yungani's objectives (FECONAKADIP 2007). The establishment of Yungani has also resulted in the creation of two surveillance and control committees for fisheries in Lake Rimachi; these committees are an important component of artisanal fishermen's associations according to Peru's General Fishing Law. Each of these committees is composed of 10 Kandozi fishermen and the committees are specifically charged with enforcement of regulations that limit minimum mesh sizes of fishing nets (10 cm), prohibit the illegal use of toxic substances (e.g., barbasco, a plant-derived fish toxin used traditionally), and limit the minimum size of fish that can be captured according to Peruvian fishing policies (Reglamento de Ordenamiento Pesquero R.M. 147–2001-PE, art. 4 numeral 4.3). The committees do not control total harvest from the lake, but they

do enforce no-fishing periods for certain species (*A. gigas*) and patrol areas that have been designated as no-take zones. All surveillance and control of fishing activities carried out by Yungani must be reported to the Regional Directorate of Fisheries Production (DIREPRO) and coordinated with the respective regional authorities. In essence, the role of Yungani is to guarantee the sustainable use of fisheries resources in Lake Rimachi (FECONAKADIP 2007).

Following the establishment of Yungani, the Kandozi developed a fisheries management plan according to guidelines set forth by Peruvian law (Reglamento de Ordenamiento pesquero de la Amazonia; R.M. N° 147–2001-PE) and with technical assistance from outside organizations such as WWF-Peru, FundAmazonía, and independent consultants. Both Kandozi fishermen and the international scientific community provided information that was incorporated into the plan. For example, Kandozi fishermen shared traditional ecological knowledge on fish species and the spatial and temporal variability of water conditions in Lake Rimachi and surrounding water bodies. With respect to *P. nigricans*, this included information on reproductive and migratory behavior, as well as designation of spawning areas. The Kandozi also provided information on valuable species from a socioeconomic perspective, fishing areas, fishing techniques, and objectives of fisheries management (Figure 5). During 2004–2005, scientific studies on water quality conditions and fish population dynamics were

