CO-MANAGEMENT OF NATURAL RESOURCES IN THE LOWER JURUÁ EXTRACTIVE RESERVE, CENTRAL-WEST BRAZILIAN AMAZON

By

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To my parents, Cristina and Paulo,for always offering me the best of themselves.
To my son Bento, who daily teaches me what love really is.

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The institutionalization of extractive reserves in 1990 represented a landmark in the decentralization of environmental policies in Brazil. However, their incorporation into the National System of Protected Areas in 2000 led to changes in the model, from self-management conceived by rupper tappers to co-management arrangements with the government. This research examined different perspectives of natural resource governance in the co-management of the Lower Juruá Extractive Reserve (LJER), in the central-western Brazilian Amazon, involving the federal government (ICMBio) and local communities.Through an interdisciplinary approach and employing both qualitative and quantitative methods, I investigated the extent to which co-management permits the sharing of authority over natural resources, and its implications for rule compliance. In a context where communities have management rights, such as in *pirarucu* management, I examined the role of social capital in facilitating collective action, as well as the multiple factors of social-ecological systems affecting the sustainability of *pirarucu* management. Results showed that under extractive reserve co-management, government shares little authority to communities with regard to natural resource governance, but that community participation in rule making is key for rule compliance.

In the case of *pirarucu* management, I found that communities with higher social capital exhibited higher engagement in collective action. I found that multiple factors account for the sustainability of *pirarucu* management: leadership, community monitoring, participation in decision-making, group homogeneity, and social capital. This research provides insights relevant to scholarship on extractive reserves, decentralization common property theory, social capital, and fisheries co-management, with implications for policy making, serving both government and grassroots organizations.

CHAPTER 1
INTRODUCTION

Theoretical Framework

Perspectives on communities as allies rather than enemies of biodiversity conservation have changed in the past decades, with the increasing recognition that communities are able to design and maintain effective institutions to govern the use of natural resources in order to prevent their overexploitation (Ostrom 1990).These regimes involving institutional arrangements for governing common-pool resources (CPRs) are designated as “common property” and have been studied for various types of resource management systems, such as forests, fisheries, ground water, irrigation systems, and pastures (e.g. McCay and Acheson 1987, Berkes 1989, Pinkerton 1989, Tang 1992, Wade 1994, Ascher 1995, Pinkerton and Weinstein 1995).

Common property should not be confounded with common-pool resources (CPRs), which are those “for which exclusion is difficult and joint use involves subtractability” (Berkes and Farvar 1989:7). CPRs differ from public goods because their consumption reduces the availability to the others. These characteristics pose major problems to their effective management, as overexploitation leads to resource depletion (Acheson 2006). Solving these problems involves addressing collective action dilemmas related to conflicts between individual and collective rationalities determining optimal resource use. Two collective-action dilemmas need to be solved (Acheson 2006). The first involves defining and securing property rights to CPRs, which provide users with incentives to maintain them. The second requires establishing governance mechanisms to rule CPRs use.

Property Rights

Property rights determine who has rights to access resources, to make and enforce rules, to exclude others from using them, and to sell or transfer decision-making rights over resources (Schlager and Ostrom 1992). These rights may or may not be recognized by the government (*de jure* rights), but they may in any event be enforced and legitimated by local communities (*de facto* rights; Schlager and Ostrom 1992). Schlager and Ostrom (1992) conceptualized those rights as operational, collective-choice, and constitutional-choice. The first consists of access and withdrawal rights to resources. Collective-choice rights refer to resource management (regulating and improving resource use), exclusion (determining who will have access rights, and whether and how they can be transferred), and alienation (selling or leasing management and/or exclusion rights). Finally, the constitutional level determines rights to devise collective-choice rights.

The dominant view is that, if individuals need to restrain their use of CPRs to gain collective benefits, they will not do so without external enforcement (Wade 1987). Rational individuals would seek to maximize their individual benefits and ignore the collective costs of their use (Olson 1965). For Olson, “unless the number of individuals is quite small, or unless there is coercion or some other special advice to make individuals act in their common interest, rational, self-interested individuals will not act to achieve their common or group interest” (1965:2).

Lack of incentives to act cooperatively to solve commons problems would lead to a “tragedy of the commons” (Hardin 1968). This “tragedy” was theorized by Hardin with the illustrative example of a pasture open to all, representing a public and finite CPR. In this model, rational herdsmen would individually try to maximize their gains in the

pasture at the expense of the others. In the absence of property regimes defining membership and rules, each individual would have incentives to increase his/her herd. At some point, overgrazing would cause pasture degradation, the “tragedy”, bringing ruin to all. As herdsmen alone could not cooperate and find a common solution, they would need external intervention by a central agency (either private or state control) to avoid the tragedy.

This recommendation had profound policy implications, leading to privatization or nationalization of forests around the world (Ostrom 1990). These “solutions” resulted in major negative outcomes such as social inequalities and displacement, and did not solve environmental problems (Baland and Platteau 1996, Acheson 2006). Private and state systems are subject to failures and inefficiencies, and tend to homogenize solutions over large territories when diverse and local approaches would be more appropriate (Acheson 2006).

In addition, these models have problems with their assumptions and the terms they employ. For example, Hardin’s model has been criticized for its misleading assumptions about common property institutions (Wade 1987). It assumes that herdsmen have no information about the state of the commons and its closeness to collapse, as if they would choose resource degradation over their own self-interest. Hardin’s model fits well in situations in which resources are not important for people’s livelihoods, but when they are, it fails to predict collective behavior. In addition, it did not differentiate between unregulated and regulated common property regimes.

The distinction between regulated and unregulated common property regimes caused confusion in the commons literature, because the same term (common

property) was used to define resources and regimes (Ostrom 1990, Schlager and Ostrom 1992). However, regimes should be defined as common property and resources as common-pool. Common-pool resources can be used without restrictions (open access regimes), with minor restrictions defining only membership rules (unregulated common property regime) or defining both membership and resource use rules (regulated common property regime; Baland and Platteau 1996). This distinction is also key for comparing common property and private property systems (Baland and Platteau 1996). Although private property cannot be compared to unregulated common property, its comparison to regulated common property shows that both may be inefficient in many situations, such as when there is incomplete information about ecological processes or when exclusion of outsiders is impossible. In this case, both private and common property systems require state intervention. In addition, the two property regimes differ, as private property is not subject to collective action dilemmas, and its owner bears the full costs of resource management, while costs are shared among users in regulated common property (Baland and Platteau 1996).

In conclusion, there is no single system that brings solutions to all environmental problems (Baland and Platteau 1996, Acheson 2006). Comparing private, state, and common property shows that, in fact, all models are subject to imperfect monitoring. Private ownership may be too costly or inequitable; state ownership may be ineffective; and community management may be unrealistic as it does not necessarily result in successful collective action (Baland and Platteau 1996). However, these are overly simplistic classifications and there are many combinations of state and community property regimes, leading to multiple potential solutions (Baland and Platteau 1996).

Mechanisms regulating successful common-propertyinstitutions

Ostrom (1990) was a landmark for the understanding of common property regimes, contributing to change the paradigm that resource use by communities would necessarily lead to a tragedy of the commons in the absence of an external authority. She showed several cases around the world in which resource users were able to design and maintain successful common property institutions[1] over long periods of time. Long-enduring institutions can be effective in circumventing the tragedy through creation, experimentation, and enforcement of local rules that respond to local conditions and that result in greater compliance. In addition, as local management institutions are closer to the resource base, they are better able to devise diverse and flexible solutions to commons problems than private or state systems. For example, they can change harvest rates to match replenishment of resource stocks.

In the theory of self-organized collective action elaborated by Ostrom (1990, 2000), cooperation is an essential element. Rational individuals cooperate if perceived benefits are greater than costs over time. Cooperation in common property regimes depends on relations of trust and reciprocity. Individuals collectively design and follow rules if they believe others in the group will do the same; otherwise it might be more advantageous to free ride (Ostrom 1990). This is defined as a collective action dilemma. Individuals in a group may perceive (or not) the advantages to design and maintain institutions regulating their interdependent use of common-pool resources, in order to obtain “higher joint benefits or reduce their joint harm” (Ostrom 1990:39).

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[1] Ostrom defines institutions as sets of rules determining “who is eligible to make decisions in some arena, what actions are allowed or constrained, what aggregation rules will be used, what procedures must be followed, what information must or must not be provided, and what payoffs will be assigned to individuals dependent on their actions” (1990: 51)

Ostrom (1990) proposed eight design principles based on common elements characterizing all long-enduring institutions that were able to overcome the commons dilemma. Successful common property regimes had relative autonomy to craft their own institutions (principle 7), and “the incentives and means to improve these institutions over time” (1990:60). These incentives and means were determined by rules defining clear boundaries to users and areas (principle 1), congruence between appropriation (resource use) and provision rules (related to resource availability) and local conditions (principle 2), monitoring (principle 4), sanctioning (principle 5), conflict-resolution mechanisms (principle 6), and collective-choice arrangements by which most individuals affected by operational rules can participate in modifying those rules (principle 3). In the case of CPRs that were part of larger systems, those rules and mechanisms were nested in multiple layers (principle 8).

The conditions for successful common property regimes have been examined in depth for a wide array of systems through case study method. However, most studies fail to consider how resource systems, certain characteristics of resource users, and the external environment together may influence the success of common property institutions (Agrawal 2001). In addition, studies generate too many variables and do not “systematically test findings, compare postulated causal connections across contexts, or carefully specify the contextual and historical factors relevant to success” (Agrawal 2003:246).

Agrawal (2003) addresses this gap by synthesizing and complementing the conditions for successful common property institutions based on three of the most relevant and informative studies on the commons (Ostrom 1990, Wade 1994, Baland

and Platteau 1996). This more complete set of facilitating conditions for common property sustainability encompasses characteristics of resources, resource systems, users, the external environment, and interactions among them.

In addition, common property studies have been criticized for their assumptions about communities (Agrawal and Gibson 1999). Communities are not necessarily small, homogenous and with shared norms as often assumed in the literature. In fact, communities encompass power relations among actors with different interests. It would therefore be more appropriate to focus on institutions for collective action rather than on communities (Agrawal and Gibson 1999). Agrawal (2003, 2005) argues that scholars should adopt a more political approach to the commons that considers historical relationships between humans and the environment and how these relationships shape common property arrangements.

Another central critique is that studies often assume rather than test the relationship between robust institutions and sustainable management (Baland and Platteau 1996). Conservation of natural resource stocks at present levels is assumed to be optimal. In addition, the ability of groups to design institutions for solving allocation problems (related to resource sharing) is often confounded with their capacity to solve resource management problems that conserve resource stocks (Baland and Platteau 1996). The former does not necessarily lead to the latter, and both problems should be approached separately.

Despite the richness and legitimacy of local knowledge, resource users might not have complete information about ecological processes, such as the consequences of human action on resource stock and flow (Baland and Platteau 1996). As a result, they

might not adequately perceive the nature of the problem and may not respond accordingly. Sharing rules and solving assignment problems does not necessarily reduce pressure on resources and conserve them; similarly, controlling access by outsiders does not mean that insiders are using resources appropriately (Baland and Platteau 1996). In addition, the type of resource influences the user's ability to conserve them. Baland and Platteau assert that "awareness of ecological stress under increasing human pressure on natural resources grows only slowly and typically requires concrete, visible experiences of depletion or degradation to be stimulated" (1996:226). Thus, more localized, visible and predictable resources have greater chances to be conserved than seasonal, unpredictable and less visible resources spread over large areas. In the latter case, human responses may be delayed and fail to avoid resource degradation, and learning will not be as effective.

Despite these critiques, common property theory became an established field that has significantly contributed to broader concerns in social sciences (Agrawal 2003). Although it is difficult to assert its role in decentralization of environmental policies in the 1980s and 1990s, it has certainly informed policy making on the importance of formal and informal institutions in guiding human behavior and its implications for natural resource management (Agrawal 2001, 2003). Common property theory provided the alternative of communities and communal ownership to state and market regulation, which are relevant for understanding the shift from central control to more inclusive policy choices.

Shift from Government to Governance

Central regulation tends to homogenize diverse interests and ignore local aspirations, value systems, politics, culture, and land-use practices (Western 1994). In

addition, governments often assumed control of resources without the means of regulating, thus not solving environmental problems and imposing heavy costs on local communities (Western 1994). Decentralization encouraged various arrangements between governments and communities, emerging as result of increasing civil society dissatisfaction with state-based and market-based regulation in the previous decades (Larson and Soto 2008).

Decentralization in natural resource management

There is general agreement on the need to bring decision-making closer to the people (Child et al. 1997, Murphree 2000, Jentoft 2003, Borrini-Feyerabend et al. 2004, Child 2004, Ribot 2004). According to the subsidiarity principle, “the relevant level for decisions is the most-local possible level at which decision making will not result in negative effects at higher social or political administrative levels” (Ribot 2004:9). The question is what powers should be transferred and to what scale.

Ribot (2002, 2004) discusses two forms of decentralization: democratic decentralization (also called political decentralization or devolution) and deconcentration or administrative decentralization. He argues that the former generates the greatest benefits because it transfers power to “authorities representative of and downwardly accountable to local populations” aiming to “increase popular participation in local decision making” (Ribot 2002:4). By contrast, deconcentration refers to power transfers to local branches or representatives of the central government. These are upward accountable to the state but have limited downward accountability in their functions.

Democratic decentralization potentially brings increased participation, equity and efficiency, and it is considered “more apt to be socially and environmentally responsible” (Ribot 2003:59). However, it is very difficult to measure decentralization’s outcomes and

there are few studies showing its advantages to natural resource management (Ribot 2004). One is Agrawal and Ostrom's (2001) comparison of four cases of forestry decentralization in South Asia. They found evidence of improved forest conditions in cases characterized by more effective decentralization of property rights. For them, communities should have "at least the rights to manage resources and make decisions about resource use and exclusion" (2001:508).

However, decentralization is more rethoric than practice: most reforms in fact did not effectively transfer powers to local institutions, and instead remained under control of central governments (Ribot 2002). Decentralization often fails to provide people with real powers as local elites are co-opted, bureaucratic hierarchies continue to exist, and participation only gives people responsibilities and no authority (Murphree 1994). Recentralization of authority is documented for forestry and wildlife in Africa, Asia and Latin America (Metcalfe 1994), both for local governments and local communities (Ribot 1999, Ribot et al. 2006). Two lessons became apparent in these studies: i) policies alone are not sufficient to provide security of rights to communities and ii) decentralization needs time to succeed (Ribot 1999, 2002, 2003, Jones et al. 2006).

Other authors argue that greater authority should be devolved to local people (e.g. Murphree 1993, 1994, 2000, Child et al. 1997). Devolution consists of "the creation of relatively autonomous realms of authority, responsibility and entitlement, with a primary accountability to their own constituencies" (Murphree 2000:6). Experiences of community-based management have been implemented throughout the world, with varying degrees of success, providing lessons about the strengths and weaknesses of this approach.

Community-based natural resource management

In the past few decades, several bottom-up conservation strategies, collectively known as community-based natural resource management (CBNRM), were implemented in Africa, Asia, Oceania, Latin America and North America (Western and Wright 1994, Kellert et al. 2000, Hulme and Murphree 2001, Brosius et al. 2005) as promising alternatives to top-down initiatives (Berkes 2004). CBNRM initiatives have several characteristics in common: the desire to reconcile conservation and development; a commitment to engage local communities and institutions in conservation; the goal of devolving power and authority from central governments to lower levels of governance, including local communities and their organizations, and to legitimize their rights; and a belief in the need to include local values and knowledge in resource management strategies (Kellert et al. 2000).

The underlying logic of CBNRM is that communities, which depend on natural resources and are close to them, will manage these appropriately if provided incentives (Agrawal and Gibson 1999). Although not all bottom-up projects of community participation succeed, almost all top-down approaches that do not involve communities fail (Strum1994). Thus, despite concerns of whether it is more effective than central authority (Western and Wright 1994), community-based management offers greater opportunities for effective conservation (Agrawal and Gibson 1999). This is especially true for resources that are important for local livelihoods (Agrawal and Gibson 1999).

Local participation in management decisions and practices is at the center of community-based conservation (Adams and Hulme 2001). The idea of communities as protagonists in environmental conservation was supported by findings that environments are not pristine and have been used and modified by humans for

millennia (Heckenberger et al. 2003, Willis et al. 2004). Assumptions that they were used sustainably and that similar results could be accomplished nowadays contributed to favor community-based conservation (Agrawal and Gibson 1999). The contrasting view that, if communities are not directly involved in natural resource management they will use resources destructively, also provided arguments for community conservation.

Evidence from community forest management in south Asia shows that delegating only operational rights to access and use forests “does not produce much change in either the condition of vegetation or the relationships between state and community actors” (Agrawal and Ostrom 2001:508). These authors argue that decentralization has minimal impact when local users do not have rights at collective and constitutional levels, which determine their control over rule design, management and enforcement.

CAMPFIRE (Communal Areas Management Programme for Indigenous Resources), a CBNRM program established in southern Africa in the late 1980s, has provided relevant lessons for successful community-based management. It showed that proprietorship, combined with economic incentives, capacity building and adaptive management, was key to effective natural resource management (Murphree 1993, 1994, Child 2004). Proprietorship consists of granting local people with rights to sanction, to determine how resources are going to be used and managed, rights of access, inclusion and exclusion and to fully benefit from management (Murphree 1993, 1994). The program provided private and communal land owners with institutional and financial incentives for conserving wildlife outside protected areas (Metcalfe 1994, Child et al. 1997, Hulme and Murphree 2001, Jones et al. 2006), leading to positive changes

in local attitudes to wildlife, reduced poaching and increased wildlife abundance (Child 2005). Devolution also empowered local communities, motivating them to effectively engage in conservation (Child 2004).

Despite successful experiences, several CBNRM projects worldwide have been unsuccessful and were therefore criticized.Some critics questioned the role of local communities in conserving natural resources and raised doubts about the prospect of reconciling conservation and development goals (Kellert et al. 2000, Berkes 2004). Kellert and collaborators (2000) examined five case studies in Nepal, Kenya and the United States, and found these cases succeeded more in terms of human development, empowerment and equity. However, they also found that the projects had limited success in conflict resolution and integration of local knowledge and values into CBNRM projects, and rarely exhibited success in biodiversity protection and sustainable use of natural resources.

Incorrect assumptions about communities were also pointed out as factors for disillusion with community-based approaches (Little 1994, Agrawal and Gibson 1999). Communities were generally idealized as “authentic”, “indigenous”, “customary” or “conservationists” (Western and Wright 1994, Ribot 1999, Berkes 2004), or misconceived as small spatial units with homogeneous social structures and consisting of groups with shared norms and interests (Agrawal and Gibson 1999). Projects also failed by empowering indigenous authorities that were not necessarily representative and accountable to their people, hindering equity and participation goals (Ribot 1999).

For Baland and Platteau (1996), criticisms of CBNRM projects are misplaced as externally-designed projects often did not consider communities priorities, their social

organization, leadership, decision-making structure, and needs. Conservation and development programs were“generally paternalistic, lacking in expertise, and one-sided – driven largely by the agendas of conservationists, with little indigenous input” (Chapin 2004:20). Most unsuccessful experiences were designed and decided by external agencies with little meaningful participation by local peoples (Little 1994, Berkes 2004). Projects had overly ambitious goals and timetables, were highly dependent on outside expertise rather than indigenous knowledge, and did not consider local people’s dependency on outside markets (Western and Wright 1994).

Changes need to happen at all levels of governance for community-based approaches to succeed. It is necessary to understand the role of culture in community-based conservation and promote greater knowledge exchange among communities and between communitiesand scientists (Kleymeyer 1994). There should be a more political approach to communities, examining the multiple interests within them, their internal and external institutions and how they shape decision making (Agrawal and Gibson 1999). At higher levels, challenges related to contradictory policies, bureaucracy, and poor coordination among governmental agencies need to be faced (Metcalfe 1994). Projects need effective mechanisms for communication, transparency and accountability to improve information flow and availability (Wright 1994), and tackle corruption and nepotism that often occur both at the top and the bottom (Strum 1994). Projects need to ensure resource and social security and make explicit the costs and benefits of conservation and who are bearing them (Western 1994).

Instead of asking about the role of communities in conservation, we should rethink conservation strategies themselves (Berkes 2004). These should recognize the

importance of equity and empowerment, and address issues of scale and participation. Conservation should operate via cross-scale relations, but start from the ground up (Berkes 2004). This is because communities cannot act alone; they need external support in terms of training, extension, information, funding, arbitration, and legislation (Murphree 1994). The co-management approach to conservation serves both sides: governments cannot solve environmental problems alone, and thus need communities and their institutions to protect natural resources; communities need governments to legitimate and support local governance. The co-management literature focuses on how power should be shared between communities and governments to improve local governance.

Co-management

There are multiple definitions of co-management, and arrangements vary in terms of the level of power sharing in decision-making processes (Berkes 2009). In general, co-management is established through a vertical partnership primarily between a governmental agency and local resource users.The partnership defines the distribution and sharing of management functions, rights and responsibilities (Borrini-Feyerabend 1996). Other authors define co-management as a continuum in which the government shares power with local communities, but holds final authority (Pomeroy and Berkes 1997). In its broader definition, co-management or collaborative management involve all relevant stakeholders in the management of an area (e.g. Borrini-Feyerabend 1996) or all users of a given resource (e.g. Pinkerton 1989, 1994, Wilson et al. 2003). The World Conservation Union (IUCN) defines co-management of protected areas as shared decision-making power, responsibility and accountability

between governmental agencies and other stakeholders, in particular local communities (Borrini-Feyerabend et al. 2004).

Analytically, co-management is seen as “a middle course between pure state property and pure communal property regimes” (Pomeroy and Berkes 1997:467). It consists of a hierarchy of vertical arrangements that fall in between the extremes of government centralized management and community self-management. Power and authority shared varies in a continuum from weak to strong co-management, from situations in which communities are only consulted by the government in policy making to cases in which communities design, implement and enforce laws and regulations with government assistance (Borrini-Feyerabend 1996, Pomeroy and Berkes 1997).

Co-management is argued to be a better alternative to state or community-based management. It is located in between as it involves power sharing by government with local communities, but does not challenge governmental authority (Jentoft and McCay 2003). The government is critical to co-management in providing authority and legal rights. The question is how much and what kind of government is desired (Pomeroy and Berkes 1997). Co-management brings government support to communities, so theoretically it corrects for problems associated with the small scale of community-based initiatives (Jentoft and McCay 2003), such as the enforcement arbitration needed to support communities in protecting resources against outsiders (Agrawal and Gibson 1999). Co-management is also a way to legitimize local management and bring social equity (Jentoft 2003).

Most studies focus on participation by resource users or communities in co-management (e.g. Jentoft 1989, 2000, Pinkerton 1992, Jentoft and McCay 1995,

Pinkerton and Weinstein 1995, McCay and Jentoft 1996, Pinkerton and John 2008), while relatively few examine the reasons for government engagement (Pomeroy and Berkes 1997, Wilson 2003). Communities engage in co-management because they need governmental support in terms of bureaucratic authority and financial resources (Wilson 2003). Communities that cooperate with the government can control larger areas, because state authority decreases costs. In addition, state support provides legitimacy in conflict management, especially at larger scales. For their part, governments engage in co-management as it reduces challenges to their authority (Pomeroy and Berkes 1997) and improves their accountability at local levels (Wilson 2003). Governmental authority works better at larger scales (through law enforcement), but at smaller scales its ability to understand process and influence decisions and behaviors is more limited. Thus, government engages in co-management because it needs local institutional mechanisms in natural resource management rather than only legal enforcement.

In fact, there are multiple stakeholders involved in co-management, such as research institutions, NGOs, and market actors (Jentoft 2003). Thus, co-management should bring greater democratization, community empowerment and development (Pomeroy and Berkes 1997) and be more effective, cost-efficient and better accepted by stakeholders, which in turn should improve compliance (Jentoft et al. 2003, Pomeroy 2003). As other actors besides communities are involved in resource management, co-management embraces the broader socio-ecological context (Pomeroy 2003). Co-management potentially bridges knowledge at the local level with tools, techniques and broader knowledge available to governments and other actors at regional and national

levels (Hanna 2003, Berkes 2009). Co-management brings together the dispersed knowledge funds of multiple stakeholders (Berkes 2009).

Based on numerous experiences of collaborative management of protected areas throughout the world, Borrini-Feyerabend (1996) reviews its advantages and disadvantages. For example, she points out the positive role of alliances, knowledge, skills, sharing of responsibilities, improved dialogue and communication, and trust building in co-management, which together contribute to a more participatory and democratic society. However, co-management implies high costs, difficulties in maintaining agreements, and opposition by powerful actors. This author recommends that these challenges should be addressed through the design of appropriate levels of decision making in which representatives can put into practice agreements; establishment of procedures for conflict resolution and mechanisms for active communication among parties; regular monitoring of compliance and enforcement of those who violate agreements; and learning-by-doing (Borrini-Feyerabend 1996).

Berkes (2009) points out that co-management should not be seen as a panacea for legitimacy. There is not enough evidence that it reduces poverty or empowers marginalized groups. In addition, co-management, as decentralization, often reinforces the powers of governments or local elites if authority is not truly shared. Regarding governments, co-management can lead to regulatory capture or can be used as a pretext for co-opting communities. In relation to local elites, failure to include marginalized people may cause greater inequity and reduce community welfare. Co-management may also fail if governments are weak. It is the role of governments to facilitate co-management in a way that lower levels can handle management

responsibilities (Jentoft 2003). In addition, not everything that involves government and local peoples is co-management. True co-management is an arrangement that empowers users to set management objectives on equal terms with the government (Hara and Nielsen 2003). Other problems relate to trade-offs such as increased costs and time to conduct participatory processes, ineffective participation, problems of representation, and disputed legitimacy (Pahl Wostl 2009). Stakeholders may vary in their legitimacy, power and urgency (Jentoft et al. 2003).

Another important approach to the study of natural resource governance is provided by social capital theory, which offers a conceptual framework in which to examine the social relations among people, communities and organizations that facilitate collection action.

Social Capital

The social capital literature has become popular in the social sciences because it approaches people's real values, focusing on "how people interact in their daily lives, in families, neighborhoods, and work groups, not just as buyers, sellers, and citizens" (Bowles and Gintis 2000:3). According to Woolcock and Narayan (2000), the social capital concept was coined in 1916 by Hanifan, then disappeared for several decades reappearing in the sociological literature in the 1950s, 1960s, and 1970s. However, it only gained academic and policy notoriety after the studies of Coleman (1987, 1988, 1990) and Putnam (1993, 1995). Since the 1990s, an extensive literature on social capital has accumulated, with multiple attempts to define it (Bordieu 1985, Coleman 1988, 1990, Putnam 1993, 1995), measure it (Narayan and Pritchett 1999, Narayan and Cassidy 2001, Onyx and Bullen 2001, Woolcock 2001), synthesize it (Portes 1998,

Woolcock and Narayan 2000, Adler and Kwon 2002) or apply it on the ground (Gittell and Vidal 1998).

Woolcock and Narayan (2000) categorize research on social capital into four distinct perspectives: the communitarian view, the network view, the institutional view, and the synergy view. The communitarian view centers attention on participation in local organizations such as clubs, associations, and civic groups. The network view analyses the vertical and horizontal linkages between actors, whether persons, communities or firms. The institutional view stresses the importance of the broader context in which social networks are embedded. The synergy view integrates research on these two latter perspectives (networks and institutional). Adler and Kwon (2002) classify research on social capital in terms of two broader types: a) formal structure of the ties that characterize social networks (e.g. closure, structural holes); and b) content of ties (shared norms and beliefs, abilities) that determine social capital within the social network.

Social capital has multiple properties: a) it can be used for multiple purposes, b) it can be converted to other forms of capital (economic, human capital etc.), c) it can substitute or complement other capitals; d) it grows with use (e.g. reputation) but may depreciate if not used; e) it is not owned by a person, meaning that others can use it without reducing its stock; however, people can be excluded from using it; f) it is different from other forms of capital, because it is located in the social relation among actors, not in the actors themselves; thus it requires two persons to build it but just one to destroy it; and g) different from other forms of capital, investments in developing social capital cannot be measured (Adler and Kwon 2002).

Moreover, social capital is multidimensional: it can refer to social relations among actors from the same social group (family members, close friends, neighbors), known as “bonding” social capital; among actors of different groups (more distant friends, colleagues, associates), designated as “bridging” social capital; or to power relations between regular citizens and the state, defined as “linking” social capital (Gittell and Vidal 1998, Woolcock 2001).

Definitions of social capital vary accordingly, emphasizing more the external linkages of social actors (e.g. Bordieu 1985), the internal linkages (e.g. Coleman 1988, Putnam 1995), or both (e.g. Woolcock 1998, Adler and Kwon 2002). Bordieu defined it as the “aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition" (1985:248). For Coleman, “social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in common: they all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure" (1990:302). Putnam defined it as a “feature of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit” (1995:67). For Woolcock, social capital consists in“information, trust, and norms of reciprocity inhering in one's social networks" (1998:153). Adler and Kwon conceptualized it as “the goodwill available to individuals or groups. Its source lies in the structure and content of the actor’s social relations. Its effects flow from the information, influence, and solidarity it makes available to the actor” (2002:23).

Despite its wide acceptance, the concept has been criticized for being too broad, allowing for different meanings, and causing confusion. Its causes and consequences are often lefyt obscure in definitions, leading to lack of explanatory power and tautological reasoning (Woolcock 2001, Adler and Kwon 2002). For example, trust is commonly considered a source of social capital, while it is actually an outcome of repeated interactions (Woolcock 2001). To simplify, Woolcock (2001) argues that definitions of social capital should focus on what it *is* rather than on what it *does*. Social capital has also been criticized for not being actual "capital", as it lies in the relations among people and not in people themselves. However, this usage is metaphorical, and the term should be understood as an asset in which people invest to later reap the benefits (Adler and Kwon 2002).

Social capital has been pointed out as a key factor for self-organization and for the collective management of natural resources (Ostrom 2005, Pretty 2003, Pretty and Smith 2004). This concept has been incorporated in studies of common property, given its power to characterize and understand the social relations among actors that make them work together for the collective good. Different from other forms of capital (e.g. financial or human capital), its power lies not in the actors, but in the social relations among them, be these people, communities, or organizations (Woolcock and Narayan 2000).

In the context of CPRs, it is important to understand the motivations people have to engage in collective action for controlling the use of natural resources. People engage in common property regimes depending on conditions of the resource system and on whether they perceive the need to organize to manage CPRs (Varughese and

Ostrom 2001), but a key question is what makes them comply with rules and invest in the collective gain over their own individual benefits, without being sure that others in the group will do the same (Portes 1998, Ostrom 2000). For Portes (1998), there are two types of motivations: a) consummatory, consisting in deeply internalized norms based on shared previous experience; and b) instrumental, by which the community enforces norms of obligations on parties. According to Putnam (1993), norms of generalized reciprocity guide people's behavior in social groups, resolving problems of collective action and connecting communities. These norms "transform individuals from self-seeking and egocentric agents with little sense of obligation to others into members of a community with shared interests, a common identity, and a commitment to the common good" (Adler and Kwon 2002:25).

One important aspect of the social structure is its closure, or the extent to which people in a social network are connected. Closure contributes to create trust and effective norms that permit the dissemination of obligations and expectations in the social structure, facilitating collective action (Coleman 1988). Therefore, smaller networks with frequent interactions would have more trust and effective social norms than larger networks with unconnected actors, who can free ride more easily without being noticed. Thus, smaller networks are more prone to collective action that larger ones.

Despite general evidence of the benefits of social capital, it is not always used for the collective good. For example, criminal organizations have strong social capital and mobilize it for their collective interests over society's values and welfare. In fisheries management, communities with strong social capital, but low willingness to report rule

breaking, may not engage in collective action in the absence of appropriate leadership even if they perceive the need to organize it in face of fisheries overexploitation (Bodin and Crona 2008). Gutierrez et al. (2011) also reported the key roles of robust social capital and strong community leadership for successful fisheries co-management.

Conservation biologists have appropriated the concept of social capital in strategies to change people's behaviors towards the environment. For Pretty and Smith (2004), governments, donors, and agencies working with conservation and development should invest in creating social capital through social learning, so as to achieve the desired environmental outcomes. Communities in protected areas are relevant targets for such initiatives.

Protected Areas Management

Protected areas are the world's largest strategy for conservation and land use planning, covering more than 11% of marine and terrestrial territories, most of which were designed within the past 50 years (Dudley et al. 2010). A protected area is "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley et al. 2010:486).

Based on management objectives, IUCN classifies protected areas in six broad categories: four categories are for strict nature protection and the other two (categories V and VI) reconcile resource use and cultural values with biodiversity conservation. Categories V and VI have been created in the context of increasing concerns with local participation in decision making over natural resources that has marked the shift from government to governance (Borrini-Feyerabend et al. 2004). These emerged in response to numerous tensions between social and conservation agendas following the

expansion of exclusionary protected areas for biological conservation, especially in forest-rich countries. As conservation started to incorporate the needs of the rural poor rather than creating parks for urban elites, a heated debate has divided proponents and opponents of people-based approaches (Western and Wright 1994). The former group has posed arguments for the rights of communities to land and its resources, while the latter has argued for the rights of society to deny local communities their claims to use species and resources (Western and Wright 1994).

Parks for people in the Brazilian Amazon

In Brazil, the first categories of protected areas, national park and national forest, were created in the 1934 and 1965 Forest Codes, inspired by the U.S. models of protected areas (Rylands and Brandon 2005). Extractive reserves (ERs) emerged in the Amazon as an alternative model of protected areas, conceived by rubber tappers via their grassroots organizations inthe mid-1980s. ERs are intended to guarantee land rights to local peoples and thereby protect their forest livelihoods (Schwartzmann 1989, Allegretti 1990, Almeida 2002).

Extractive reserves

ERs correspond to IUCN category VI. ERs are an innovative model of protected area that has been created in the Amazon and elsewhere in Brazil since 1990 (Gomes 2009, Pacheco 2010). ERs constitute an example of the sustainable use approach to protected areas.They were first institutionalized due to the demands of rubber tappers to guarantee their land rights in areas with conflicts over access to natural resources (Allegretti 1990, 2002, Almeida 2002). ERs emerged in a context of national political reform after twenty years of military rule (Schmink and Wood 1992, Allegretti 2002,

Hochstetler and Keck 2007) and increased worldwide ecological concern (Cardoso 2002).

ERs have been in the center of the debate over people and parks (Gomes 2009). For the first time, conservation areas in Brazil were created for people and not in spite of them (Ehringhaus 2005). ERs were regarded as a promising public policy that could permit rational development of the Amazon by reconciling the extractivist vocation of the forest with social justice (Fearnside 1989, Schwartzman 1989, Allegretti 1990, Hall 1997). Others criticized the model due to uncertainties and economic and environmental constraints associated with the sustainability of extractivism (Fearnside 1989, Browder 1992, Homma 1992, Peres et al. 2003).

The institutional design conceived by the rubber tappers for ERs considered their traditional forms of land use for social and economic reproduction, combining characteristics of agrarian reform settlements with indigenous reserves (Allegretti 2002). Rubber tappers conceived a model of self-management by which the government would grant them land rights and autonomy to manage resources, without losing government support for protecting their territories, securing their livelihoods and improving their social and economic development (Allegretti 2002).

The incorporation of ERs into the national system of protected areas, however, led to substantial changes in the model (Cunha 2010, Pacheco 2010). The model has shifted from self-management to co-management, in which both the national government and local communities are responsible for federal extractive reserve governance. Incorporation into the federal system brought new governance mechanisms such as the management plan regulating resource use, and the

Deliberative Council that expanded participation in decision-making to include other stakeholders in ER governance (Brasil - MMA 2000). These changes potentially reduced the autonomy of local residents and their organizations (Cunha 2010, Pacheco 2010).

More than twenty years after the creation of the first ERs, a vast and diverse research literature has accumulated, focusing on the political organization and empowerment of rubber tappers (Keck 1995, Brown and Rosendo 2000*a*, Allegretti 2002, Almeida 2002, Allegretti and Schmink 2009, Gomes 2009); institutionalization and implementation of ERs (Murrieta and Rueda 1995, Allegretti 2002, Ehringhaus 2005, Gomes 2009, Cunha 2010); institutional design in ERs (Brown and Rosendo 2000*b*, Cardoso 2002); changes in the rubber tapper movement (Ehringhaus 2005, Pacheco 2010); debates over the sustainability of extractivism and ERs (Allegretti and Schwartzmann 1989, Fearnside 1989, Schwartzmann1989, Allegretti 1990, 1994, 1995, Browder 1990, 1992, Homma 1992, Salafski et al. 1993, Simonian and Glaser 2000, Peres et al. 2003, Goelsch and Igliori 2004, 2006, Ehringhaus 2005, Ruiz-Perez et al. 2005, Wadt et al. 2008); changes in rubber tapper livelihoods and impacts on land-use/land-cover (Gomes 2001, 2009, Ehringhaus 2005, Ruiz-Perez et al. 2005, Salisbury and Schmink 2007, Vadjunec et al. 2009, Vadjunec and Rocheleau 2009), rubber tapper identities (Campbell 1996, Vadjunec et al. 2011) and culture (Wallace 2004); and the effectiveness of ERs for forest conservation (Souza 2006, Nepstad et al. 2006).

This literature is geographically concentrated in the southwestern Brazilian Amazon, in the state of Acre. While Acre was the place where the rubber tapper movement was born and gained national and international attention, ERs have

nonetheless became a strategy for conservation and development adopted by both state and federal governments in many regions of Brazil (Ehringhaus 2005, Gomes 2009, Pacheco 2010). Rubber tappers from remote areas, such as in Amazonas state, were also connected to the social movement that led to institutionalization of ERs. However, their struggle was against other pressures (e.g. fisheries invasions and lack of autonomy from rubber patronage system) rather than deforestation (Derickx 2007, Nelcioney 2007).

Field studies of ERs point out their effectiveness in securing land rights and the positive implications for traditional livelihoods (Ehringhaus 2005, Ruiz-Peres et al. 2005). However, such research has also documented changing livelihoods, from rubber to adoption of cattle ranching in ERs close to the development frontiers (Gomes 2001, 2009, Salisbury and Schmink 2007, Vadjunec et al. 2009), as well as diversification of strategies encompassing forest products, timber management, small-scale agriculture and animal husbandry, especially in more remote regions (Ehringhaus 2005, Ruiz-Perez et al. 2005). However, the social and economic development of local residents remains a priority, as well as their demand for greater autonomy in reserve governance (CNS 2009).

The main challenges to governance of ERspointed out in the literature are:

1. Poor implementation of governance mechanisms (Pacheco 2010);
2. Poor participation of local residents in developing regulations for resource use, resulting in partial acceptance and compliance with local rules (Ehringhaus 2005) and reduced importance of local knowledge (Cunha 2010);
3. Top-down implementation and management as reserve funding comes mostly from external agencies (Ehringhaus 2005, Cunha 2010);
4. Weaker authority of local community organizations and reduced importance of local knowledge to reserve management with the incorporation of ERs into the national

system of protected areas, leading to weak co-management (Ehringhaus 2005, Cunha 2010, Pacheco 2010);

5. Weak institutional arrangements and representation of the association in relation to its constituencies (Cardoso 2002);

6. Blurred relationships between social movements and the government, leading to cooptation of grassroots leaders and lack of autonomy of the movement (Pacheco 2010); and

7. The large size of ERs makes it difficult for them to be appropriately managed and monitored either by residents or the government (Cardoso 2002, Ehringhaus 2005, Ruiz-Peres et al. 2005).