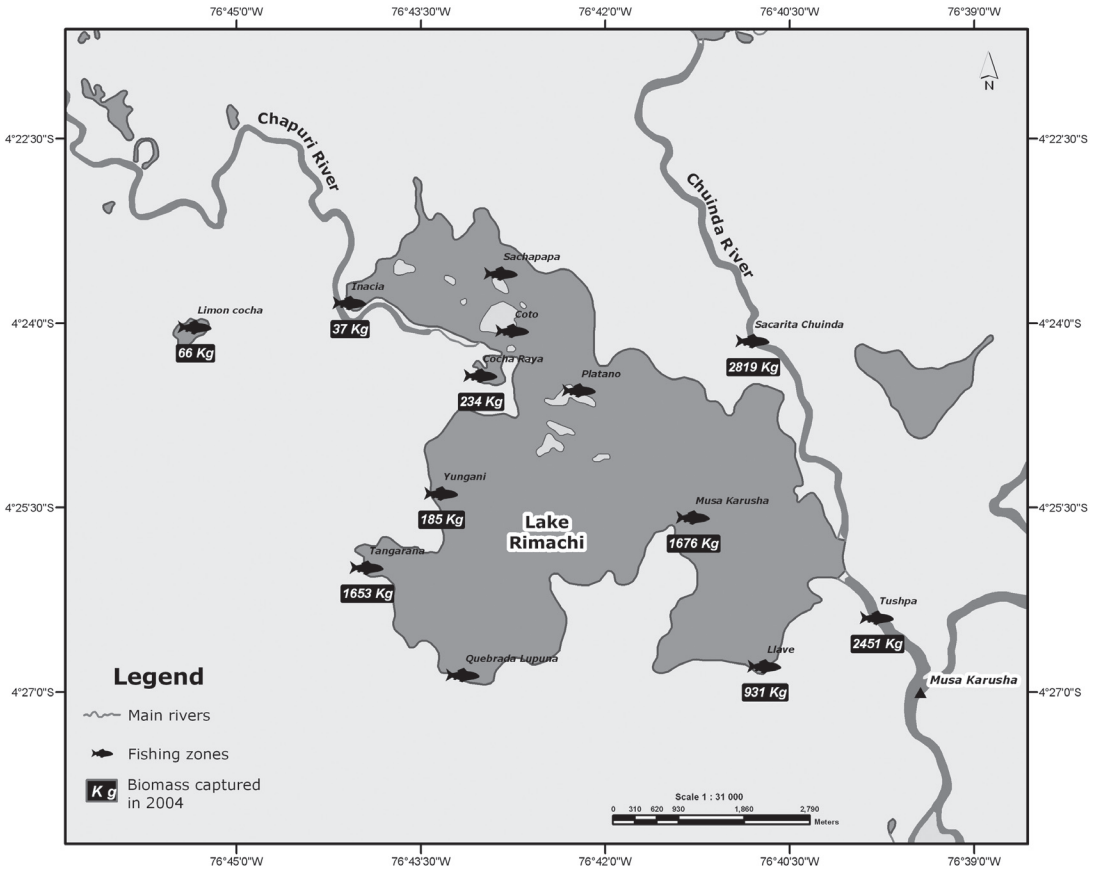

Figure 5.—General locations of fishing areas in and around Lake Rimachi (FECONAKADIP 2007). Numbers (kg) represent biomass of fish captured in 2004 near Kandozi communities. Figure: C. Alvarez, WWF-Peru.

conducted and their results incorporated into the development of the plan (Escobedo et al. 2005). In 2007, the Lake Rimachi fisheries management plan was completed and approved (see Table 1 for contents of the plan). The plan covers a 5-year period (2007–2011) and is implemented by Yungani in coordination with local authorities and with technical support from WWF-Peru.

The Lake Rimachi fisheries management plan focuses on the sustainable management of *P. nigricans* and three other key species. The plan recognizes the importance of *P. nigricans* to the livelihoods of the Kandozi and to the ecology of the lake and surrounding water bodies. The other species recognized in the plan include *Cichla monoculus*, *Hypothalamus edentatus*, and *Colossoma macropomum*, on the basis of their importance to the Kandozi fisheries. Specifically for *P. nigricans*, the plan limits the size of individuals that can be captured (>25 cm) and the stretched mesh size of fishing nets (10 cm). It also prohibits fishing of *P. nigricans* during spawning periods. These regulations represent a combination of general focus of local management systems on how to fish and more scientific management systems that focus on how much and what to fish (de Castro and McGrath 2003). In addition to the sustainable management of *P. nigricans* and the other three fish species, the Lake Rimachi plan also lists five more specific objectives: (1) to conserve freshwater resources and aquatic biodiversity in Lake Rimachi and surrounding water bodies, (2) to improve fisheries production in Lake Rimachi, (3) to establish a research program on the population ecology of species with high economic value like *P. nigricans*, (4) to transfer fisheries management tools applied in Lake Rimachi to other parts of the Peruvian Amazon, and (5) to strengthen Kandozi local organizations and secure their resource rights to Lake Rimachi (FECONAKADIP 2007).

Fisheries Co-Management as a Tool for Addressing Threats to *Prochilodus nigricans*

How has the formation of the Kandozi association of artisanal fishermen (Yungani) and the development and implementation of the fisheries management plan helped to address threats to *P. nigricans* and other fishes in the Peruvian Amazon? Because the fisheries management plan is still in its early phases of implementation, it is difficult to quantify its effects on fish populations and its overall success as a conservation tool. Nevertheless, several trends are evident that suggest that the plan is an appropriate management response to threats of overfishing and petroleum exploration and exploitation activities in the lower Pastaza River basin.

Table 1.—General contents of the Kandozi fisheries management plan (FECONAKADIP 2007).

1. A list of fish species to be managed and an ecological characterization of Lake Rimachi.
2. Detailed justification of the need for the management plan.
3. Objectives and expected results of the plan, including information about market prices and exploitation estimates.
4. Rights and obligations of fishermen from Kandozi communities, technical organizations, and state authorities that are part of the management plan.
5. Information about each fish species included in the plan.
6. Explanation of ongoing and future research and monitoring activities.
7. Fishing regulations and management techniques, including number of fishermen, fishing intensity, periods, quotas, and zones.
8. Description of resource use that explains how fish will be processed, transported, marketed, and sold.
9. Explanation of control and surveillance activities.
10. Fisheries Management Plan Evaluation.
11. Adaptive management techniques for adjusting fisheries production and management if necessary.
12. Description of conservation measures for Lake Rimachi.
13. References for further information.

The fisheries management plan directly addresses the threat of overfishing by providing regulations on fishing of *P. nigricans* and the other three key fish species and by giving Yungani the authority to enforce these regulations. Specifically, the plan controls fishing methods (e.g., size of nets and type of gear) and prohibits fishing during times of the year and in areas where these species are known to spawn. The times and locations of spawning were based on information gathered from Kandozi traditional ecological knowledge and from scientific studies (Escobedo et al. 2005; FECONAKADIP 2007). Areas of Lake Rimachi where juveniles are primarily found (especially *Colossoma macropomum*) are identified as no-fishing zones under the plan. Preliminary evidence suggests that these restrictions will have a substantial effect on sustainable fisheries management. In combination with the fisheries management plan, Yungani's control and surveillance committees also help to address threats of overfishing in Lake Rimachi through enforcement of general Peruvian standards that limit the minimum size of captured fishes and the minimum mesh size of fishing nets (Reglamento de Ordenamiento Pesquero; R.M. No. 147–2001-PE). For *P. nigricans*, the minimum mesh size of fishing nets is 10 cm, and when nets with smaller mesh are encountered, they are taken from the fisherman and given to DIREPRO. If one of the committees encounters a fisherman with fish that have been captured with illegal nets or during no-fishing periods, these resources are taken and distributed in the Kandozi community.

Sustainable management of fisheries resources by the Kandozi, formalized through the management plan, indirectly addresses threats stemming from overfishing and petroleum activities because it formally articulates the socioeconomic importance of *P. nigricans* and other fishes to Kandozi livelihoods and because it increases organization of the Kandozi community. The fishery based on *P. nigricans* in Lake Rimachi is a profitable activity that provides the main source of income for Kandozi families. The development of the fisheries management plan facilitated coordination between Kandozi fishermen and other local and regional authorities over the management of the lake and generated the interest of other municipalities to buy the fish from the Kandozi. Commercial fishermen from other municipalities are now aware that they must abide by the regulations for fishing established in the Kandozi fisheries management plan for Lake Rimachi. Regarding the unique management challenges posed by the migratory behavior of *P. nigricans*, commercial fishermen from downstream areas have recognized that they will benefit from the Kandozi's management practices, noting that the *P. nigricans* stocks upon which they depend for income most likely spawn in the area of Lake Rimachi. Further, within the Kandozi community, it can be argued that as members of Yungani, Kandozi fishermen have greater incentive to exercise control of their own fishing practices of *P. nigricans* and follow the regulations of the fisheries management plan (FECONAKADIP 2007).