Challenges to natural resources governance in ERs can be addressed through strengthening co-management in a way that the government enables greater participation of communities in decision making over natural resources. Natural resources governed by communities can be more effective than resources controlled solely by governments (Ostrom 1990), especially if communities have greater incentives to protect and manage resources such as *de jure* management rights and economic benefits (Murphree 1993, Child 2004).

In this context, small-scale fisheries provide interesting cases of co-management involving government and rural communities in the Amazon. However, most studies on fisheries were held outside of ERs (Begossi et al. 1999, Lopes et al. 2011), while research within these protected areas has focused more on forest livelihoods (e.g. Campbell 1996, Stone 2003, Ehringhaus 2005, Wadt et al. 2008, Vadjunec et al. 2009). This dissertation therefore focuses on fisheries management in an ER in the Brazilian Amazon.

Fisheries Management

Fisheries are classic examples of common-pool resources for which exclusion is difficult and joint use involves subtractability (Berkes and Farvar 1989). For these

reasons, fisheries pose intriguing challenges to policy makers (Caddy and Cochrane 2001, Pauly et al. 2002, FAO 2005), and have been widely studied by scholars of the commons (e.g. Berkes 1986, 1989, Ostrom 1990, Schlager and Ostrom 1999, Castro 2000, Pereira 2000, Castello et al. 2009).

Overexploited or collapsing fish populations may lead to species extinction,though fish populations may rapidly recover if effective management measures are adopted (Pauly et al. 2002). In the past decades, different strategies have been implemented and failed (Hilborn et al. 2004). For example, the overly simplistic scientific modeling of “maximum sustainable yield” (MSY) consisted of making adjustments in fishing effort to certain optimum levels for managing single species stocks (Pauly et al. 2002). Alternative proposals such as precautionary reductions in catch limits, ecosystem management, marine protected areas with no-take zones at their core, individual transferable quotas, cooperative fisheries and community ownership of fishing grounds have been pointed out in the literature with varying degrees of enthusiasm (Holland and Brazee 1996, Caddy 1999, Ward et al. 2001, Pauly et al. 2002, Hilborn et al. 2004, Beddington et al. 2007).

Conventional management has failed both in social and ecological terms, especially in small-scale fisheries. It has ignored the needs and livelihoods of fishers, and neglected integrated ecosystem management approaches, as well as the potential of participatory and interdisciplinary tools to meet those needs (Berkes 2003). In the last decades, better suited approaches to overcome these limitations have been developed (Berkes et al. 2001), shifting traditional management focused on single species stocks to more integrative and participatory ecosystem-based approaches that are better able

to deal with complexity and uncertainty (Berkes 2003, Chapin et al. 2009). Participatory management has decentralized authority and responsibility to local communities under the labels of community-based fisheries management or fisheries co-management (Berkes et al. 2001).

In the Amazon, new arrangements resulted from the political organization of riverine communities since the 1960s and increasing acceptance of the federal government in sharing management authority over fisheries. Although not so articulated, their history of organization and control of territories in the floodplains resembles the trajectory of the rubber tappers in the Amazon uplands (Castro 2000).

Small-scale fisheries in the Amazon

The Amazon floodplain or *várzea* is a dynamic landscape encompassing a main river channel, forested natural levees bordering the channel, and permanent floodplain lakes and seasonally inundated grasslands in the transition between levees and lakes (McGrath et al. 2005). These areas are subject to marked seasonal flooding, with water levels varying about 12m every year. In the wet season, the whole ecosystem is flooded, while in the dry season only the main river, some connecting channels and lakes retain water (Junk 1997). The flood pulse affects temporal and spatial habitat and thus food availability for aquatic organisms, determining seasonal patterns of fish migration and fishing dynamics (Crampton 1999, Castro 2000).

Floodplains are amongst the most important aquatic systems in the Amazon for their high biodiversity and because of their economic importance for fisheries (Crampton 1999, Capobianco et al. 2001). Small-scale fishing in the floodplains is a significant component of local people's livelihoods, holding valuable cultural, economic, and biological meanings (Castro 2000). It has long been a traditional subsistence activity,

and became commercially important during the first rubber boom at the end of the 19th century and beginning of the 20th century. Small-scale fishing regained commercial importance after the 1960s when fishing was modernized (Castro 2000).

Development of commercial fisheries combined with their poor regulation led to fish overexploitation and numerous conflicts throughout the Amazon floodplain (Hartmann 1989, Barthem 1999, Castro and McGrath 2001). Conflicts over control of resources and territories incentivized the organization of local populations against outsiders and development of local management schemes to protect lake systems (Ruffino 2008). The Catholic Church was influential in the process of socio-political organization among rubber tappers and riverine peoples in the Amazon, aggregating dispersed households into communities and stimulating the rise of social movements (Castro 2000, Allegretti 2002, Pacheco 2010).

The Catholic Church also incentivized the rational use of natural resources, based on the idea that resources should be protected for future generations (Derickx 2007). Lake management schemes emerged between the 1960s and 1980s and are still in use today in many parts of the Amazon (Castro 2000, McGrath et al. 2005). These schemes consist in lake systems zoning that designate lakes by their functions, rotating them through time: no-take; for subsistence; or commercial fishing (when needed). Rules limiting fishing technology, effort etc. vary in terms of restrictions according to lake function. No fishing is allowed in no-take lakes, which work as sources-sinks to replenish fish stocks in the other lakes. Rules are decided, monitored and enforced by communities (Castro and McGrath 2001).

Since the 1990s, community-based fisheries management initiatives have been recognized by governmental authorities, shifting the technocratic model of fisheries management to co-management based on local knowledge and practices (Castro 2000, McGrath 2000, McGrath et al. 2005, 2008). Therefore, many informal fishing agreements have been formalized by theBrazilian federal government, thereby granting *de jure* rights both to rural communities and urban fishers (Castro and McGrath 2001).

Within small-scale fisheries, *pirarucu* management is recognized as a successful example of resource management in which shifting management authority from the central government to local people has resulted in better social and environmental outcomes. It also illustrates the shift from conventional single-species management to ecosystem-management in which multiple fisheries and aquatic organisms are conserved.

***Pirarucu* management**

The largest freshwater fish with scales in the world, *Arapaima* sp. (*pirarucu*), is endemic to the Amazon basin. This top-predator fish can weigh up to 200 kg and achieve 3 m in length. Like other floodplain fish in the Amazon, its life cycle is regulated by the flood pulse: *pirarucu* live in flooded forests, moving to lakes and other remaining water bodies when waters are low. These fish build nests and reproduce in flooded forests when the waters are rising (Castello 2008*b*). As an obligatory air-breathing fish, *pirarucu* needs to gulp air at regular intervals (every 5-15 min), making it easily harpooned by fishers, especially in the open waters of lakes.

The geographic distribution of *pirarucu*, and its taxonomic and conservation status are uncertain (Castello and Stewart 2010). The species is listed in Appendix II of the Convention of International Trade of Endangered Species (CITES) as “data

deficient," and it may be at risk of extinction if no protective measures are taken. The main threat to *pirarucu* is overfishing, as its meat is highly appreciated in the Amazon.

Pirarucu management provides an interesting model to examine how governance mechanisms influence the sustainable use and conservation of natural resources. Different from other fish species that are highly mobile, *pirarucu* is relatively sedentary, making it well suited for management in floodplain lakes (McGrath et al. 2005). Because of its large size and air-gulping habit, scientist and local fishersfrom the Mamirauá Sustainable Development Reserve (Amazonas state) were able to jointly develop a method to count *pirarucu* in lakes during the dry season, when lakes are isolated from the main river (Castello 2004). Experienced fishers can reliably count juvenile and adult *pirarucu* in lakes based on visual or acoustic identification of individuals at the moment of aerial breathing, and through detection of waves of individuals surfacing more or less simultaneously. This knowledge and skills are acquired from practical experience of artisanal fishing, in which fishers observe and listen to *pirarucu* surfacing and catch them immediately after with harpoons. Less experienced fishers can be trained and learn these count techniques. *Pirarucu* counts by fishers in closed lakes were strongly correlated with mark-recapture abundance estimates (Castello 2004).

The development of this cost-effective counting method, based on both scientific and local knowledge, changed conservation strategies of *pirarucu* in the Amazon (Castello et al. 2009), from ineffective regulation by the government to community-based management. Communities managing *pirarucu* have annual permits from the federal government agency (Brazilian Institute for the Environment and Renewable Natural Resources- IBAMA) to catch up to 30% of adults counted within managed lakes.

This fish quota is considered to be sustainable, with documented increased *pirarucu* size and abundance in managed lakes in Mamirauá Reserve as compared to unmanaged lakes (Castello et al. 2009, 2011).

Pirarucu management has improved fisher subsistence and incomes. As lake systems are the units of management, other fisheries and aquatic organisms are conserved. Management of *pirarucu* resulted in increased catch per unit of effort (conventional index of fish abundance) in a similar fashion as *pirarucu* abundance. After eight years of experimental management, “the combined population of juveniles and adults of *pirarucu* increased 9-fold; the adult population of *pirarucu* increased 23-fold; the harvest quotas increased 10-fold; the number of fishers participating in the management scheme more than doubled; per capita income of the involved fishers increased 8-fold” (2009:203). *Pirarucu* populations monitored in neighboring areas during this period did not increase, thus it is very likely that the observed increase resulted from the management scheme (Castello et al. 2009).

Integrating fishers in management strategies is important, because they provide valuable cultural, social and human capital (Castello et al. 2009). However, it is not clear under what conditions management is effective in conserving *pirarucu* populations. Castello et al. (2009) investigated that question by comparing the presence or absence of Ostrom’s (1990) design principles in the *pirarucu* fishery among communities of Mamirauá Reserve, before and after participatory management was implemented. These authors noticed that management improved local governance, especially when communities established and implemented the complete set of principles. First, communities were granted *de jure* rights to manage *pirarucu*. Second, *pirarucu* quotas

were adequate to permit the replenishment of stocks. And third, quotas varied with the number of *pirarucu* in lakes, such that the better the management, the greater the quotas. Thus, effective management requires strong commitment by communities as well as authorities in monitoring and enforcing the rules.

The *pirarucu* management experience in Mamirauá provides lessons for other small-scale fisheries around the world.They can be improved if they i) apply fisher's knowledge and skills in resource management and monitoring; ii) integrate scientific and local knowledge systems; iii) collaborate with fishers who are interested and capable of conserving resources; and iv) implement management even under conditions of uncertainty (Castello et al. 2009).

Problem Statement

The institutionalization of ERs in 1990 represented a landmark in the decentralization of environmental policies in Brazil, by which powers were shifted from the national government to local communities. These innovative protected areas were conceived by grassroots organizations as a model of territorial self-management supervised by the federal government. However, the model was reconfigured to co-management after ERs were included in the national system of protected areas (SNUC) in 2000. This change brought about new arrangements in reserve governance, restructuring decision-making power among communities, the government, and other stakeholders, potentially disempowering communities and grassroots organizations.

Co-management of federal ERs involves the sharing of rights and responsibilities between the federal government (Chico Mendes Institute for Biodiversity Conservation-ICMBio) and communities. ICMBio has a critical role in providing communities with authority and legal rights, and in facilitating co-management so that communities can

handle responsibilities related to resource conservation. Sharing management powers poses challenges to the integration of traditional and scientific knowledge, and has implications for natural resource conservation. However, no study has investigated in detail whether powers concerning management are in fact shared between ICMBio and communities in relation to natural resources.

Communities play a key role in co-management of natural resources, but their success in controlling resource use and avoiding resource overexploitation varies. In some areas, difficulties to enforce rule compliance and exclude outsiders lead to *quasi* open access regimes. In others, communities are able to design and enforce effective mechanisms to control resource use and avoid free riding, with positive environmental outcomes. Understanding the social-ecological conditions under which communities are able to manage resources sustainably is thus key for adequate conservation and development strategies in the co-management of ERs.

Social capital is pivotal for the collective management of natural resources by communities. It consists of the norms and networks that characterize social relations among actors, leading to general understanding on obligations and expectations, thus facilitating collective action. Thus, in-depth examination of communities' social capital contributes to a better comprehension of the reasons people invest in the collective good in spite of their own individual benefit. Nevertheless, this aspect of natural resource management in Amazon ERs is relatively understudied.

In this dissertation, I investigate the following aspects of co-management of natural resources in Amazon ERs: 1) the sharing of rights between ICMBio and communities in relation to governance of natural resources; and 2) the role of social

capital in fostering collective action for resource management and the broader social-ecological conditions that lead to sustainable co-management of resources; in particular, I focus on community and governance characteristics and implementation of Agrawal's (2003) compilation of management principles in order to evaluate their importance for the sustainability of *pirarucu* populations.

Research Questions

In light of the theoretical frameworkand problem statement outlined above, the main objectives of this research were to 1) examine the extent that government shares rights to communities in natural resource governance, and its implications for rule compliance; 2) investigate the role of social capital in facilitating collective action for resource management, and the underlying motivations for people's engagement on it; and 3) investigate the social-ecological conditions under which natural resources, featuring *pirarucu,* are managed sustainably by government and communities in ERs.

Therefore, I pose the following research questions addressing distinct perspectives of natural resource co-management in Brazilian Amazon ERs:

1. To what extent do co-management regimes in Brazilian Amazon extractive reserves permit sharing of authority over natural resources governance with communities, and to what extent do they affect the engagement of community members with rule compliance?
2. When authority over natural resources governance is shared to communities in the co-management of extractive reserves, such as in *pirarucu* management, do management systems with higher social capital present higher engagement in collective action?
3. Considering the co-management of *pirarucu*, what are the social-ecological conditions leading to sustainable resource management in Brazilian Amazon extractive reserves?

The first question investigates the extent to which the federal government engages in co-management of ERs by sharing authority over management of resources

with local communities. It is important to understand what powers are in fact shared with communities, as the environmental governance literature points out numerous cases of power recentralization by governments worldwide. In the case of ERs, this is especially important as their institutionalization resulted from local people's empowerment and their management involves jointly defined management plans. In addition, I examine the relationship between community participation in rule making and rule compliance. I hypothesize that co-management regimes involve little sharing of authority over resource governance from ICMBio to communities (H1); and yet that communities are more engaged in rule enforcement and compliance when they participate in management decisions (H2). Then, I explore different dimensions of natural resource management when rights are shared between government and communities, using the management of *pirarucu* as case study. In the second question, I investigate the role of social capital in facilitating collective action. I hypothesize that the greater the social capital, the greater the participation in *pirarucu* management (H3). Finally, the third question explores multiple characteristics of resource systems, actors, governance systems, and interactions among them that affect the sustainability of resource management.

Study Area

I conducted field work in the Lower Juruá Extractive Reserve (LJER; Figure 1-1), a federal protected area covering 187,982 hectares of non-flooded and flooded forests in the central-west Brazilian Amazon. The LJER is located in Juruá and Uarini municipalities in Amazonas state, nearly 1,000 km by river from the state capital, Manaus. The reserve borders the Juruá town perimeter, in which live nearly 9,000

people. The main environmental threats to the area are overfishing, commercial hunting and illegal timber exploitation.

In the LJER, there are 643 residents belonging to 132 families, with a very low population density (0.33 person/km^2). In addition, 105 former residents living in Juruá town are authorized to use resources in the ER, due to kinship and production relations with local communities. Residents are former rubber tappers from families living in the area for many generations. Their main activities are small-scale agriculture, fishing, forest extractivism, small animal husbandry and small-scale cattle ranching. These families live in isolated households or groups of households in nucleated communities, in a total of 15 settlements. From the 1970s to the 1990s, the Catholic Church was vital to the political organization of rubber tappers and the establishment of communities in the Juruá region. Fishery conflicts with outsiders were the main reason for creating the LJER in 2001, besides claims to land rights and access to public policies.

The reserve is managed by ICMBio and local residents, represented by the Rural Workers Association of Juruá (ASTRUJ) created in 1998. The LJER's Deliberative Council and management plan were both established in 2009. At the time of field work (2012-2013), the Council was composed of 17 institutional representatives: eight from resident communities, seven from governmental agencies and two from non-governmental organizations. As in most ERs, the process of territorial consolidation through land concessions in LJER was not completed. The implementation of LJER is funded by the Amazon Protected Areas Program (ARPA)[2]. In 2012,there were four

[2] The ARPA Program is coordinated by the Ministry of Environment in Brazil, with technical and financial support of national (BNDES, Natura and O Boticário) and international donors (WWF, GEF, KfW). Financial resources are for reserve infrastructure, monitoring, and establishment of reserve's council and management plan.

ICMBio employees managing the reserve. [3] ICMBio's office is located in Tefé municipality[4] and its employees use ASTRUJ's office to work while in Juruá town.

Pirarucu management started in the LJER by the initiative of ASTRUJ and ICMBio, with voluntary participation of local communities. Communities have autonomy to decide who participates in management activities, how benefits are distributed, and to establish harvesting rules, as well as monitoring and sanctioning mechanisms. In 2006, local fishers were trained on the *pirarucu* count method by fishers and technicians from the Mamirauá Institute. Since then, *pirarucu* have been counted using this method in six management systems of the LJER, involving a set of lakes and connecting channels, under ASTRUJ and ICMBio supervision. Counts inform management quotas for the following year. Since 2006, the number of community beneficiaries has increased, as well as the overall *pirarucu* abundance in management systems (ASTRUJ, unpublished data). However, in two of the six cases the number of *pirarucu* has decreased.

The LJER provides an interesting case for the study of co-management of natural resources. The LJER has a history of local organization and common property institutions; this history features innovations in fisheries management which furthermore combine local and scientific knowledge; there has been a constructive and harmonious relationship between the federal government (ICMBio) and the local community association (ASTRUJ); their engagement has focused on *pirarucu* management with

[3] Although I was an ICMBio employee at the time of field work, I was not a member of the LJER team. Previously, I had worked as manager of the Middle Juruá Extractive Reserve, another federal protected in the Juruá river (in Carauari, Amazonas state) located upriver (distant 12 hours in a fast boat from the LJER). I took a leave of absence from ICMBio to conduct the PhD, so my role in the LJER was as a researcher. For these reasons, I consider that being an ICMBio employee did not hinder my ability to interact with communities; rather, my professional experience improved my understanding of the co-management arrangements involving government and communities.

[4] Distant 12 hours in a fast boat from the Juruá municipality.

substantial community participation; and community management success depends substantially on social capital.

Organization of the Dissertation

This dissertation is organized in five chapters. The introductory chapter has laid out the theoretical framework, problem statement and research questions guiding the research. Research methods are described in detail in each of the three core chapters. Chapter 2 investigates the share of rights between government and communities and the implication of community participation in rule design for community member compliance with rules controlling the use of natural resources. In the following chapters, I use *pirarucu* management as a focus in order to understand people's motivations for participating in collective action and how community design of management institutions may yield effective outcomes for sustainable fisheries when they have rights to organize. In Chapter 3, I explore the underlying norms and networks (social capital) operating in communities that make them more disposed to engage in collective action. In Chapter 4, I conduct a broad study of *pirarucu* management systems, examining the multiple factors of social-ecological systems affecting management sustainability. The concluding chapter summarizes key findings and limitations of the research, and points out its significance to scholarship on ERs, common property, social capital, and fisheries co-management, and their implications for policy making, serving both government and grassroots organizations.