With respect to petroleum activities, while the fisheries management plan cannot prevent oil spills and other forms of environmental contamination, it does put the Kandozi in a better position for negotiation over resource rights and for making claims in the case of contamination events. This advantage is important considering that the lower Pastaza River basin has been divided into lots and is being considered for exploration by multinational petroleum companies. In fact, one of these lots lies right over Lake Rimachi. A Brazilian company currently holds the concession to the Lake Rimachi lot, and they have already signed a contract with the Peruvian government that permits exploration and possible future exploitation of petroleum reserves in the area. Some believe that this contract was signed without adequate consultation with the Kandozi people, despite the fact that the Peruvian government signed the Convention 169 (concerning indigenous and tribal peoples) from the International Labor Organization that obligates the government to have a consultation process before deciding any administrative or legislative measure that could affect indigenous communities directly (Greenspan 2006). In the past, consultation processes between petroleum companies and indigenous communities over resource or land rights have suffered from a lack of transparency and petroleum companies have often been given unfair advantage (Greenspan 2006). One of the problems indigenous communities face in negotiation with petroleum companies is the lack of quantitative evidence that supports their socioeconomic dependence on the resources in question, in this case, fishes of Lake Rimachi. By establishing a direct link between the livelihoods of the Kandozi and the survival of *P. nigricans* and other fishes found

in Lake Rimachi, the fisheries management plan advocates conservation of freshwater resources and makes a solid case for limiting petroleum activities in certain areas of the lower Pastaza River basin.

Challenges

The development and initial implementation of a fisheries co-management strategy and plan is only a part of the task of enabling the survival of *P. nigricans* and other species in Lake Rimachi while supporting the fisheries-based livelihoods of the Kandozi. Long-term implementation and adaptation of the plan presents an additional challenge, and thus the overall success of fisheries co-management in Lake Rimachi remains to be seen. Experiences from other parts of the Amazon basin have shown that community-based or co-management programs depend on the ability of local people to manage and defend natural resources and on appropriate and adequate financial, legal, and scientific support (Crampton et al. 2004a). Crampton et al. (2004a) list five provisos essential to successful local management of fisheries: (1) a single group has rights of access to the resource, (2) strong economic incentives for protecting fish stocks exist, (3) fishers have a general awareness of ecological and resource management concepts, (4) sound science or traditional ecological knowledge underpins management strategies, and (5) management includes efforts to protect habitats (e.g., like flooded forests).

Most of these conditions are manifest in the case of the Kandozi and fisheries co-management in Lake Rimachi. Nevertheless, several challenges for the long-term success of the program have been identified. First, enforcement of the regulations stipulated by the management plan, now being carried out by control and vigilance committees, depends on strong organization and leadership within Yungani, as well as the respect of other fishermen for the plan and the committees. Second, the maintenance and effectiveness of the Kandozi fishermen's association (Yungani), with minimal to no assistance from nongovernmental organizations (e.g., WWF-Peru and Racimos de Ungurahui), depends on sufficient economic support. It is proposed that these resources come from the sale of fish, but this would mean substantial changes to the way funds are currently used and managed by the Kandozi. Third, there is a need to form stronger links between the fishermen's association and FECONAKADIP (Kandozi Federation) and for outside collaborators (e.g., Ministry of Fisheries) to continue providing technical support to the association. Fourth, in the case of *P. nigricans*, management of migratory fish species is complicated by the fact that Lake Rimachi populations spend part of their life cycle outside of the area where the Kandozi fisheries management plan is applicable. Other authors have suggested that for migratory species, chains of fisheries management reserves may be an effective strategy on a regional scale (Crampton et al. 2004a); the possibility of establishing similar programs in areas near Lake Rimachi needs investigation. Fifth, more research is needed to evaluate management strategies from an ecological perspective to determine whether restrictions on net mesh sizes will actually prevent population declines of species like *P. nigricans*. Finally, a change in current Peruvian laws, increased pressure from commercial fishing operations or petroleum companies, or internal conflicts within the Kandozi community could shift the dynamics of the situation in Lake Rimachi to a scenario where the current fisheries co-management strategy might not apply. It is important to recognize these inherent uncertainties now, in case adaptations to fisheries co-management strategies in Lake Rimachi are needed in the future.

Conclusions

Here, we describe threats to an indigenous fishery in the Peruvian Amazon and the innovative steps that have been taken to manage those threats through fisheries co-management. The Kandozi example reinforces the importance of *P. nigricans* to indigenous communities and also shows that economics play a major role in how natural resources, particularly fisheries, are managed in the Amazon. Because *P. nigricans* is among the most important species for subsistence and artisanal fisheries for indigenous communities throughout the Amazon, some of the fishing regulations developed and implemented by the Kandozi for this species could potentially be exported to other parts of the basin.

In Lake Rimachi and among the Kandozi, a system for fisheries co-management emerged in response to increasing threats to the resources from commercial fisheries and the adoption of more efficient gear and more intense fishing practices. Thus,

while the Kandozi depend on the fisheries for their livelihoods, increasing external and internal pressures have produced a situation where the long-term survival of *P. nigricans* and other fishes now depend on the Kandozi. Long-term sustainability of fisheries resources in Lake Rimachi will require continued involvement of the Kandozi community and local government authorities, regional recognition and respect for the Kandozi from other fishermen, and an adaptive approach to fisheries co-management.

Acknowledgments

The activities described in this article received support from a number of organizations including the Kandozi community, FECONAKADIP, the Regional Coordinator of Indigenous Peoples (CORPI), the Peruvian Ministry of Fisheries, WWF-Peru Programme Office, Racimos de Ungurahui, Fundación Amazonia, and the Global Water for Sustainability (GLOWS) Program. Technical assistance was provided by the Wildlife Conservation Society, the University of Kent-DICE, Florida International University, FundAmazonía (Luis Moya), and independent consultants (J. C. Pacheco). The MacArthur Foundation, DGIS, WWF-International, WWF-CH, and the U.S. Agency for International Development provided financial support for related technical studies and development of the fisheries management plan. Special thanks go to the organizers of the special session on Management and Governance of Diadromous Fishes at the 2007 Challenges for Diadromous Fishes in a Dynamic Global Environment Symposium. This manuscript was improved by comments from several reviewers.

References

Allan, J. D., R. Abell, Z. Hogan, C. Revenga, B. W. Taylor, R. L. Welcomme, and K. Winemiller. 2005. Overfishing of inland waters. Bioscience 55(12):1041–1051.

Almeida, O. T., K. Lorenzen, and D. G. McGrath. 2003. Commercial fishing in the Brazilian Amazon: regional differentiation in fleet characteristics and efficiency. Fisheries Management and Ecology 20:109–115.

Araujo-Lima, C. A. R. M., and M. L. Ruffino. 2004. Migratory fishes of the Brazilian Amazon. Pages 233–302 *in* J. Carolsfield, B. Harvey, C. Ross, and A. Baer, editors. Migratory fishes of South America. International Development Research Center and the World Bank, Washington, D.C.

Araujo-Lima, C. A. R. M., B. R. Forsberg, R. Victoria, and L. Martinelli. 1986. Energy sources for detritivorous fishes in the Amazon. Science 234:1256–1258.

Batista, V. S., A. J. Inhamuns, C. E. C. Freitas, and D. Freire-Brasil. 1998. Characterization of the fishery in river communities in the low-Solimões/high-Amazon region. Fisheries Management and Ecology 5:419–435.

Bayley, P. B. 1981. Fish yield from the Amazon in Brazil: comparisons with African river yields and management possibilities. Transactions of the American Fisheries Society 110:351–359.

Bayley, P. B., and M. Petrere. 1989. Amazon fisheries: assessment methods, current status, and management options. Pages 385–398 *in* D. P. Dodge, editor. Proceedings of the International Symposium on Large Rivers. Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Bodmer, R., A. Escobedo, M. Inga, and D. Gallardo. 2006. Proyecto: conservación de fauna silvestre por las comunidades indígenas Kandozi del Chapuri. Technical Report prepared for WWF-Peru, Lima.

Bowen, S. H. 1983. Detrivory in neotropical fish communities. Environmental Biology of Fishes 9:137–144.