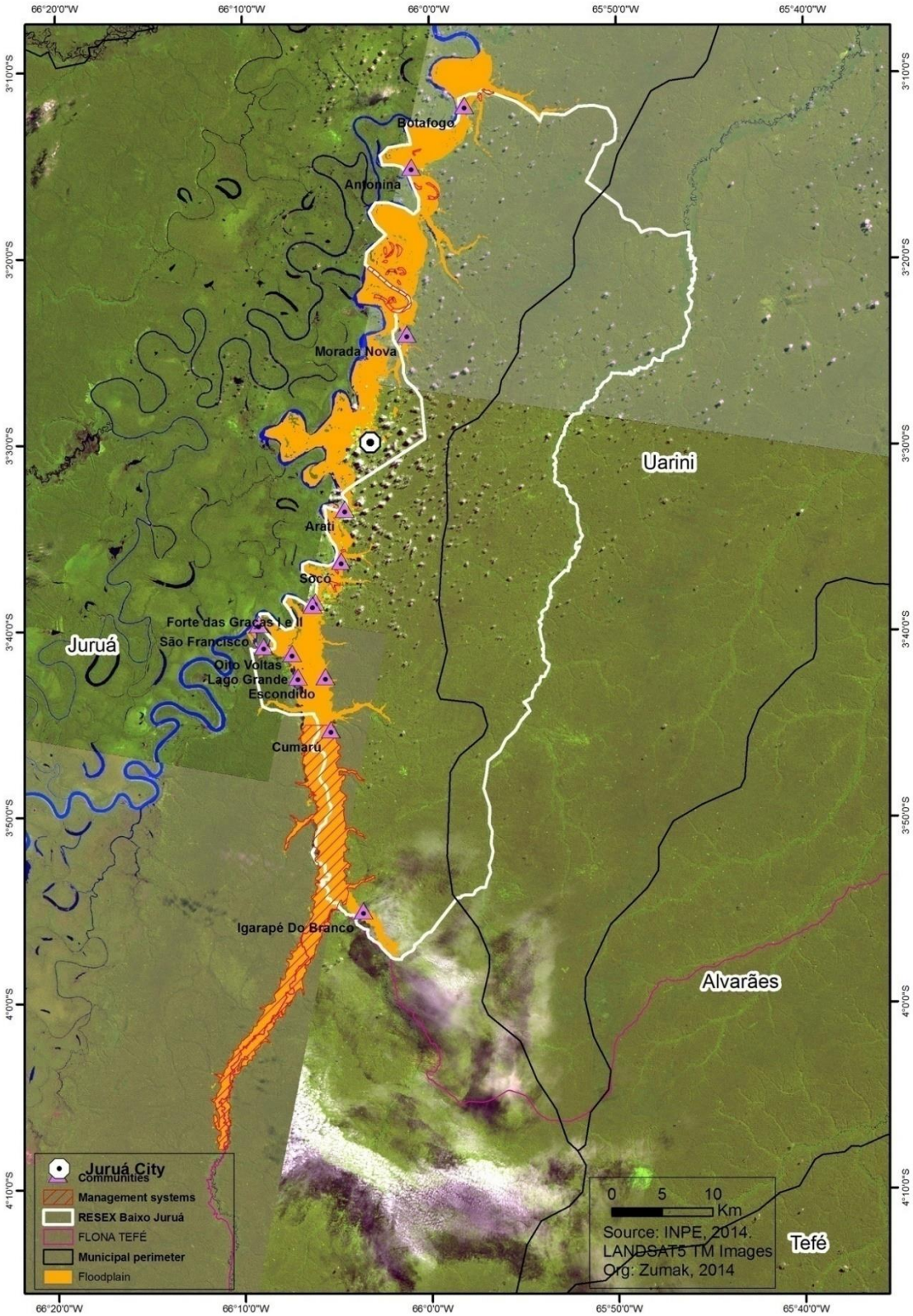

Figure 1-1. Map of the LJER showing communities and flooded forests.

CHAPTER 2
DECENTRALIZATION OF PROPERTY RIGHTS OVER NATURAL RESOURCES TO COMMUNITIES

Introductory Remarks

In the past decades, environmental policies worldwide have increasingly recognized the importance of communities and local knowledge in natural resource management and the need to bring decision-making closer to the people (Child et al. 1997, Murphree 2000, Jentoft 2003, Borrini-Feyerabend et al. 2004, Child 2004, Ribot 2004). Decentralization of authority to communities has happened with increased dissatisfaction with state and private property regimes, which usually have proven to be inefficient, as these permit or foster inequalities and fail to effectively control access to natural resources (Acheson 2006).

Due to the limitations of unitary approaches to resource management, multi-stakeholder approaches have gained more attention, such as co-management. Within different property system arrangements, co-management is potentially better than pure state and communal property regimes. Analytically, co-management consists of a hierarchy of vertical arrangements between the extremes of government centralized management, and community self-management (Pomeroy and Berkes 1997). Governmental authority (law enforcement) works better at larger scales, but at smaller scales the ability of the state to understand process and influence decisions and behaviors is limited (Acheson 2006). As a result, government needs to partner with communities and local institutions in natural resource management rather than only legal enforcement. On the other hand, co-management brings government to communities, so theoretically it corrects for problems associated with the small-scale of community-based initiatives (Jentoft and McCay 2003), such as the enforcement

arbitration needed to support communities in protecting resources against outsiders (Agrawal and Gibson 1999). According to the subsidiarity principle, “the relevant level for decisions is the most-local possible level at which decision making will not result in negative effects at higher social or political administrative levels” (Ribot 2004:9).

The question then becomes one of what powers should remain with the state and which should be transferred to communities. Government is critical in co-management for providing authority and legal rights to communities (Pomeroy and Berkes 1997). Sharing of power and authority varies along a continuum from weak to strong co-management, from situations in which communities are only consulted by the government in policy making, to ones in which communities themselves design, implement and enforce laws and regulations with government assistance (Borrini-Feyerabend 1996, Pomeroy and Berkes 1997). True co-management is an arrangement which empowers users to set management objectives on equal terms with the government (Hara and Nielsen 2003).

However, there are numerous cases worldwide of recentralization of authority by central governments (Ribot et al. 2006). Evidence from community forest management in South Asia shows that delegating only operational rights to access and use forests “does not produce much change in either the condition of vegetation or the relationships between state and community actors” (Agrawal and Ostrom 2001:508). These authors argue that decentralization has minimal impact when local users do not have rights at the collective and constitutional levels, which determine their control over rule design, management and enforcement.

Extractive reserves (ERs) in Brazil provide an interesting case to examine protected areas co-management and the extent to which it decentralizes authority over natural resources to communities. ERs were idealized in the 1980s by grassroots organizations as self-management territories granted by the State to rubber tappers, inspired by agrarian land reform and indigenous lands (Allegretti 1990). In these areas, local peoples would protect resources against deforestation that threatened their extractive livelihoods, as well as gain land rights and become visible actors to socioeconomic policies. In 1990, the first ERs were created in the Brazilian Amazon, and since then, ERs became widespread throughout Brazilian territory (Gomes 2009). However, despite the achievements of grassroots organizations, the incorporation of ERs into the National System of Conservation Units (SNUC) in 2000 potentially disempowered extractivist peoples (Cunha 2010, Esterci and Schweickardt 2010, Pacheco 2010).

Institutionalization of ERs as protected areas led this model to shift to co-management with the government, bringing new governance arrangements such as collaborative management planning and the Deliberative Council. The management plan consists of a technical document combining scientific and local knowledge that regulates use and conservation of natural resources, as in other protected areas. It also explicitly sets forth the respective roles of government, communities, their representative association, and the Deliberative Council in monitoring, sanctioning, and conflict resolution. Critics point out the limited participation of local residents in developing regulations for resource use, resulting in only partial acceptance and

compliance with local rules (Ehringhaus 2005) and reduced importance of local knowledge (Cunha 2010, Esterci and Schweickardt 2010).

Deliberative Councils are chaired by the government agency managing the reserve represented by the head of the protected area, and are composed by representatives of communities, and governmental and non-governmental organizations. Hence, communities participate at the same decision-making level as other actors (Esterci and Schweickardt 2010) despite their greater direct connection to the resources. As a co-management arrangement involving government and communities, Deliberative Councils in ERs provide a focus for evaluation of questions related to the sharing of rights and local participation in resource governance.

In this chapter, I address community rights and participation in decision making in co-management of natural resources in ERs. The research question guiding this study was: *To what extent do co-management regimes in Brazilian Amazon extractive reserves permit sharing of authority over natural resources governance with communities, and to what extent do they affect the engagement of community members with rule compliance?* I hypothesized that co-management regimes involve little sharing of authority over resource governance from ICMBio to communities (H1); and yet that communities are more engaged in rule enforcement and compliance when they participate in management decisions (H2).

Study Area

I conducted this study in the Lower Juruá Extractive Reserve (LJER) in the central-west Brazilian Amazon (Juruá, Amazonas state). This federal protected area,

managed by ICMBio (Chico Mendes Institute for Biodiversity Conservation)[1], was created in 2001 in response to demands by extractivist communities represented by the Rural Workers Association of Juruá (ASTRUJ). Public lands have not been formally granted to extractivist families yet, although peoples' rights to land have been recognized since the LJER's creation. In ERs, the State concedes land to extractivist families through land concession contracts known as CCDRU (*Contratos de Concessão de Direito Real de Uso*). A broader contract is signed between the State and residents' representative association; then, the association signs specific contracts with beneficiary families conceding collective usufruct rights over ER territory.

The LJER is still highly conserved due to its historical use for extractivism, and the large distance from Amazonian agricultural frontiers. There are no roads to Juruá town, which is 994 km by river from the nearest state capital (Manaus). The reserve covers 187,982 hectares of Amazon forest, including upland forests, flooded forests and aquatic systems.

The LJER exhibits very low population densities (0.33 person/km^2). In 2009, there were only 625 residents, who belonged to 132 families living in 15 communities (ICMBio 2009). Families are increasingly migrating to the nearest town, Juruá, searching for secondary education for their children, as this is lacking in most rural communities. However, they are still considered beneficiaries of LJER, due to continued livelihoods or family ties in reserve communities. Most people of the LJER are descended from rubber tappers, from families who have lived in the area for

[1] Before ICMBio's creation in 2007, federal protected areas in Brazil were created and managed by IBAMA (Brazilian Institute for the Environment and Renewable Natural Resources). Then, ICMBio assumed this role and IBAMA became responsible only for environmental monitoring and licensing within and outside federal protected areas.

generations. Livelihoods derive mostly from small-scale agriculture, fishing, forest extractivism, small animal husbandry and small-scale cattle ranching.

The LJER's Deliberative Council was created in 2009. By April 2013, it was composed of 17 seats, of which eight were occupied by representatives of communities (Botafogo, Antonina, Socó, Forte das Graças 1, Cumaru, Igarapé do Branco/Escondido) and their organizations (ASTRUJ and Protagonist Youth Group[2]); seven by government organizations (ICMBio, IBAMA, National Institute for Colonization and Agrarian Reform – INCRA, National Institute of Amazon Research - INPA, Institute of Agricultural Development and Sustainable Forestry of Amazonas State - IDAM, Military Police of Juruá and City Hall of Juruá), and two private entities (Catholic Church of Tefé and Z-21 Fishing Organization).

Compared to other federal protected areas in the Brazilian Amazon, the LJER is relatively well structured in terms of implementation status, and its financial and human resources. The reserve's management plan was developed in 2009, and contains rules for resource governance (the 'use plan') as designed collectively by communities in meetings coordinated by ICMBio. The Deliberative Council was installed in 2009 and since then it has usually met twice a year. The reserve is supported by the Amazon Protected Areas (ARPA) Program. At the time of data collection, there were three environmental analysts on the team[3], including the LJER's head. All team members lived and worked in Tefé, where ICMBio has an office for all federal protected area managers in the region. They typically went to Juruá every month or two, usually

[2]Youth group formed by young leaders (12 to 18 years old) of LJER.

[3] A fourth one left the reserve at the beginning of data collection, in June 2012.

spending 10 to 15 days there each time, working at ASTRUJ's office in Juruá town[4] and going out to communities. The management team was in sufficient number so that they could take turns going to Juruá more often; thus ICMBio had frequent representation in the region. ASTRUJ had two permanent board directors who lived in town and used the office more frequently. Other members passed by ASTRUJ's office when they went to town for personal reasons or whenever there were meetings.

Methods

In order to examine the sharing of authority over resource management in co-management of the LJER, I investigated the extent that communities could organize and make decisions concerning natural resource regulation, through an analysis of community rights established in the reserve's management plan, and rights exercised on the ground and in the Deliberative Council.

I used Schlager and Ostrom's (1992) classification ofproperty rights (access and withdrawal, management, exclusion and alienation) as a framework to determine the level of sharing of authority over resource management. Access rights authorize users "to enter a defined physical property"; withdrawal rights, "to obtain the 'products' of a resource"; management rights, "to regulate internal use patterns and transform the resource by making improvements"; exclusion rights, "to determine who will have an access right, and how that right may be transferred"; and alienation rights, "to sell or lease either or both of the above collective-choice rights" (Schlager and Ostrom 1992:250-251). Thus, access and withdrawal rights categorize authorized users, who have little authority as they only participate in operational rules but cannot modify them.

[4] ICMBio does not have an office in Juruá town.

The others (management, exclusion, alienation) are collective-choice rights that provide users with authority to devise future operational rights.

From the management plan, I collected secondary data on operational and collective-choice rules for various natural resources (land, forest, timber, non-timber forest products, game animals, fish, and turtles). Operational rules designated who could use resources and under what conditions (operational rights), while collective-choice rules determined who could make decisions regarding resource use (collective-choice rights; Schlager and Ostrom 1992). I examined the degree to which collective-choice rights were shared with communities through the descriptive quantitative method, classifying cases as: no rights (situations in which only government could make decisions); partial rights (sharing of decision-making authority between government and communities); or full rights (exclusive decision-making authority vested in communities). Using these measures, I was able to analyze the extent to which property rights (access, withdrawal, management, exclusion and alienation) were decentralized to communities in the LJER.

On the ground, communities could have varied arrangements for regulating resources, presenting greater or lesser incentives or barriers to organize and enforce rules. I therefore characterized and compared operational rules in play at communities for various types of natural resources (land, forest, timber, non-timber forest products, game animals, fish, and turtles). I then analyzed community authority to make and modify rules and whether that authority was extended to enforcing rule compliance.

I conducted focus groups with key community informants, identified through a snowball sampling technique (Bernard 2011). I focus on six communities in the LJER:

Botafogo, Antonina, Socó, Forte das Graças 1 (FG1), Cumaru, and Igarapé do Branco (Ig. Branco). For informants in each, I asked about the following issues: 1) whether there were rules regulating natural resource use (operational rules), 2) who created and who could modify those rules (rule making), and 3) whether these rules were in fact followed in practice (rule compliance). The three questions were asked for each of the various different natural resources noted above. Research instruments are presented in Appendix A.

I used quantitative descriptive analysis to characterize and compare communities in their operational rules, rule making and compliance. Then, I characterized whether rules for different resources were created or could be modified only by government (no community rights), communities and government (partial community rights), or communities alone (full community rights). Finally, I compared overall authority in rule making (no, partial or full rights) for each of the natural resources in terms of degree of rule compliance (no, partial, or full), in order to understand whether community authority was related to a higher engagement in following regulations.

In addition, I analyzed the recorded minutes from meetings of the Deliberative Council from its creation in March 2009 to April 2013, extracting relevant information regarding sharing of decision making over natural resources, focusing particularly on collective-choice rights (management and exclusion). I complemented the secondary data with primary data collection through participant observation of meetings held in Juruá in May and December of 2012, and April 2013, for which I examined community authority in decision-making processes.

Results

Sharing of Rights in Management Planning

The LJER management plan includes 35 rules for regulating use of various natural resources. The plan was constructed collectively by community representatives in meetings coordinated by ICMBio (Table 2-1). Among these rules, there are 20 operational rules which indicate who, when, where, how, how many and for what purpose natural resources could be extracted. In addition, there are 15 collective-choice rules which establish who had the authority to determine who could use natural resources. Thus, the operational rules define operational rights (to use and withdrawal resources), while collective-choice rules determined collective-choice rights (decision making over natural resource use). For example, the LJER's management plan says that resident families can clear one hectare of primary forest per year and up to two hectares of secondary forest per year for crops, either on flooded or upland forest (operational rule). However, if they needed to open more than that (between one and two hectares in primary forest or between two and three hectares in secondary forest), they would have to ask the community's permission. The association would then request ICMBio authorization (collective-choice rule).

A breakdown of the rules by the manner of their creation gives an idea of the extent of co-management in the LJER. Among the 15 collective-choice rights established by the management plan, communities participated in 11, ICMBio or IBAMA in seven, ASTRUJ in two, and the Deliberative Council in two (Table 2-2). Collective-choice rules granted no rights to communities on decision making regarding wildlife management and breeding, ornamental fishing, commercial logging and large-scale NTFP exploitation. Partial rights were granted in the cases of acceptance of new

residents, former resident crops, clearing of primary or secondary forests, total area cleared, and fisheries management. Full decision making rights granted to communities concerned the location of resident crops; hunting and harvesting of NTFPs in other communities' areas; the amount of turtles to be captured for subsistence; fishing by visitors; and transportation of fish for subsistence consumption to Juruá town (Table 2-3).

In terms of Schlager and Ostrom's (1992) framework, LJER communities are granted full access rights, but only partial withdrawal, management and exclusion rights over resources (Table 2-4). Although they have full withdrawal rights for subsistence, some decisions regarding resource use are shared with other actors. For example, final decisions over the acceptance of new residents and maintenance of former resident crops in the reserve is made by the Deliberative Council, and final authority over whether residents can expand their cropfield's size is held by ICMBio.

Communities have the authority to withdraw some resources for small-scale commercialization. This includes surplus agricultural produce; wooden goods such as canoes, paddles, and furniture; NTFPs; and fish. Other activities require technical studies or management plans to be approved by ICMBio or IBAMA. These include fisheries management, ornamental fishing, captive wildlife breeding (for subsistence or commercial purposes), logging, and small-scale commercialization of fallen (due to natural processes) or felled wood (from opening of cropfields).

Amazon river turtles[5] can be consumed in small amounts decided by each community, but they cannot be sold, as these are a threatened species protected by

[5]Consisting of three species locally known as *tartaruga-da-Amazônia* (*Podocnemis expansa*), *tracajá* (*Podocnemis unifilis*) and *iaçá* (*Podocnemis sextuberculata*).

law. Although communities have protected and monitored turtle populations on spawning beaches for many years, they are not allowed to manage turtles for commercialization. Selling game meat is also prohibited by law. Establishing zoning areas for fishing, for example, is a management right exercised by communities with little interference from ICMBio. However, establishing reserve zoning is a shared management decision, as both communities and ICMBio actively participate in its definition.

Finally, communities have partial exclusion rights as they share with ICMBio decisions over criteria to identify who is authorized to use resources in LJER, defined as beneficiaries. Beneficiaries include residents, and specify conditions for other authorized users (e.g. former residents can be considered as beneficiaries if they keep strong social ties and production in communities).

Sharing of Rights on the Ground

Among communities, all of the natural resources have rules limiting who, what, where, when, how, how many, and for what purpose these could be used (Table 2-6). The highest number of rule categories pertained to fishing (12) and turtle harvesting (11), followed by forest clearing (8) and timber extraction (8), while the smaller numbers of rules applied to land occupation (6), NTFP extraction (6) and hunting (5).

All communities had rules for all types of natural resource use (Table 2-6). For land occupation, rules frequently specified who was authorized to live in or use natural resources in the area, generally imposing some restrictions to new residents or users. For example, to be admitted as a community resident with voting rights, a person has to be respectful and obey local rules for one year. Rules for regulating forest clearing most often concerned forest conversion to agriculture (who was authorized, plot size and

opening of pastures) and location (not in primary forest or along river margins, which is prohibited by law). Most rules for regulating timber use among communities defined who could extract it, and impeded timber transport to town and sale, which corresponds to the law in the absence of a timber management plan. Regarding NTFPs, rules specified who could extract forest products and the conditions for their sustainable use (avoid felling of palms; only extract ripe products; etc.). Fishing rules most often restricted who was authorized to fish, in what amount, the fishing materials and techniques allowed, and the permitted types of fishing boats. Hunting rules frequently specified who could hunt, and internalized legal prohibitions for game meat transport to town and sale. Most rules regulating turtle harvesting defined who could harvest eggs or animals for subsistence, of which species, and prohibited the use of gillnets near spawn beaches, as well as the sale or transport to town of eggs and animals, in accordance with the law.