Bowen, S. H., A. A. Bonetto, and M. O. Ahlgren. 1984. Microorganisms and detritus in the diet of a typical neotropical riverine detritivore, *Prochilodus platensis* (Pisces:Prochilidontidae). Limnology and Oceanography 29:1120–1122.

Carvalho de Lima, A. C., and C. A. R. M. Araujo-Lima. 2004. The distributions of larval and juvenile fishes in Amazonian rivers of different nutrient status. Freshwater Biology 49:787–800.

Crampton, W. G. R., L. Castello, and J. P. Viana. 2004a. Fisheries in the Amazon Varzea: historical trends, current status, and factors affecting sustainability. Pages 76–98 *in* K. M. Silvius, R. E. Bodmer, and J. M. V. Fragoso, editors. People in nature: wildlife conservation in South and Central America. Columbia University Press, New York.

Crampton, W. G. R., J. P. Viana, L. Castello, and J. M. B. Damasceno. 2004b. Fisheries management in the Mamirauá Sustainable Development Reserve. Pages 99–122 *in* K. M. Silvius, R. E. Bodmer , and J. M. V. Fragoso, editors. People in nature: wildlife conservation in South and Central America. Columbia University Press, New York.

de Castro, F., and D. G. McGrath. 2003. Moving toward sustainability in the local management of floodplain lake fisheries in the Brazilian Amazon. Human Organization 62(2):123–133.

de Merona, B. 1985. Les peuplements de poissons et la peche dans le Bas Tocantins (Amazonia Bresilienne)

avant fermerture du barrage de Tucurui. Verhanlungen der International Verein fur Limnologie 22:2698–2703.

Dyer, C. L., and J. R. McGoodwin, editors. 1994. Folk management in the world's fisheries: lessons for modern fisheries management. University Press of Colorado, Niwot.

Escobedo, A., L. Moya, and R. Bodmer. 2005. Iniciativas para el Manejo de los Recursos Naturales por los Kandozi del Lago Rimachi, Río Pastaza. Technical Report prepared for WWF-Peru, Iquitos.

FECONAKADIP (Federación de comunidades nativas Kandozi del Distrito de Pastaza and Asociación de Pescadores artesanales "Yungani" del Pueblo Kandozi cuenca del Pastaza). 2007. Programa de Manejo Pesquero de las Especies "boquichico, gamitana, tucunare, maparate." FECONAKADIP, San Lorenzo, Peru.

Fernándes, C. C. 1997. Lateral migration of fishes in Amazon floodplains. Ecology of Freshwater Fish 6:36–44.

Flecker, A. S. 1992. Fish trophic guilds and the organization of a neotropical stream: weak direct versus strong indirect effects. Ecology 73:927–940.

Flecker, A. S. 1996. Ecosystem engineering by a dominant detritivore in a diverse tropical stream. Ecology 77:1845–1854.

Forsberg, B. R., C. A. R. M. Araujo-Lima, L. A. Martinelli, R. L. Victoria, and J. A. Bonassi. 1993. Autotrophic carbon sources for fish of the central Amazon. Ecology 74:643–652.

Goulding, M. 1981. Man and fisheries on an Amazon frontier. Dr W Junk Publishers, Boston.

Greenspan, E. 2006. Strategies for improving government consultations with indigenous people in the Peruvian Amazon. Master's thesis. Harvard University, Cambridge, Massachusetts.

Junk, W. J., M. G. M. Soares, and P. B. Bayley. 2007. Freshwater fishes of the Amazon River basin: their biodiversity, fisheries, and habitats. Aquatic Ecosystem Health & Management 10(2):153–173.

Kimerling, J. 2006. Indigenous people and the oil frontier in Amazonia: the case of Ecuador, ChevronTexaco and Aguinda vs Texaco. International Law and Politics 38:413–664.

Maccord, P. F. L., R. A. M. Silvano, M. S. Ramires, M. Clauzet, and A. Begossi. 2007. Dynamics of artisanal fisheries in two Brazilian Amazonian reserves: implications of co-management. Hydrobiologia 583:365–376.