Among the six communities studied, of the total 56 types of rules catalogued for regulating natural resource use, between 32 and 41 were adopted by a given community (Table 2-6). Antonina and Botafogo each had 41 categories of rules, followed by FG1 with 39 rules. The remaining three communities reported 32 rules each. Land occupation had more rules in Antonina and fewer in Botafogo; forest clearance was more regulated in Antonina and less in Socó, FG1 and Cumaru; timber extraction had more rules in FG1 and less in Botafogo; NTFPs had a higher number of rules in Cumaru and fewer in FG1; fisheries had more rules in FG1 and less in Ig. Branco; hunting was more regulated in Socó and less in Antonina, Botafogo, Cumaru and Ig. Branco; and turtle harvesting presented more rules in Socó and less in Cumaru.

A review of the detailed rules for the regulation of specific natural resources permits an evaluation of sharing of authority with communities in the JLER. The total sum of rules for all types of natural resources across all communities was 217. Of that total, more than a half, or 112 (51.6%) were reported as created collectively with other communities for the management plan coordinated by ICMBio. In addition, 72 (33.2%) were created by the community, and 33 (15.2%) were pre-established governmental laws or regulations (Table 2-7). Rules made for the management plan (communities and ICMBio) were more frequent for controlling forest clearance. For most resource uses (land occupation, NTFP extraction, fishing and turtle harvesting), the number of rules made by communities, or communities with the ICMBio, were similar. A high number of government laws and regulations were found for controlling timber exploitation and turtle harvesting, with an intermediate frequency of occurrence for hunting (Table 2-7).

Regarding rule modification, communities said most rules could be changed for all of the kinds of natural resources (Table 2-8): 100% for NTFP extraction, 93% for forest clearing; 89% for land occupation, 86% for fishing, 69% for turtle harvesting, 62% for hunting, and 55% for timber extraction. When asked who could change rules, informants reported that communities had authority for most rules for turtle harvesting (52%) and NTFP extraction (50%). Communities and ICMBio were most cited as the authority for forest clearance (64%), land occupation (56%), hunting (54%), and fishing (49%); and the Deliberative Council was the main forum for changing rules regarding timber extraction (64%). Overall, for the power to change rules, 28% could be modified by communities alone, 43% by communities and ICMBio, and 29% by the government only.

Among the 217 responses to rule making, it is important to consider those that communities report on the level of rule compliance (196 responses). I found that 41% of rules indicated as created by communities had no or partial compliance, which implies that 59% had full compliance. Of the rules created collectively by communities under ICMBio coordination (management plan), 17% had no or partial compliance, while 83% had full compliance. And of rules that were created only by government, 66% had no or partial compliance, and 34% had full compliance (Table 2-9). These findings confirm the importance of community involvement in rule-making to promote greater compliance.

Sharing of Rights on the Deliberative Council

Collective-choice rights assigned to the Deliberative Council by the management plan referred only to access and withdrawal rights over land (acceptance of new residents and former resident crops). However, throughout Council meetings, there were frequent discussions on other topics, notably about resource use and management rights over timber, NTFPs, and fish, and about exclusion rights (land concessions and definition of ER beneficiaries). I therefore offer a discussion of sharing of rights on the Deliberative Council that reflects not only assigned rights but also actual discussions on other rules.

During the time period studied, there were only two requests from families to come to live in the LJER. Both had been previously approved by the respective recipient communities, and both were unanimously approved by the Deliberative Council. Regarding crops of former residents, this topic was not discussed in council meetings, although many of them had agricultural plots in the LJER.

Discussions on timber exploitation were held in the last three council meetings and aimed to overcome legal-administrative barriers over use of fallen or felled wood,

logging and timber transport from the LJER to town. Authorization to use fallen or felled wood for commercial purposes depends on a technical study signed by a forestry technician indicating the location, volume and species identification of the wood in question. Communities can use wood to produce wood crafts, which does not require authorization. But logging requires a community-based Sustainable Forest Management Plan (SFMP) conducted by forestry specialists, following scientific methods for inventorying forest management areas (including data on species identification, mapping of locations for felling, quantification of volumes, etc.). ICMBio approves SFMPs in federal conservation units only after all legal-administrative procedures are performed, including land regularization through CCDRU. Transporting timber outside the LJER for subsistence purposes, e.g. to build a house or boat in town, requires a document attesting the origin of extraction[6] (*Documento de Origem Florestal – DOF*), which can only be emitted by IBAMA for areas with SFMPs. If people are caught in environmental inspections transporting timber without possessing DOF authorization, they can be fined and/or have their timber and materials (chainsaw, boat etc.) seized. While I was in Juruá, one family from Botafogo community was caught by inspectors while transporting timber to build a house in town, and had their production seized. As with other LJER residents, they needed to build a house to live temporarily in town while their children were studying, as there was only an elementary school in Botafogo. ICMBio managers intervened and the family was not fined; however they had economic losses of sawing and transporting wood. According to one ASTRUJ leader,

> Residents have the right to use timber for building structures within the reserve, but as we do not have wood processing structure (sawmill) in the

[6]Besides origin, DOF also requires information on species, product type, quantity and value of the cargo, and detailed transportation route.

> communities, we have to take it to town. However, if IBAMA inspectors catch it on the river, they will seize it. This transport has been held irregularly, and those that do not do it feel wronged. At this moment, ASTRUJ faces this difficulty, as we cannot transport timber to process it in town to reconstruct the floating house of Planeta Complex management area. We have already discussed this for some time; in every council meeting communities bring this issue seeking a solution. I hope we have progress on this matter.

This problem was previously discussed in the First Regional Meeting of Councils of the Middle and Upper Solimões River. The regional meeting brought together council representatives from federal protected areas in central Amazonas state, including the LJER, in April 2012. ICMBio's president and the ICMBio director of socioenvironmental matters were also present. This meeting also discussed challenges for land regularization, community-based management, environmental education, social organization and participatory management in federal protected areas. Results from the regional meeting were then reported in the LJER Deliberative Council's meeting in the following month. The focus on these topics made evident the need to overcome barriers for timber exploitation in ERs, so ICMBio's central office committed to organize a seminar on community-based timber management to discuss challenges and alternatives. However, this meeting had not occurred before the end of data collection in May 2013.

At the LJER Deliberative Council meetings, participants looked for solutions in different ways. INPA's representative was responsible for gathering information on licensing of portable sawmills by the state environmental agency (IPAAM), which would allow for wood processing on site in communities. However, this would not solve the problem of building a house in town. He also would try to gain INPA's support in providing communities with technical assistance on working with fallen wood, such as

training on inlay design (*marchetaria*). The Deliberative Council also forwarded a letter to ICMBio's central office arguing for more rights for community-based timber management. ICMBio's head consulted the ICMBio Prosecutor's Office (legal counsel), which informed the LJER Deliberative Council that all timber management activities (including the use of fallen or felled wood) required DOF authorization. He suggested that ASTRUJ ask IBAMA's permission based on ICMBio's official letter stating timber transport to town was for local use only. However, this did not work as DOF required a timber management plan, which in turn depended upon land regularization.

Communities also desired a timber management plan as an alternative income source and to reduce illegal logging in Juruá town, which was common in 2012-2013.[7] Studies for a multiple use forest management plan were conducted in the LJER in 2006 by a forestry specialist hired by IBAMA. Two areas of the LJER were mapped and inventoried for both timber and NTFPs, but the process did not forward due to unresolved questions of land tenure. After many years, inventories got old (as timber might have been extracted from these areas) and were not valid anymore.

In the case of NTFPs, debates were held in four out of eight meetings of the LJER Deliberative Council, regarding the *andiroba* management plan and oil production. Juruá town received an oil plant unit in 2010 as part of a project approved by IDAM with the Ministry of National Integration some years before. However, the plant was not working because it lacked infrastructure and a filter press. IDAM therefore sought to procure additional funding to buy the needed equipment. The Deliberative Council decided to write official letters. One went to IDAM's president arguing for more

[7]Throughout this study, I often saw dozens of wood boards on the river margins of Juruá town, most from illegal logging.

information on acquisition of filter equipment; another was sent to the president of the Secretary of Production of Amazonas State (SEPROR) for support in implementing the oil plant; and a third went to the local government in Juruá town requesting donation of the property where the oil plant was installed to ICMBio, so that they could make all necessary reforms to the building.

In parallel, ICMBio managers hired a forestry team to provide technical assistance on oil plant production, as part of a two-year project funded by the Brazilian Forest Service (SFB), in partnership with ASTRUJ. This team went to communities to identify their interest in participation in *andiroba* seed collection and oil production. They also trained community members on forest management practices and inventoried *andiroba* management areas. In addition, they would still take community representatives to other production areas for knowledge exchange with related cooperatives, and elaborate studies on the plant oil production chain and business plan.

Fishing was discussed in three meetings, generally referring to management of *pirarucu* and other species such as *tambaqui*, *pirapitinga* and *pacu*. Results of fishery management were often presented and discussed, in terms of their ecological, economic, social, and organizational aspects. Problems reported most often referred to lake invasions and community monitoring, management quotas, fish storage structures, and commercialization. Among these, debates over setting fishing quotas gained the most attention in terms of people's participation in decision making.

IBAMA explained that the method for defining management quotas had been changed. Before 2012, it calculated 30% of adult stocks from counts of the previous

year. From that time on, IBAMA changed this calculation to require a ratio of adult to juvenile stock as a 1:2 proportion. As explained by the IBAMA council representative:

> IBAMA has noticed that the proportion of young and adults has decreased (based on IDS Mamirauá[8] database), while a population in equilibrium should have more young than adults. Analyses of some reports and scientific papers showed there were seven young to one adult *pirarucu* and some years later, the proportion became two young to one adult. So, we decided to use a correction factor to come up with the (management) quota.

For example, if there were 100 adults and 150 young *pirarucu* in the population counted, the adult stock considered was adjusted to consist of 75 adults, so the ratio would be 30% of it (25 instead of 33 adults). However, this change was criticized by fishery specialists, managers, and fishers: it had no scientific basis and was not discussed with researchers, fishers and their organizations. It came from a bureaucrat's head and was imposed on management areas without a wider debate on whether the proportion of juvenile and adults was in fact being reduced in other areas. Different management areas may exhibit natural differences in fish population structure, and if that was the case, site-specific changes in quotas would be a better alternative to recover fish populations. The change also impacted income from fishing, as quotas were generally reduced, without evidence that it would have the desired ecological effect. ASTRUJ sent an official complaint to IBAMA, and the author collaborated with Dr. Leandro Castello (who created the count method for *pirarucu*) to endorse ASTRUJ's request in a technical briefing document that discussed the inadequacy of this new

[8]Mamirauá Sustainable Development Institute (IDS Mamirauá) is a renowned research institution in Amazonas state that created the *pirarucu* count method, based on both scientific and local knowledge of fishers, which allowed fishery management. IDSM studied *pirarucu* populations in the middle Solimões river since the 1990's, so they have the most complete dataset on *pirarucu* management.

method for quota setting for the LJER. Despite the critiques, the new method is still used by IBAMA.

Land use concessions were debated in four meetings. These were strongly demanded by grassroots organizations, as people could not access some policies (e.g. some of INCRA's credit lines) or get authorization to manage timber if land tenure was not resolved. In council meetings, ICMBio and community leaders closely followed the progress of the discussions with the National Council of Extractive Populations (CNS), and informed council members on the status of the LJER and other land concessions in Amazonas state. Most LJER land was owned by the state government, while flooded areas (*várzeas*) were federal lands.[9] Between 2012 and 2013, when this study was conducted, a negotiation process was proceeding between the federal and state governments, overseen by the Public Prosecutor's Office, with participation of grassroots organizations and NGOs. The Amazonas state government did not agree to transfer control of its lands within federal protected areas to the federal government. However, they agreed that the state government would formally concede its lands to families living in those areas through the state CCDRU. The federal government would continue to be responsible for CCDRU of families living in *várzea* areas of these ERs. Another debate referred to the timeframe for regularizing families in land concessions. The state government wanted CCDRUs for five years only, and renewable. However, the CNS adopted a position against that proposal. Finally, they all agreed on indeterminate timeframes for CCDRUs. When my data collection concluded, the land tenure was still unresolved.

[9] Owned by SPU – Secretary of Union Patrimony.

In the 2012 and 2013 meetings, the definition of reserve beneficiaries was an important topic under discussion. ICMBio's central office asked ER communities to define criteria and identify who were going to be the authorized users of reserve resources (among residents and non-residents) in Council meetings. As stated by ICMBio's head, they should

> identify traditional families according to their livelihoods and relationships with the ER territory, defining who has usufruct and management rights over the territory, who are beneficiaries of land concessions, so that families have access to public policies towards their social, economic, cultural and political development.

Council members first determined that ASTRUJ's board of directors would meet to propose criteria for identifying users and residents. Second, they would discuss these criteria in a series of community meetings, followed by a general meeting with community leaders, to decide on user eligibility criteria. Third, their conclusions would be submitted for the council's approval and then sent to the Federal Prosecutor's Office of ICMBio for legal analysis. However, one ICMBio manager said that the Deliberative Council should have the final say on the process. So they agreed that the proposal should return from the Prosecutor's Office for the council's final approval. Then, after those steps, ICMBio would register ER beneficiaries.

Finally, it is interesting to notice the role of ICMBio's team in co-management. In two years, they approved three projects on social organization, leadership and participatory management of the LJER. The first, named the Youth Protagonist Project, was conceptualized by one ICMBio manager in the LJER to empower and transform young people's reality. It was so successful that it became a model of participatory management for the Environmental Education Department in ICMBio's central office, being carried out in seven other federal and one state protected area. Some examples

of project success were: one young leader became ASTRUJ's vice-president in the following year; the Youth Group got a seat on the LJER's Deliberative Council; and one young leader from the Tefé National Forest where the project was implemented, became part of the CNS Board of Directors at the national level, and thus responsible for the CNS youth leadership agenda. The second project aimed to identify obstacles and opportunities for participatory management by communities. ICMBio hired an experienced anthropologist working in the Amazon to conduct a study to help ICMBio and ASTRUJ to strengthen community participation in decision making. The third project focused on strengthening ASTRUJ's role in co-management, which was just beginning when I finished fieldwork.

These projects were conceived in response to communities' and ASTRUJ's concerns about the need to renew community leaders and strengthen their social organization. In community meetings, older leaders often complained that community circumstances had changed a lot. Old leaders pointed out that young people were not motivated to address community issues and reproduce the traditional rural life-style, often noting that they moved to town to study and thus became more interested in the urban culture. This would undermine community organization and the role of communities in ER governance in the future. More generally, communities faced challenges of getting people involved in decision making and complying with local rules. Community meetings were conceived as arenas for conflict resolution, but if rule breakers did not participate in meetings, it was hard for communities to solve local problems.

Discussion

Decentralization of Rights

Co-management brought new arrangements for natural resource regulation in ERs. This study examined the extent to which rights were shared between government and communities in the LJER, analyzing how it operated at three aspects of governance: the management plan; on the ground; and via the Deliberative Council. On the ground, I also examined whether participation in management decisions influenced rule compliance. Overall, I found that government shared little authority with communities in natural resource management. However, when authority to devise rules was shared, it resulted in higher rule compliance by communities. Consequently, I am able to confirm the expectations set forth for both hypotheses of the study.

The management planning incorporated many informal operational rules that already existed in communities to govern resource use, but also reflected formal government rules or laws as well. Examples include rules regarding timber exploitation, hunting and turtle harvesting. In addition, new rules were collectively created for the plan, such as those for forest clearing. These did not exist before in communities, and were discussed at meetings with ICMBio, for which controlling deforestation is a regional and national priority due to alarming rates of forest loss. However, it seems that rules setting limits for forest clearing were agreed with communities rather than imposed on them, as during this study there was no complaint about deforestation rules.

Regarding collective-choice rules established by the management plan, communities were assigned full rights only to subsistence activities with small ecological impacts, such as location of resident crops, hunting in another community's area, or the amount of fish residents could take to town. However, it was surprising that decisions on

regulations on the amount of turtles to be harvested from protected spawning beaches were in the hands of community guards. First, turtles are a threatened species listed on the IUCN Red List,[10]and turtle harvesting is considered hunting by law. Second, this was decentralized to the lowest level possible (individual guards). As communities were the level of management, it would be more appropriate that they be the decision units, considering the subsidiarity principle: “the relevant level for decision is the most-local possible level at which decision making will not result in negative effects at higher social or political administrative levels” (Ribot 2004:9). Giving so much power to individual guards (instead of the group) could contribute to corruption and inequality.

Other rules set partial rights for communities and other actors. Decisions not requiring technical studies, such as acceptance of new residents and forest clearance for agriculture, were decided by communities and the Deliberative Council. That way, multiple actors would participate in decisions over controversial issues such as population growth and deforestation. However, these did not seem to be controversial in the LJER: there was no decision on forest clearance for agriculture in Council meetings, and there were only two cases of new residents brought before the Council, which agreed with the community’s decisions. But this number of cases is too low to conclude whether government or other actors in the Deliberative Council actually withheld or shared authority over decision making with communities.

Fisheries management decisions were shared between communities and government. These provided good examples of how co-management can be fragile in setting rights for communities, since these depend on the government’s will in sharing

[10] At the time they were considered of low threat of extinction in the 2006 IUCN Red List of Threatened Species.

authority with communities. In the management plan held by ICMBio, communities decided fishing zones in the reserve according to their local practices: areas for strict protection, subsistence or commercial fishing, and management. Nonetheless, changes in fishing management quotas of *pirarucu* by IBAMA were imposed rather than discussed with fishers, counteracting the participatory process that had characterized *pirarucu* management since its beginning (Castello et al. 2009). This could undermine the motivation of fishers to sustain *pirarucu* management and lake governance. The way it worked before, the better the lake protection, the higher the number of fish counted in lakes and the larger the resulting management quotas. Consequently, effective community governance of lakes resulted in better economic and subsistence outcomes, a direct relationship easily perceived by fishers. Thus, community investment in governance was proportional to the benefits, a precondition for success in community-based natural resource management (Murphree 1993, Child et al. 1997). Notwithstanding, IBAMA changed the method for setting management quotas by adopting a relatively complex correction factor without considering fishers' knowledge and the reality on the ground. The target ratio of two young fish per adult did not correspond to an observed pattern in nature. It was found for some lakes in the Mamirauá reserve, but not all (L. Castello, pers. comm.). In addition, in Mamirauá, flooded forests are much more extensive than in other areas, including the LJER, providing more food and habitat availability for young *pirarucu*, which could increase their survival and recruitment. After implementing this ratio for calculating quotas, the increase in number of adults counted (resulting from better governance) would not

necessarily result in higher management quotas, as these depended on juveniles as well.

Overall, ICMBio decentralized few rights to communities, restricting livelihoods to a few extractivist products for commercialization. Communities had the autonomy to organize rules for controlling resource use (withdrawal rights) and protect the resource base (management rights regarding lake zoning and monitoring of turtle spawning beaches). However, management decisions related to higher ecological impact or large-scale economic activities such as wildlife management and breeding, ornamental fishing or commercial logging were controlled by the government. These activities demand technical expertise, which is expensive considering the complexity of logistics in the Amazon, including large territories, long distances, difficult accessibility, lack of scientists in the interior, and demand for specialists to come from distant areas. Moreover, high-profile management decisions usually require government permits involving time-consuming bureaucratic procedures that require approval by multiple sectors within governmental organizations. ICMBio's local team was reduced and overworked, so government control of natural resource management rights was not effective in improving communities livelihoods.

Exclusion rights determining "who will have an access right, and how that right may be transferred" (Schlager and Ostrom 1992:251) were the utmost key decision-making power shared with communities in ERs. This right was exercised in two ways: a) decisions on eligibility to be reserve beneficiaries; and b) access to CCDRU, which would formalize people's land rights. In the former, rights were shared between communities, ASTRUJ and the Deliberative Council. ASTRUJ and communities would

have a key role in defining criteria for beneficiaries and deciding who these would be. Decisions would be taken to the Deliberative Council for approval. When I finished field work, discussions about beneficiaries were only beginning, so I cannot draw any conclusion on how participatory this process was. However, it was interesting to note that in the planning stage at council meeting, ICMBio managers intervened to assure that legitimate council decisions would not be overruled when reviewed by ICMBio's central office. This suggests that ICMBio managers on the ground were more willing to decentralize rights than were higher-level bureaucrats in ICMBio's central office in Brasília. Regarding CCDRUs, communities had no decision-making power, as these depended exclusively on State willingness to decentralize rights. Nonetheless, communities were indirectly represented by CNS in negotiations between federal and state governments, which was key in securing land concessions for an indeterminate timeframe rather than only five years, as proposed by the state government.

Resource Governance on the Ground (Rules-in-Use)

In the communities, rules ranged in origin from the national to the local level, and in nature from the formal to the informal. Most rules were reported as having been created jointly by communities and government for the LJER's management plan. Socó and Ig. Branco declared that all rules were jointly created for the management plan, inflating the observed number of co-management rules. However, in other communities, around half or more rules were said to be created by local peoples. Differences in the number of rules seemed more related to community size than age: very small communities (Ig. Branco, with four families, and Socó, six families), in existence for 12 and 22 years respectively, had no community-created rules, while the other communities ranged from ten to 45 families, and had existed for 13 to nearly 40 years.

Some resources were more regulated than others: fisheries and turtles had the highest number of rules, while hunting, NTFPs and land had the lowest. The type of resource influences a user's ability to conserve them. As asserted by Baland and Platteau (1996:226), "awareness of ecological stress under increasing human pressure on natural resources grows only slowly and typically requires concrete, visible experiences of depletion or degradation to be stimulated". Thus, more localized, visible and predictable resources have a greater chance to be conserved than seasonal, unpredictable and more cryptic or fugitive resources spread over large areas.

Fish, turtles and game animals are common-pool resources for which exclusion is difficult and joint use involves subtractability (Berkes and Farvar 1989). These are mobile animals that move around in aquatic or terrestrial systems. All of them provide important food supplies to rural and urban peoples and are subject to overexploitation due to illegal trade. If resources are overexploited, depletion can be detected through direct observation (e.g. visualization or audition) or indirectly (as via tracks). Extractivist peoples have accumulated local knowledge due to their dependency and intimate relationship with nature, which has been orally transmitted through generations. On that basis, reductions in fish, turtles or game animals generally will be perceived. Why then would communities establish more rules for fish and turtles compared to game animals? I believe there are three possible explanations. First, stock depletion of fish and turtles is more visible than for game animals. Fishing stocks are evaluated through daily fishing by most riverine people, as fish is their most important protein source. Fishing effort, given by time spent or amount of materials invested in fishing (e.g. gillnets), is usually an effective way of assessing stocks, although there are others (e.g. hearing the sound

of *pirarucu* bubbles in lakes or ripples on a lake when they surface). River turtles can also be seen when they are thermoregulating on top of fallen trees in rivers, along river banks, captured in gill nets, or on spawning beaches during the dry season. In addition, aquatic environments are highly accessible while most terrestrial areas in the region are hard to reach, working as refuge areas that can replenish stocks of game animals (Antunes et al. 2016). Game animals (such as peccaries, deers, tapirs etc.) are highly sensitive and escape to deeper forests when they hear the noise of dogs or gunshots. Also, there are relatively few hunters in communities, so communication on perceived resource depletion may be less frequent than for fish and turtles. Second, communities had more time and incentives to protect fisheries and turtles than game animals. They have protected lakes and spawning beaches for decades, before communities were created, by the initiative of rubber barons or the influence of the Catholic Church (through MEB – *Movimento de Educação de Base*, which worked on social organization and defense of community territories; Castro 2000). As long as I am aware of, there are no such organized and long-lived governance schemes for controlling hunting in non-indigenous areas in the Amazon, although local institutions do exist. And finally, fish and turtles are much more important for people's livelihoods in the region (in terms of subsistence and income) than game animals.

Although this study did not evaluate the status of resource stocks or perceived stocks, NTFPs did not seem to suffer high pressure, as these were used mostly for subsistence, and only some families commercialized products at a small-scale (e.g. *açaí* and handicrafts made of vines or straw). In addition, NTFPs are spread out in

forests, and harvesting occurs only in accessible areas[11]. Some resources are seasonal (e.g. *açaí*, *andiroba* seeds, Brazil nuts) while others are perennial (e.g. resins, vines, honey, straws). Finally, in the case of land occupation, it involves no resource depletion, so simple, broad rules can regulate behavior and achieve desired outcomes (e.g. new resident behavior is observed for one year before they can be considered as community members).

Communities incorporated forest clearance rules conceived for the management plan, through the influence of ICMBio. In the case of the communities I studied, apparently there was no need to set rules for controlling deforestation, because deforestation rates were already very low in the region (ICMBio 2009) and they had already adopted practices, norms and beliefs conducive to forest conservation. In general, communities did not live by illegal logging or cattle ranching. Their agroextractive livelihoods demanded little conversion of forests to pastures or agricultural plots: communities from this study lived basically on small-scale agriculture (selling surplus production), complemented by extractive activities. Their rotating agricultural systems contributed to the extended use of a small number of areas, as overused areas could be fallowed for several years until being used again. Thus, most families opened one to two hectares of agricultural plots in secondary forests, so there was not much need for opening plots in primary forests (except for new families being formed in the case of more populated communities). Finally, their cultural beliefs about the forest (e.g. *Mãe-da-mata* or *Curupira*, a forest entity that harms loggers for

[11] However, some species occur only in flooded forests, and overuse could be a factor of risk (C. Peres, pers. comm.).

unsustainable practices), continue to be transmitted through generations, and also help to account for not cutting the forest beyond necessity.

Timber was a good example of a government-controlled resource. Almost all rules reported by communities about logging consisted of government laws or regulations restricting timber use, transport and selling. Although communities were overall dissatisfied about them, the rules had been internalized, probably due to the large negative consequences of rule breaking. Good quality wood that fell down or was felled during opening of agricultural plots could generate income instead of decomposing on the forest floor. Another issue was that timber could be used within the reserve, but not outside of it, as IBAMA could not provide timber transport permits (DOF authorization) without a forest management plan. Although communities had the right to use timber for subsistence in the reserve, this right was restricted due to inadequate legislation. The Deliberative Council had no power to influence change or pass new legislation regarding timber transport to town for subsistence purposes, such as building a house for families in need of schooling for their children. Ironically, it was very common to find wood boards from illegal logging (not necessarily practiced in the reserve) at the city port of Juruá, indicating that government centralizes control without the means of exercising it.

One basic principle of successful common property regimes investigated by Ostrom (1990) is that those affected by rules should participate in modifying them. In the case of fallen or felled wood[12] and timber transport as reported above, ICMBio's central office should decentralize control to lower levels. ASTRUJ and ICMBio's head

[12] In case of fallen wood for natural processes, trees maintain their roots so it is easy to differentiate the cause of fall (random or deliberate).

could be given joint responsibility for monitoring and issuing local authorizations under close community and Deliberative Council supervision, so as to increase transparency, accountability and social control. That way, communities could feel more incentivized to create and enforce rules for timber, potentially doing a better job than government.

Implication of Community Participation for Rule Compliance

Regarding rule compliance, I found that poor participation of local residents in developing regulations resulted in partial acceptance and compliance with local rules. Interestingly, full compliance was higher for rules created jointly by communities and government rather than communities alone, contrary to what is often expected in previous literature on community-based management. As expected, less compliance was found for rules imposed by government, in which communities had no participation. This has important implications for natural resource governance in ERs: if communities do not participate in decisions, and if their knowledge and management practices are not considered in natural resource management, then top-down initiatives will fail to conserve resources. Thus, if governments expect that rules are met in these areas, it is imperative that communities help design and enforce local rules.

Concluding Remarks

- Co-management of ERs skewed from expected when rubber tappers grassroots conceived the model;
- Government decentralizes few rights to communities in ERs, hindering social and environmental outcomes;
- Co-management presents risk of recentralization of authority;
- Government centralizes control without the means of exercising it;
- Co-management operates in different ways in different hierarchical levels. ICMBio managers on the ground are more willing to decentralize rights than higher hierarchical level bureaucrats in ICMBio's central office in Brasília;

- Decentralization operates in different ways for different resources in the ER;
- Governmental bureaucracy for authorizing large-scale natural resource management should be simplified, so that communities could access it;
- Some decisions could be held at lower levels, such as timber transport and small-scale commercialization of fallen/felled wood;
- Government (ICMBio/IBAMA) should implement experimental programs of turtle management at spawning beaches protected by communities, so as to improve community governance and control;
- Lack of confidence in local knowledge and institutions, mainly in the case of timber and turtles. However, ERs have rich social, cultural, environmental, institutional, and political capital that are necessary ingredients for effective resource governance;
- When communities are effectively involved in decision making, there are greater chances of effective rule making, enforcement and compliance;
- ICMBio should work on strategies to improve transparency, accountability and communication exchange in Deliberative Councils.

Table 2-1. Operational and collective-choice rules (marked with asterisks) from LJER's management plan.

Activity	Rules
Land occupation	1. New residents can live in the reserve if they accept local customs and ways of life and comply with community rules, and reserve regulation (management plan); to be accepted, new residents need authorization from community, ASTRUJ, and the Deliberative Council.* 2. Residents can access land, plant crops and commercialize surplus production. 3. Location of crops should be decided by communities and be authorized by other communities in case these lie in their territories. 4. Former residents living in Juruá town can have crops in LJER, provided that it is authorized by communities, ASTRUJ and Deliberative Council.*
Forest clearing	5. Crops can be located both in primary or secondary forests in upland or flooded forests. 6. When necessary, families can open one hectare/year in primary forest and up to two hectares/year in secondary forest. 7. To open between one and two hectares in primary forest or between two and three hectares in secondary forest, they should ask the community's permission, which then requests ICMBio's authorization.* 8. ICMBio's authorization is needed also if families want to open more than two hectares to the limit of three hectares/year in total of primary and secondary forests.* 9. It is prohibited to clear forest in a 50m strip along river banks.
Timber exploitation	10. Community members can extract timber for their own use (e.g. house construction) and commercialize canoes, furniture and other final products at small-scale. 11. Fallen wood from areas opened for agricultural plots can be commercialized following specific legislation. 12. Commercial timber exploitation is allowed depending on a specific forest management plan,*[13] on a sustainable basis and as a complement to people's livelihoods, not replacing other sustainable activities in the reserve.
NTFPs exploitation	13. Residents can use vines, seeds, fibers, straws, oils, and medicinal plants, among others, on a sustainable basis. 14. Only ripe products can be harvested. 15. It is prohibited to cut down the following tree and palm species: *açaí*, *copaíba*, *buriti*, *patauá*, *bacaba*, *tucumã* and *andiroba*.

[13] Although not explicitly a collective-choice rule, legally only ICMBio or IBAMA can approve management plans.

Table 2-1. continued

Activity	Rules
NTFPs exploitation	16. Products can be extracted from other community areas if authorized by the respective community.* 17. Large scale exploitation requires a sustainable management project and ICMBio's authorization*.
Hunting	18. Residents can hunt sustainably for subsistence (food) only. 19. It is prohibited to hunt threatened species[14]. 20. Residents can hunt in community or communal areas. 21. Hunting on other community area needs the respective community's authorization.* 22. Visitors or outsiders are prohibited to hunt in the reserve. 23. Surplus meat should be shared among community members (not sold). 24. Breeding and wildlife management are conditioned to specific projects authorized by ICMBio/IBAMA.*
Fishing	25. Communities can fish for subsistence or commercialization, on a sustainable basis and according to fishing zones[15]. 26. Ornamental fishing is possible if proven potential, on a sustainable basis, and if authorized by ICMBio.* 27. Visitors can fish up to 20 kg/year, if authorized by the community.* 28. Each community decides the amount of fish for subsistence (food) residents can take to town.* 29. Communities interested in fisheries management should organize to protect lakes and then ask for IBAMA authorization.* 30. Communities determined fishing zones for preservation (no fishing), subsistence, commercialization, and management.*
Turtle harvesting	31. Communities are incentivized to guard and monitor nesting beaches, with ICMBio and IBAMA support. 32. Residents and former residents are allowed to capture turtles for subsistence (food) only, in a sustainable way. 33. Community guards/monitors protecting nesting beaches should decide the amount of turtles to be captured for subsistence.* 34. Transport of turtles to Juruá town is prohibited. 35. Predatory techniques and materials are prohibited. 36. It is prohibited to capture turtles of *Podocnemis expansa* species (locally known as *tartaruga*).

[14] According to official lists of threatened species (Brazil's Ministry of Environment and IUCN).

[15] Zoning defined areas for preservation, subsistence, commercial, and management fishing.

Table 2-2. Conditions requiring authorization and by whom, in accordance with LJER's management plan.

Activity / Responsible	Community monitors	Community	ASTRUJ	ICMBio/ IBAMA	Deliberative Council
Land occupation:					
Acceptance of new residents		x	x		x
Crops of former residents (users)		x	x		x
Forest clearing for agriculture:					
Location of crops (residents)		x			
Primary or secondary forest clearance		x		x	
Total sum of primary and secondary forest clearance		x		x	
Timber exploitation:					
Commercial logging				x	
NTFPs exploitation:					
Harvesting products in other community area		x			
Large scale exploitation				x	
Fishing:					
Ornamental fishing				x	
Fishing by visitors		x			
Transporting fish for subsistence in town		x			
Fisheries management		x		x	
Hunting:					
Hunting in other community's area		x			
Wildlife management and breeding				x	
Turtle harvesting:					
Amount of animals captured for subsistence	x				

Table 2-3. Degree of authority shared to communities in LJER based on its management plan.

Activity / Responsible	No rights	Partial rights	Full rights
Land occupation:			
Acceptance of new residents		x	
Opening of crops by former residents (users)		x	
Forest clearing for agriculture:			
Location of crops (residents)			x
Primary or secondary forest clearance		x	
Total sum of primary and secondary forest clearance		x	
Timber exploitation:			
Commercial logging	x		
NTFPs exploitation:			
Harvesting products in other community's area			x
Large scale exploitation	x		
Fishing:			
Ornamental fishing	x		
Fishing by visitors			x
Transport of fish for subsistence to town			x
Fisheries management		x	
Hunting:			
Hunting in other community's area			x
Wildlife management and breeding	x		
Turtle harvesting:			
Amount of animals captured for subsistence			x

Table 2-4. Decentralization of property rights to communities over natural resources in LJER's management plan: 0 – no right; 1- partial right; 2- full right.

Resource	Level of property right				
	Access	Withdrawal	Management	Exclusion	Alienation
Land	2	1	1	1	0
Forest	2	1	1	1	0
Timber	2*	1	1	1	0
NTFPs	2*	1	1	1	0
Fish	2*	1	1	1	0
Game	2*	1	1	1	0
Turtle	2*	1	1	1	0

* Communities have access rights to river, streams, lakes, and forests in their territories, in which trees, palms, vines, game animals, fishes and turtles occur.

Table 2-5. Frequency of occurrence of operational rules controlling natural resource use in six communities of LJER.

Rule/Community	Antonina	Botafogo	Socó	FG1	Cumaru	Ig. Branco	Total
Land occupation:							
Who is allowed to live in community	1	1	1	1	1	1	6
Who is allowed to use resources	1	1	1	1	1	1	6
Restrictions to new residents or users	1	1	1	1	1	1	6
Crop sharing with outsiders	1	0	0	0	0	0	1
Land lease (secondary forest, crops, lakes, etc.)	1	0	1	0	1	1	4
Land sale	1	0	1	1	1	1	5
Forest clearing:							
Who can clear forest for agriculture	1	1	1	0	1	1	5
Forest clearing in primary forest	1	1	1	1	1	1	6
Forest clearing in secondary forest	0	1	0	0	0	0	1
Forest clearing along streams	1	1	1	1	1	1	6
Forest clearing for pasture	1	1	1	1	0	1	5
Fire use	1	0	0	0	0	0	1
Agricultural plot size	1	1	0	1	1	1	5
Agricultural plot sale	1	0	0	0	0	0	1
Timber exploitation:							
Who can extract timber	1	1	1	1	1	1	6
Amount of timber extracted	0	0	1	1	0	0	2
Types of trees	1	0	1	1	0	1	4
Location of extraction (primary forest, agricultural plot etc.)	0	0	0	1	0	1	2
Purpose of use (build canoe, paddle, house etc.)	1	0	0	0	1	0	2

Table 2-5. continued

Rule/Community	Antonina	Botafogo	Socó	FG1	Cumaru	Ig. Branco	Total
Timber processing (cannot extract logs/planks)	0	0	0	0	0	1	1
Transport to town	1	1	1	1	1	0	5
Timber sale	1	1	1	1	1	1	6
NTFPs exploitation:							
Who can extract products	1	1	1	1	1	1	6
Sustainable extractive practices	1	1	1	0	1	1	5
Avoiding felling of palms	1	1	1	1	1	1	6
Location of extraction	0	0	0	0	1	0	1
Amount of extraction	0	0	0	0	1	0	1
Products sale	0	0	1	0	0	0	1
Fishing:							
Lake preservation	1	0	0	0	0	0	1
Who can fish in lakes	1	1	1	1	1	1	6
Fishing materials	1	0	1	1	1	1	5
Techniques	1	1	1	1	1	1	6
Fishing season	1	0	1	1	0	0	3
Fishing areas	1	0	0	1	1	0	3
Types of fish	1	0	1	1	1	0	4
Fish size	0	0	1	0	0	0	1
Amount of fish	1	1	1	1	1	1	6
Presence of fishing boats	1	1	1	1	1	0	5
Fishing boat/canoe size or number	0	0	0	1	0	0	1
Fish sale	0	1	0	1	1	0	3
Hunting:							
Who can hunt	1	1	1	1	1	1	6
Hunting techniques (employment of traps, dogs etc.)	0	0	1	1	0	0	2
Amount of animals hunted	0	0	1	0	0	0	1
Transport to town	1	1	1	1	1	1	6
Game meat sale	1	1	1	1	1	1	6
Turtle harvesting:							
Who can harvest turtles	1	1	1	1	0	1	5
Who can harvest eggs	1	1	1	1	0	1	5

Table 2-5. continued

Rule/Community	Antonina	Botafogo	Socó	FG1	Cumaru	Ig. Branco	Total
Amount of eggs	1	1	1	0	0	0	3
Amount of turtles	0	1	1	0	0	0	2
Employment of gillnet near spawning beaches	1	1	1	1	0	1	5
Turtle type	1	1	1	1	0	1	5
Harvesting sites	0	0	1	1	0	1	3
Day period	0	0	0	1	0	0	1
Transport of eggs or turtles to town	1	1	1	1	1	0	5
Egg sale	1	1	1	1	1	1	6
Turtle sale	1	1	1	1	1	1	6
Total	41	32	41	39	32	32	-

Table 2-6. Frequency of occurrence of operational rules controlling natural resource use in communities of LJER.

Resource/ Community	Total N of rules	Antonina	Botafogo	Socó	FG1	Cumaru	Ig. Branco
Land occupation	6	6	3	5	4	5	5
Forest clearance	8	7	6	4	4	4	5
Timber extraction	8	5	3	5	6	4	5
NTFP extraction	6	3	3	4	2	5	3
Fisheries	12	9	5	8	10	8	4
Hunting	5	3	3	5	4	3	3
Turtle harvesting	11	8	9	10	9	3	7
Total	56	41	32	41	39	32	32

Table 2-7. Number of operational rules controlling for resource use that have been built by communities, collectively with other communities for the management plan coordinated by ICMBio (communities + government), or by government, as pointed out by communities.

Resource use	Who did build rules?		
	Community	Communities + government	Government
Land occupation	15	12	1
Forest clearing	1	28	1
Timber exploitation	4	13	11
NTFPs exploitation	9	11	0
Fishing	20	20	4
Hunting	5	12	6
Turtle harvesting	17	17	12
Total	71	113	35

Table 2-8. Number of operational rules pointed out by communities, for each type of resource use, that could or not be changed and by whom.