McDowall, R. M. 1987. Evolution and importance of diadromy: the occurrence and distribution of diadromy among fishes. Pages 1–13 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson, and J. E. Cooper, editors. Common strategies of anadromous and catadromous fishes. American Fisheries Society, Symposium 1, Bethesda, Maryland.

McDaniel, J. 1997. Communal fisheries management in the Peruvian Amazon. Human Organization 56(2):147–152.

Ministerio de Pesqueria. Reglamento y Ordenamiento Pesquero de la Amazonía Peruana, R.M. N° 147–2001-PE

Montreuil, V., A. Garcia, and R. Rodriguez. 2001. Biología reproductiva de boquichico, *Prochilodus nigricans*, en la Amazonia Peruana. Folia Amazónica 12(1–2):5–13.

Oliveira, A. C. B., M. G. M. Soares, L.A. Martinelli, and M. Z. Moreira. 2006. Carbon sources of fish in an Amazonian floodplain lake. Aquatic Sciences 68:229–238.

Pacheco, J.C. 2006. Proyecto desarrollo y fortalecimiento de la actividad pesquera de las comunidades indigenas del pueblo Kandozi. Technical Report prepared for WWF-Peru. Lima.

Pinedo, D., P. M. Summers, R. C. Smith, J. Saavedra, R. Zumaeta, and A. M. Almeyda. 2000. Community-based natural resource management as a non-linear process: a case study in the Peruvian Amazon Varzea. Instituto Bien Comun, Lima, Peru.

Pringle, C. M., M. C. Freeman, and B. J. Freeman. 2000. Regional effects of hydrologic alterations on riverine macrobiota in the new world: tropical-temperate comparisons. BioScience 50(9):807–823.

Ribeiro, M. C. L. B., M. Petrere, and A. A. Juras. 1995. Ecological integrity and fisheries ecology of the Araguaia–Tocantins River basin, Brazil. Regulated Rivers Research and Management 11:325–350.

Sen, S., and J. R. Nielsen. 1996. Fisheries co-management: a comparative analysis. Marine Policy 20:405–418.

Silva, E. A., and D. J. Stewart. 2006. Age structure, growth and survival rates of the commercial fish *Prochilodus nigricans* (bocachico) in northeastern Ecuador. Environmental Biology of Fishes 77:63–77.

Surrallés, A. 2007. Los Candozi. Pages 244–380 *in* F. Santos and F. Barclay, editors. Guía etnográfica de la alta Amazonía. Volume VI. Smithsonian Tropical Research Institute and Instituto Francés de Estudios Andinos, Lima, Peru.

Taylor, B. W., A. S. Flecker, and R. O. Hall. 2006. Loss of a harvested species disrupts carbon flow in a diverse tropical river. Science 313:833–836.

Tello, S. and P. Bayley. 2001. La pesquería comercial de Loreto con énfasis en el análisis de la relación entre captura y esfuerzo pesquero de la flota comercial de Iquitos, cuenca del Amazonas (Perú). Folia Amazónica 12:123–139.

Willink P.W., B. Chernoff, and J. McCullough, editors. 2005. A rapid biological assessment of the Aquatic ecosystems of the Pastaza River basin, Ecuador and

Perú. Conservation International, RAP Bulletin of Biological Assessment 33, Washington, D.C.

Winemiller, K. O. 1996. Factors driving spatial and temporal variation in aquatic floodplain food webs. Pages 298–312 *in* G. P. Polis and K. O. Winemiller, editors. Food webs: integration of patterns and dynamics. Chapman and Hall, New York.

Winemiller, K. O., and D. B. Jepsen. 1998. Effects of seasonality and fish movement on tropical river food webs. Journal of Fish Biology 53(Supplement A):267–296.

Yossa, M. I., and C.A.R.M. Araujo-Lima. 1998. Detrivory in two Amazonian fish species. Journal of Fish Biology 52:1141–1153.