Resource	Can rules be changed?			By whom?		
	?	No	Yes	Community	Communities + ICMBio	Deliberative Council
Land occupation	13	2	16	1	9	6
Forest clearing	0	2	28	1	18	9
Timber exploitation	8	9	11	3	1	7
NTFPs exploitation	0	0	20	10	7	3
Fishing	0	6	37	13	18	6
Hunting	0	8	13	1	7	5
Turtle harvesting	10	11	25	13	5	7
Total	31	38	150	42	65	43

Table 2-9. Level of compliance to operational rules for each type of natural resource use for all communities in LJER, according to who created rules. NA – Not Apply.

Who created rules	Total N of rules	Level of compliance				
		No	Partial	Full	?	NA
Communities	72	7	20	39	6	0
Communities + government	112	4	13	84	3	8
Government	33	7	12	10	4	0

CHAPTER 3
THE ROLE OF SOCIAL CAPITAL IN FOSTERING COLLECTIVE ACTION FOR NATURAL RESOURCE MANAGEMENT

Introductory Remarks

Social capital has been pointed out as a key factor for social organization and for the collective management of natural resources (Ostrom 2005, Pretty 2003, Pretty and Smith 2004). This concept has been incorporated in studies of common property, given its power to characterize and understand the social relations among actors that prompt them to work together for the collective good. In contrast to other forms of capital (e.g. financial or human capital), the power of social capital lies not in individual actors, but in the social relations among them, be these people, communities, or organizations (Woolcock and Narayan 2000).

In the context of governance of common-pool resources (CPRs), it is important to understand the motivations people have to engage in collective action for controlling the use of natural resources. People engage in regulating CPRs when they perceive that these are overexploited (Ostrom 1990, Baland and Platteau 1996), but a key question is what makes them invest in the collective gain over their own individual benefits and comply with rules, without being sure that others in the group will do the same (Portes 1998, Ostrom 2000). According to Putnam (1993), norms of generalized reciprocity guide people's behavior in social groups. These norms create a general understanding that if one actor does something for another, at some point in the future this other will pay the first back.

The density of social structure, or the extent to which people in a social network are connected, contributes to create trust and effective norms that permit the dissemination of obligations and expectations, facilitating collective action (Coleman

1988). Therefore, smaller networks with frequent interactions would have more trust and effective social norms than larger networks with unconnected actors, who can free ride more easily without being noticed. Thus, smaller networks are more prone to collective action than larger ones.

The social capital literature has become popular in the social sciences because it approaches people's real values, focusing on "how people interact in their daily lives, in families, neighborhoods, and work groups, not just as buyers, sellers, and citizens" (Bowles and Gintis 2000:3). Since the 1990s, social capital has gained notoriety in academic and policy circles, with multiple attempts to define it (Bordieu 1985, Coleman 1988, 1990, Putnam 1993, 1995), measure it (Narayan and Pritchett 1999, Narayan and Cassidy 2001, Onyx and Bullen 2001, Woolcock 2001), synthesize it (Portes 1998, Woolcock and Narayan 2000, Adler and Kwon 2002) and apply it on the ground (Gittell and Vidal 1998). Woolcock and Narayan (2000) categorized research on social capital into four different perspectives: a) the communitarian view, focusing in participation in local organizations such as clubs, associations, and civic groups; b) the network view, drawing on the vertical and horizontal linkages between actors, either persons, communities or firms; c) the institutional view, examining the importance of the broader context in which social networks are embedded; and d) the synergy view, which integrates research on these two latter perspectives (networks and institutions).

Social capital is multidimensional: it can refer to social relations among actors from the same social group (family members, close friends, neighbors; bonding), different groups (more distant friends, colleagues, associates; bridging), or to power relations between regular citizens and the state (Gittell and Vidal 1998, Woolcock

2001). Social capital definitions vary accordingly, emphasizing more the external linkages of social actors (e.g. Bordieu 1985), the internal linkages (e.g. Coleman 1988, Putnam 1995), or both (e.g. Woolcock 1998, Adler and Kwon 2002). Bordieu defined social capital as the “aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition" (1985:248). For Coleman, “social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in common: they all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure" (1990:302). Putnam defined it as a “feature of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit” (1995:67). For Woolcock, social capital consists in “information, trust, and norms of reciprocity inhering in one's social networks" (1998:153). Adler and Kwon conceptualized social capital as “the goodwill available to individuals or groups. Its source lies in the structure and content of the actor’s social relations. Its effects flow from the information, influence, and solidarity it makes available to the actor” (2002:23).

Despite its wide acceptance, the concept has been criticized for being too broad, allowing for different meanings, and thus causing confusion. Its causes and consequences are often mixed together in definitions of social capital, leading to lack of explanatory power and tautological reasoning (Woolcock 2001, Adler and Kwon 2002). For example, trust is commonly considered to be a source of social capital, but it is actually an outcome of repeated interactions (Woolcock 2001). To simplify, Woolcock (2001) argues that definitions of social capital should focus on what it *is* rather than on

what it *does*. Social capital has also been criticized for not being actual “capital”, as it lies in the relations among people and not in people themselves. However, this usage is metaphorical, and the term should be understood as an asset in which people invest to later reap the benefits of it (Adler and Kwon 2002).

Here I adopt Putnam’s (1995) definition of social capital, emphasizing networks, norms, and trust that facilitate collective action. More specifically, I focus on “those features that give the collectivity cohesiveness and thereby facilitate the pursuit of collective goals” (Adler and Kwon 2002:21). Despite disagreements on whether certain aspects of social relations, such as trust, are sources or consequences of social capital, I employ it in my operationalization of social capital. The purpose is not to understand the factors affecting social capital, but rather to understand its role in eliciting participation in collective action for small-scale fisheries management in the Amazon. My focus of analysis are the social connections within (bonding) and among (bridging) communities.

Collective Action in the Amazon Rural Communities

In the western Amazon, collective action among smallholders emerged with the formation of riverine communities in the 1970s-1980s by incentive of the *Movimento de Educação de Base* (MEB) of the Catholic Church. Former rubber tappers living in isolated households within the forest were aggregated into communities along the mainrivers and tributaries to become visible to public policies. At the same time, the Church stimulated their sense of collectivity, belonging, and solidarity, incentivizing labor-sharing groups (known as *mutirão* or *ajuri*) and the collective defense of lakes.

Rural communities are generally constituted by kinship and friendship relations, which facilitates collective action (Harris 2006). Closely related kin are connected by

strong norms of solidarity, in which no reciprocity is expected in return for help. Solidarity networks are based on work, food sharing, aid, and visit. Solidarity relations have more value than relationships of credit and debt among neighbors (Harris 2006).

Studies on community collective action in the Amazon focus on the emergence and outcomes of local management institutions for natural resource conservation (Castro 2000, Futemma et al. 2002, Pinho et al. 2012), with little reference to the underlying social relations accounting for engagement in collective action. This gap is particularly evident for small-scale fisheries that provide a useful study case for examining the role of social capital in fostering collective action for resource management.

Small-scale Fisheries Management

Small-scale fisheries are important activities in local livelihoods in Amazonian communities, as fishing in the Amazon holds valuable cultural, economic, and biological meanings (Castro 2000). Most riverine communities live on small-scale agriculture, but some depend economically on fishing for most or part of the year. Fish constitute their main source of protein.

New management schemes have been developed from the 1960s to the 1980s in the Amazon in response to increasing conflicts due to invasions of lakes by commercial boats (Castro 2000, Ruffino 2008). Similar to *empates* that characterized the rubber tappers social movement in Acre, riverine communities developed collective strategies to protect lakes and impede the access of commercial boats to their fishing territories. Moreover, they established lake zoning based on their functions (no-take, subsistence, or commercial fishing), rotating these with time. That way, they implemented sustainable use strategies for long-term fishery conservation.

Management of the largest fish with scales in the world, *pirarucu* (*Arapaima* sp.), endemic to the Amazon basin, emerged from the combination of scientific and traditional knowledge (Castello 2004). Together, researchers and fishers developed a method to accurately count *pirarucu* in floodplain lakes in the dry season, allowing sustainable management quotas to be set by the government (Castello 2004). Management is held through co-management arrangements with the government, but depends mostly on community organization and collective action. Communities collectively develop local rules and strategies for governing fish stocks and avoid free riding. However, there remain questions about the aspects of social capital and its importance for the emergence and effectiveness of collective action to ensure the sustainability of the *pirarucu* fishery. I therefore focus on the role of social capital in facilitating collective action for the management of *pirarucu* in this study. My main research question was: *When authority over natural resource governance is shared to communities in the co-management of extractive reserves, such as in* pirarucu *management, do management systems with higher social capital present higher engagement in collective action?* I hypothesized that the higher the social capital, the higher the participation in *pirarucu* management.

Study Area

This study was conducted in the Lower Juruá Extractive Reserve (LJER), a federal protected area covering nearly 188,000 hectares of forests and aquatic systems in the central-western Brazilian Amazon. The JLER was created in 2001 by demand from local residents to guarantee their land rights and control over fishing territories (ICMBio 2009). In the LJER there are 15 settlements, hereinafter called communities, where there reside 132 families constituted by 748 people, 643 of which are residents

and 105 are authorized users (former residents living in Juruá town; ICMBio 2009). Residents are former rubber tappers from families that had resided in the area for many generations. Their main activities are small-scale agriculture, fishing, forest extractivism, small animal husbandry and small-scale cattle ranching.

Management of *pirarucu* began in the LJER in 2006 due to demand by local communities. It started in three areas and was later expanded to another three, involving a total of eight communities in management of six social-ecological systems: Botafogo, Antonina, Planeta complex, Baixio lake, Socó lake and Andirá.

Methods

I conducted semi-structured interviews with a random sample of household heads from the eight communities involved in *pirarucu* management in the LJER. I interviewed heads of all households in smaller communities (up to ten houses) and randomly sampled at least 30% of households in larger communities. I focused interviews on males, as only a few women are involved in *pirarucu* management. I used households heads as respondents for households to compare varying levels of participation in collective action in management. When possible, I chose to interview the male rather than the female head because women usually did not participate in *pirarucu* management. I then sought to relate those indicators of participation to multiple potential explanatory variables, including indicators of social capital. I operationalized collective action as the proportion of households with at least one person engaged in *pirarucu* management. However, some households had more than one person involved in management (e.g. sons of the household head).

I evaluated household participation in *pirarucu* management (dependent variable) among management systems in terms of a set of independent variables: a) personal and household characteristics (age; origin; time of residence; years of schooling; religion; occupation; number of household members; agricultural plot size; and wealth, given by community house area, whether family owned house in town, total number of assets, and annual income); b) social and political engagement (role in the community; affiliation; participation in the ER creation; participation in meetings of the management plan; participation in community/group meetings); and c) social capital (participation in labor-sharing groups, known as *mutirões*; trust in lending of materials to others[20]; frequency of mention of norms of reciprocity, solidarity and sense of collectivity in responses to why they joined *mutirão*; frequency of food sharing and proportion of people involved in the community; and proportion of people with whom they could count on in the community). I did not measure participation in food sharing in areas involving multiple communities because this social network happens mostly within rather than between communities. Similarly, I did not measure frequency of participation in *mutirões* in these same areas because it would be biased, as labor-sharing groups met at regular periods of time for patrolling management systems. Then I scored and summed the values for each measure of social capital, ranging from 1 to 5, and calculated the social capital index for each area.

I used both quantitative and qualitative methods of data analysis. I calculated the average and standard deviation values for the continuous variables and the relative frequency for the categorical variables. Categorical variables were recorded as binary

[20] Materials important for local livelihoods: *motor rabeta* (engine for canoes), shotgun, gillnet, *haste de pirarucu* (artisanal fishing spear), *paneiro* (artisanal basket for carrying cassava from crops) and money.

options (yes or no)[21] or as a five-point Likert-scale[22]. Research instruments are presented in Appendix A.

I coded qualitative data from open questions and calculated the frequency of occurrence of themes and subthemes in responses to why they joined *mutirão* and *pirarucu* management. In this analysis, I considered only households that participated in collective action. I examined differences in qualitative and quantitative data among areas using descriptive quantitative analysis.

Results

I interviewed a sample of 59 family heads from 95 households (62%) within communities involved in the six *pirarucu* management systems in the LJER (Table 3-1). Ninety percent of respondents were male. Four out of the six systems presented high levels of household participation in *pirarucu* management: 86% in Baixio lake (N=6), 82% in Antonina (N=14), 80% in Planeta (N=28; 13 from Botafogo and 15 from Antonina), and 70% in Botafogo (N=7). Socó lake (N=15) and Andirá (N=18) exhibited low levels (33% and 31%, respectively) of participation in *pirarucu* management. In some areas, participation involved not only resident families but also authorized outside users, who were former residents who moved to Juruá town but were still connected to their communities by kinship and/or production ties. One user family from Socó community was involved in management at Baixio and Socó lakes; and six user families

[21] In the case of origin (whether person was from the same or other community/area); religion (Protestant, Catholic, none, other); occupation (agriculturalist; fisherman, extractivist, waged labor, retired, student, carpenter, other); whether owned house in town; role in the community (environmental agent, health agent, part of the directory board, *pirarucu* counter, midwife, etc.); membership in formal organizations (ASTRUJ, STTRN, Colpesca, Sindipesca, other); participation in the ER creation, on meetings of the management plan, in *mutirões*, of *pirarucu* management, and in food sharing networks.

[22] Trust in lending of materials to others; proportion of people they could count on in the community/group; and frequency of participation in community/group meetings, *mutirões*, and food sharing networks.

from Botafogo and two from Antonina were involved in management at the Planeta complex.

In terms of personal characteristics (Table 3-2), household heads of Planeta were the oldest on average (45.4 ± 15.3 years), while those from Baixio lake were the youngest (31.6 ± 14.5 years). All family heads from Baixio lake originated from other areas, as well as most people in Antonina (67%), Socó lake (62%), and Planeta (56%). Most respondents in Andirá (58%) and Botafogo (56%) had roots in the same community. Time of residence varied from an average of 15.9 ± 14.6 years in Baixio lake to 36.8 ± 11.1 years in Botafogo. Catholics represented between 78% and 100% of household heads in all areas, with some agnostics in Baixio (14%) and Socó lake (8%), and Protestants in Botafogo (22%) and Socó lake (8%). Regarding occupation, most respondents (67% to 86%) from Andirá, Baixio, Botafogo, and Antonina were small farmers. In Socó lake, small farmers and fisherman were equally represented (38%). A relatively high proportion of other occupations (students, retired, wage labor and carpenters) was found in Planeta complex and Antonina (33% to 44%).

Among household characteristics (Table 3-3), the highest average number of household members was found in Andirá (6.1 ± 2.8) and the lowest in Baixio lake (4 ± 1.5) and Planeta (4.1 ± 2). Agricultural plot size varied greatly among areas: from 11,555 ± 9,258 *covas* in Planeta to only 4,684 ± 5,427 *covas* in Socó lake. In terms of wealth, Baixio lake differed substantially from the other areas: on average, it presented the highest annual income (US$ 13,339 ± 6,232), the smallest number of assets (7.3 ± 4.5 of the range of items considered) and community house area (39.7 ± 35.6 m^2), and the lowest proportion of families (14%) who owned a house in town. The opposite

pattern was found for Planeta: it presented the largest community house area (73.6 ± 47.5 m^2) and number of assets (17.4 ± 9.4), as well as a high proportion of people (67%) who owned a house in town, and the lowest annual income (US$ 10,732 ± 5,254) among all systems. In general, small-scale agriculture comprised the most important economic activity among households, except in Socó lake and Andirá where extractive activities (*açaí*, fishing, handicraft etc.) had a more prominent role than in other areas. The productive component (coming from agriculture, extractivism, and animal husbandry) represented between 27% (Socó lake and Andirá) and 40% (Botafogo) of annual household income. Thus, the non-productive component, consisting of wage labor, services, and governmental social benefits[23] provided the most important source of annual income in all systems, varying from US$ 6,523 to US$ 9,550. When examining *per capita* income, households in Baixio lake were the richest, followed by Planeta, Botafogo and Antonina, Socó lake, and Andirá, varying in a similar fashion as participation in *pirarucu* management.

Regarding social and political engagement (Table 3-4), role in the community (mainly directory board and voluntary environmental agent) was relatively high in all management systems (78-100%), except in Socó lake (54%). There was no substantial variation in membership in formal organizations,[24] ranging from 78% in Planeta to 100% in Botafogo. However, considering only affiliation to ASTRUJ, Baixio lake and Socó lake exhibited considerably lower levels (43% and 38%, respectively) compared to full

[23]Benefits such as pension, payment for closed fishing season (*defeso*) and conditional cash transfer programs (e.g. *Bolsa Família*, *Bolsa Verde*).

[24]Association of Rural Workers of Juruá – ASTRUJ; Union of Rural Workers of Juruá – STTR; Fishery organizations (*Colônia de Pescadores de Juruá* and *Sindicato da Pesca de Juruá*), and political parties.

membership in Botafogo and intermediate frequencies in the other areas (67%-78%). All or most household heads from Andirá (100%), Planeta (89%), and Botafogo (89%) participated in meetings for the LJER creation, while only a minority (29%) in Baixio lake did. A similar pattern was found for participation in the LJER management planning meetings, which presented high participation in most areas except in Socó (54%) and Baixio lakes (43%). Botafogo showed the highest value (78%) for participation in community/group meetings, and Socó lake the smallest (23%). Considering all of the above indicators, overall Botafogo exhibited the highest degree of social and political engagement, while Baixio and Socó lake presented the lowest ones.

The social capital index varied from 0.69 (Baixio lake) to 0.47 (Andirá).Social capital varied in a similar fashion among the management systems with levels of participation in *pirarucu* management. Participationin management systems, measured by household participation in labor-sharing groups (*mutirões*), varied from high to moderate levels: the highest value of 100% was in Baixio lake, followed by 92% in Socó lake, 89% in Antonina, 83% in Andirá, 78% in Botafogo, and 67% in Planeta (Table 3-5). Baixio lake also presented the largest proportion (71%) of households frequently involved in *mutirões*. When I asked why they joined *mutirão*, responses regarding a sense of collectivity appeared in all areas, with the highest values for Planeta (47%) and lowest for Baixio lake (17%), Socó lake and Andirá (13%). Trust in lending of materials to others also varied substantially among areas: Baixio lake (100%) and Planeta (89%) presented the highest levels of trust, while Botafogo (33%) and Socó lake (15%) exhibited the lowest levels. Norms of reciprocity and solidarity did not appear frequently in motivations for joining a *mutirão*. Norms of reciprocity were highest in Baixio lake

(33%) and lowest in Andirá (7%), and were not mentioned in Botafogo. Norms of solidarity varied from 44% in Antonina and 40% in Planeta and Andirá to 13% in Botafogo. All households in Baixio lake and Antonina and most in Socó lake (92%) and Botafogo (78%) participated in food sharing networks based on kinship and/or neighborhood. Frequent food sharing was more common in Botafogo (89%) and less in Socó lake (62%). Baixio lake presented the highest frequency of people who said they could count on most people in the community/group, while Andirá (17%), Socó lake (15%), and Botafogo (11%) reported the lowest frequencies.

Household heads listed several reasons for engaging in collective action. From qualitative coding, I identified 11 subthemes related to human relations and five subthemes of utilitarian motivations among 56 household heads participating in *mutirão* (Table 3-6). The most commonly-mentioned subthemes within the former were a sense of collectivity (18), norms of solidarity (17), norms of reciprocity (9), invitation (5), interdependence (4), and friendship/integration (4). Within the latter, the most common subthemes were efficiency/easiness (17) and satisfaction with work (5). Among reasons of 48 household heads for joining *pirarucu* management, I identified nine subthemes within human relations and 16 regarding utilitarian motivations (Table 3-7). The most frequently-mentioned subthemes within human relations were sense of collectivity (10), excitement (5), norms of solidarity (3), and integration (3). Among utilitarian motivations, the most common subthemes were income (14), natural resource conservation (10), livelihood (4), and management success (4). Overall motivations for engaging in collective action were markedly different between *mutirões* and *pirarucu* management: in the former, people reported to be guided mostly by human relations, while in the

latter, utilitarian reasons were predominant (Table 3-8). This pattern was found in all areas, except for Baixio lake, in which frequencies of human relations and utilitarian motivations were more balanced in the case of *pirarucu* management.

Discussion

Collective action is an important element of community livelihoods in the Amazon. Through *mutirões*, community members get together to clear land for agriculture, plant and harvest crops, produce manioc flour, clean the community area, build infrastructure (community houses, bridges etc.), clear the soccer field, take away fallen wood or grasses that impede access of canoes on waterways (*igarapés* or *furos*), guard lakes, *igarapé* mouths, or turtle nesting beaches against poaching, and organize community *festejos* (religious parties). Communities also count on social networks based on kinship and/or friendship for food sharing, child care, etc. These social networks, based on relations of trust, reciprocity and solidarity within the social group (bonding social capital), are the basis of a community's social and economic system of production and reproduction. Therefore, bonding social capital enhances connectedness and collective action within the community.

Collective action in *pirarucu* management involves collective decision making, monitoring each other's behavior, guarding of lakes and other aquatic bodies against free riders, as well as fishery management, and benefit sharing. As fisheries are common-pool resources, it is difficult to prevent others from using them, and use by one reduces the availability of the pool to others. Unless there is a high level of trust and effective norms of reciprocity, the possibility of free riding is likely to be high. In systems with dense social networks in which members are highly connected to each other, and they have frequent face-to-face interaction and long-term experience living together,

they therefore have more information about each other and their behavior, and free riding becomes much more costly and thus less likely (Adler and Kwon 2002). Thus, bonding social capital within communities is important for the collective good and enhances engagement in collective action.

Among multi-community management systems such as Planeta, both bonding and bridging social capital come into play. *Pirarucu* management there involves social arrangements within and between communities. In Planeta, young members from Botafogo and Antonina studying and living in town (authorized users) participated in management of *pirarucu* by forming guarding groups that rotated on weekends, replacing adults that stayed on week days in the floating house. Although they worked fewer days a year, they received the same amount from management as adults at the end of the year. Managers decided on equal payment because they understood the importance of participation by young managers. Youths comprised almost one-third of managers from Planeta, providing valuable human and social capital for *pirarucu* management. First, it reduced the period of time that household heads spent in guarding the floating house, thus allowing them more time for other livelihood activities in their communities. Second, the youths were healthier than the adults, most of whom were in their 40s and could no longer carry heavy weights due to serious back problems. Third, because they were sons, grandsons, nephews, cousins and/or brothers of adult managers (who were household heads), youths occupied a subordinate social status in decision making. Respect for elders is a strong norm in the social structure of rural Amazonian communities. Kinship and hierarchy, which Coleman (1988) calls “intergenerational social capital”, contributed to the density of the social

network, increasing trust and connectedness among members. And fourth, participation in *pirarucu* management strengthened the young generation's connection to the extractive reserve, to traditional livelihoods and to the collective defense of community territories. As the young of rural communities moved to town to study, they tended to be increasingly influenced by the urban culture and drifted apart from the traditional rural lifestyle, which was a concern to their families and local leaders. That way, older managers saw future possibilities of young people gaining benefits from the fishery and continuing their collective struggle.

Management systems varied substantially in terms of the personal and household indicators examined, independent of people's participation in *pirarucu* management. Baixio lake was composed of younger household heads, all of them born elsewhere, moving to the community some years before the reserve was created; most did not participate in the process of LJER creation or in the management planning meetings. They were mostly small farmers, Catholic, with low levels of education and relatively low social and political engagement. Baixio lake households were the richest in terms of average income, but they invested little in their material wellbeing. Antonina had a high proportion of household heads born in other areas, who were on average older and had lived in the community for a longer period of time than in Baixio. Most were small farmers, Catholic, with moderate levels of education, high incomes, big houses in the community, a moderate number of durable goods as assets, and a house in town. They presented moderate to high social and political engagement. Planeta had the oldest respondents, all of them Catholic, with equal proportions of small farmers as compared to other occupations such as students, retirees, and wage laborers. They

presented high levels of education, one of the biggest averages areas in agricultural plots, and one of the highest incomes from agriculture. In general, managers of Planeta could be considered the wealthiest among all areas, as they had one of the highest *per capita* annual income from productive activities, the biggest community houses, the highest number of durable goods items as assets, and a moderate proportion of people who owned a house in town. Botafogo differed from the other areas for its highest level of education, significant proportion of Protestants (although the majority of the group was Catholic), income from agriculture, and social and political engagement. Socó lake showed the greatest religious diversity and highest frequency of fisherman along with small farmers. They had small agricultural areas, enough for subsistence, and showed one of the lowest incomes from agriculture and the highest from extractivism (mostly due to fishing). Household heads there reported the lowest degree of social and political engagement, despite their high membership in formal organizations. This system was the only one in the LJER whose community (FG1) had an association. Finally, Andirá was the most complex management system, involving five communities. The dominant community (Cumarú) was indigenous. All household heads were Catholic, with low levels of education, and few people owned a house in town. They were the poorest group, exhibiting the lowest *per capita* income and small number of assets. As in Socó lake, they presented low levels of income from agriculture and high levels from extractivism. Andirá showed a moderate to high degree of social and political engagement.

Two indicators varied with participation in *pirarucu* management: *per capita* annual income and social capital. Areas with higher income *per capita* tended to have

higher participation in management. It could be that annual income reflected higher income from *pirarucu* management, and thus high income would attract more people to the activity than low income. However, this was not the case: the area with highest participation (Baixio lake) presented one of the lowest incomes from management (US$ 190), while the one with lowest participation (Andirá) exhibited moderate income from the fishery (US$ 440). Another possibility is that *per capita* income was positively associated with social capital. Thus, areas with high social capital area would be the ones able to mobilize more resources and have higher economic gain. Grootaert and Narayan (2004) found a positive relationship between social capital and household welfare in Bolivia.

This discussion raises the key issue of whether higher social capital motivated higher participation in fishery management. In the present study, social capital overall was higher in areas with higher participation in management (Baixio lake, Antonina, and Planeta), and lower in areas with lower participation (Botafogo, Socó lake, and Andirá).This key finding thus confirms the hypothesis set forth earlier for this question. Group members more connected to each other by relations of trust, reciprocity, and solidarity, were more prone to act collectively. Baixio lake presented the highest social capital: this small group comprised kin related households connected by frequent, reciprocal relations of cooperation, based on high levels of trust and solidarity. Antonina was an intermediate size community, but mostly kin related, presenting high levels of social capital, and also exhibiting high cooperation and solidarity. Planeta exhibited moderately high social capital, given by high levels of trust, norms of solidarity and a stronger sense of collectivity than in other areas. Despite having members who were

not bound by kin ties, as well as having less experience of working together and less information about each other's behavior, they did have long-term friendships and a shared set of internal norms of solidarity and sense of collectivity. They trusted each other more as a group of collaborating managers than their peers from their own communities, probably because of known free riders from Antonina and Botafogo who were not involved in management of the Planeta complex of lakes. The other areas exhibited lower levels of social capital, varying slightly. Among those three, Botafogo showed a higher sense of collectivity; Socó lake showed higher cooperation; and Andirá presented higher trust and norms of solidarity.

In one way or the other, all management systems had a certain level of social capital that permitted them to collectively engage in a corresponding level of collective management of *pirarucu*. Systems with high social capital also had relatively high levels of participation in social networks, either *mutirões* or food sharing. All areas presented a high level of participation in *mutirões* regardless of their degree of participation in *pirarucu* management. Interestingly, the level of participation in *mutirão* was generally higher than in *pirarucu* management (except in Planeta), probably because people trusted more each other and were more used to the former kind of social relation. *Mutirão* for agriculture, which was the most common type of labor-sharing group, is an older and more established form of collective action within communities as part of their subsistence strategy. It can involve more people, depending on the level of group organization. In small to moderate size communities (e.g. Botafogo and Antonina), families invited others to join them in *mutirão*, and people were accustomed to collaboration, with or without expectations of future reciprocal behavior. In bigger

communities such as FG1 (from Socó lake), *mutirões* were organized in monthly meetings of the community association, in which associates assumed the commitment to participate, hence increasing trustworthiness in working for labor-sharing groups.

Pirarucu management, a market-oriented activity, usually involved more people than *mutirões*. It depends on labor availability more than on strict relations of cooperation among members, although that also plays a role. Labor force availability was key for patrolling areas against free riding and for the *pirarucu* fishery, as a single fish could weigh more than 100 kg. Therefore, task contingencies explained differences in the value of social capital between these social networks (Adler and Kwon 2002). *Mutirão* was more dependent on trust and cooperation; thus it was better to have embedded ties with repeated exchanges between a small number of actors (denser networks). *Pirarucu* management also depended on trust and cooperation, but required more actors and involved a stronger element of economic rationality. Thus, the former required fewer but stronger ties, while in the latter it was better to have more ties even if they had weaker connections.

Both humanistic and utilitarian motivations guided people's motivations for engaging in collective action. However, motivations for joining *mutirão* were more consensual than for *pirarucu* management. In the former, there were 16 reasons, while in the latter, 25. For *mutirão*, a sense of collectivity, norms of solidarity and reciprocity were mentioned by 44 out of 56 household heads; efficiency or easiness came out in 17 out of 22 responses. For *pirarucu* management, a sense of collectivity and excitement appeared in 15 out of 27 responses, while income and natural resource conservation were reported by 24 out of 52 people. Another important difference between *mutirão*

and *pirarucu* management is that the former was motivated mostly by human relations, while the latter involved more pragmatic thinking related to income, subsistence and fishery conservation. Interestingly, this rational thinking was not always self-centered. Individual gains (income) were not the main motivation for engagement in *pirarucu* management in the LJER. For example, managers of Baixio lake invested most income from management on water pumps for the collective benefit of the community, as households did not have piped water, and instead they had to get water from the river. In Botafogo, every year managers invested their income from management either on fuel or new parts for the community's power generator, as they had no electricity. In Socó lake, they decided for two years not to sell fish, but to split it among all families in Socó and FG1 for consumption, even if most of them did not participate in management.

Alongside motivation, Adler and Kwon (2002) pointed out two other key features individuals or groups must attend to in order to activate social capital: ability and opportunity. There certainly exist differences in capacity to manage fishery resources across areas, which I did not measure; however, groups tend to learn and improve their management capacity over time. Regarding opportunity, it is interesting to note that *pirarucu* management is a male activity, and there are barriers for women's participation, which may vary across areas. In general, within LJER communities there is a gender division of labor common among rural areas, in which women are more dedicated to agriculture, domestic labor and child care, while men are in charge of fishing, hunting, and construction, besides agriculture. In all areas, female participation in management consisted in voluntarily cooking during the *pirarucu* fishery in solidarity

with men. Only in Andirá were women involved in guarding the floating house, as they would take small children with them and accompany the men. In other management systems, women were not able to participate, as they could not leave their small children alone. This has important implications, not only for the social capital of groups, but for interpretation of the results of this study: communities with divorced or widowed women with small children as household heads (e.g. Botafogo) exhibit less participation in management.

Concluding Remarks

- Social capital is key for community livelihoods in the Amazon. Social relations of cooperation based on trust, norms of solidarity and reciprocity are invisible forces that unite groups within (bonding) and among communities (bridging);
- Community social capital is an important attribute of social relations that foster collective action for *pirarucu* management;
- People have various motivations for engaging in *pirarucu* management, both humanistic and utilitarian, focusing on the collective gains and not only on their individual benefits;
- This study focused on bonding and bridging social capital and whether it fosters collective action for *pirarucu* management. The key finding from this study is that indeed, greater social capital does tend to correspond with greater participation in collective action required for sustainable *pirarucu* management;
- At the same time, communities are embedded in a broader institutional context of co-management of the LJER, in which the vertical connections (linking social capital) from communities to the community representative association (ASTRUJ) and the federal government (ICMBio) also play an important role in motivating and supporting the emergence and outcomes of collective action for sustainable resource management. These issues are approached in the next Chapter.

Table 3-1. Number of households in communities in the LJER, relative frequency of participation in *pirarucu* management, and sampling data.

Management area	Baixio lake	Antonina	Planeta	Botafogo	Socó lake	Andirá
Participation in *pirarucu* management	N=6 (86%)	N=14 (82%)	N=28 (80%) Botafogo (N=13) Antonina (N=15)	N=7 (70%)	N=15 (33%) Socó (N=6) FG1 (N=9)	N=18 (31%) FG1 (N=4) Cumarú (N=10) Escondido (N=2) Itaúba (N=1) Ig. Branco (N=1)
Communities (N of households)	Socó (N=7)	Antonina (N=17)	Total N=35 Botafogo (N=16) Antonina (N=19)	Botafogo (N=10)	Total N=45 Socó (N=7) FG1 (N=38)	Total N=58 FG1 (N=38) Cumarú (N=12) Escondido (N=3) Itaúba (N=1) Ig. Branco (N=4)
Sampled households	N=7	N=9	N=9	N=9	N=13	N=12
Gender (male respondents)	86%	89%	100%	89%	92%	83%

Table 3-2. Personal characteristics of household heads of the six management systems in the LJER.

Indicator/Management area	Baixio lake (N=7)	Antonina (N=9)	Planeta (N=9)	Botafogo (N=9)	Socó lake (N=13)	Andirá (N=12)
Age (average ± standard deviation)	31.6 ± 14.5	38.7 ± 5.2	45.4 ± 15.3	40.9 ± 8.3	39.5 ± 13.7	40 ± 10.4
Origin:						
Same community	0%	33%	44%	56%	38%	58%
Other area	100%	67%	56%	44%	62%	42%
Time of residence	15.9 ± 14.6	28.3 ± 12.5	34.2 ± 13.7	36.8 ± 11.1	27.3 ± 15.3	32.6 ± 12.5
Years of schooling	2.3 ± 1.4	4.3 ± 3.5	5 ± 3.2	5.7 ± 2.9	3.3 ± 3.6	2.7 ± 2.4
Religion:						
None	14%	0%	0%	0%	8%	0%
Catholic	86%	100%	100%	78%	85%	100%
Protestant	0%	0%	0%	22%	8%	0%
Occupation:						
Farmer	86%	67%	44%	78%	38%	67%
Fisherman	0%	0%	11%	0%	38%	8%
Other (wage labor, student, retired, carpenter)	14%	33%	44%	22%	23%	25%

Table 3-3. Characteristics of households from the six management systems in the LJER.

Indicator/Management area	Baixio lake (N=7)	Antonina (N=9)	Planeta (N=9)	Botafogo (N=9)	Socó lake (N=13)	Andirá (N=12)
Number of household members	4 ± 1.5	5.3 ± 1.7	4.1± 2	4.9 ± 2	5.4 ± 2.4	6.1 ± 2.8
Agricultural plot size (number of *covas*)	8,857 ± 3,590	10,889 ± 4,833	11,555 ± 9,258	11,000 ± 9,500	4,684 ± 5,427	8,550 ± 4,520
Wealth:						
House area (m^2)	39.7 ± 35.6	59.8 ± 32.4	73.6 ± 47.5	60.6 ± 21.1	60.4 ± 17.7	62.4 ± 20.8
Own house in town	14%	78%	67%	38%	31%	17%
Total number of assets	7.3 ± 4.5	12.8 ± 3.1	17.4 ± 9.4	15.6 ± 8.4	11.9 ± 4.8	8.2 ± 3.4
Annual income (US$[1]) from:						
Agriculture	2,856 ± 2,411	3,059 ± 3,053	3,691 ± 3,981	3,760 ± 3,912	1,713 ± 3,697	1,797 ± 2,921
Extractivism	932 ± 750	494 ± 737	471 ± 817	598 ± 1,526	1,400 ± 1,632	1,321 ± 1,822
Non-production (wage, services, and governmental social benefits)	9,550 ± 4,575	8,427 ± 4,914	6,523 ± 4,827	7,214 ± 4,641	8,679 ± 7,727	8,337 ± 5,532
Total income (US$)	13,339 ± 6,232	12,076 ± 6,669	10,732 ± 5,254	11,191 ± 7,634	11,809 ± 9,244	11,457 ± 5,312
Per capita annual income (US$)	3,335	2,279	2,618	2,284	2,186	1,878

[1] I considered the value of the dollar at the time of the data collection, which was 1:2 in relation to Brazilian Real.

Table 3-4. Social and political engagement of households from the six management systems of the LJER.

Indicator/Management area	Baixio lake (N=7)	Antonina (N=9)	Planeta (N=9)	Botafogo (N=9)	Socó lake (N=13)	Andirá (N=12)
Role in the community	86%	78%	89%	89%	54%	100%
Membership to formal organizations	86%	89%	78%	100%	92%	83%
Membership to ASTRUJ	43%	78%	78%	100%	38%	67%
Participation in the ER creation	29%	67%	89%	89%	69%	100%
Participation in meetings of the management plan	43%	89%	89%	100%	54%	83%
Frequent participation in community/group meetings	43%	56%	67%	78%	23%	58%

Table 3-5. Social capital indicators and index scores (in brackets) of households from the six management systems of the LJER.

Indicator/Management area	Baixio lake (N=7)	Antonina (N=9)	Planeta (N=9)	Botafogo (N=9)	Socó lake (N=13)	Andirá (N=12)
Social capital index[a]	0.69	0.66	0.60	0.51	0.49	0.47
Cooperation:						
Participation in *mutirões* (%)	100% (5)	89% (5)	67% (4)	78% (4)	92% (5)	83% (5)
Frequent participation in *mutirões* (%)	71% (4)	56% (3)	-	56% (3)	31% (2)	-
Trust:						
High trust in lending materials	100% (5)	67% (4)	89% (5)	33% (2)	15% (1)	67% (4)
Reciprocity:						
Norms of reciprocity in participation in *mutirões*	33% (2)	22% (2)	13% (1)	0% (1)	13% (1)	7% (1)
Solidarity:						
Norms of solidarity in participation in *mutirões*	33% (2)	44% (3)	40% (2)	13% (1)	21% (2)	40% (2)
Participation in food sharing	100% (5)	100% (5)	-	78% (4)	92% (5)	-
Frequent food sharing	71% (4)	67% (4)	-	89% (5)	62% (4)	-
Proportion of people who count on the majority of the community/group	43% (3)	22% (2)	22% (2)	11% (1)	15% (1)	17% (1)
Social cohesion:						
Sense of collectivity in participation in *mutirões*	17% (1)	28% (2)	47% (3)	33% (2)	13% (1)	13% (1)

[a] Values were scored from 1 (low) to 5 (high) according to the degree of social capital (1: <20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: >80%). The index varies from 0 to 1 and it is proportional to the number of indicators.

Table 3-6. Reasons for engagement in *mutirão* of household heads in the six management systems of the LJER.

Indicator/Management area	Baixio lake (N=7)	Antonina (N=8)	Planeta (N=9)	Botafogo (N=7)	Socó lake (N=12)	Andirá (N=13)	Total (N=56)
Human relations:							
Sense of collectivity	2	4	5	4	3	0	18
Norms of solidarity	1	4	3	2	3	4	17
Norms of reciprocity	2	3	1	0	2	1	9
Invitation	1	0	1	1	0	2	5
Interdependence	0	2	2	0	0	0	4
Friendship / integration (*amizade/entrosamento*)	1	0	0	0	1	2	4
Excitement (*animação*)	0	0	0	0	0	3	3
Incentive to participate	0	1	1	0	0	0	2
Kinship	1	0	0	0	1	0	2
Habit	0	1	1	0	0	0	2
Concern with others' opinions	0	0	0	0	1	0	1
Utilitarian motivations:							
Efficiency/easiness	1	2	4	3	3	4	17
Satisfaction with work	1	0	0	0	2	2	5
River	0	0	0	0	0	1	1
Natural resource conservation	1	0	0	0	0	0	1
Livelihood	1	0	0	0	0	0	1

Table 3-7. Reasons for engagement in *pirarucu* management of household heads in the six management systems of the LJER.

Indicator/Management area	Baixio lake (N=6)	Antonina (N=7)	Planeta (N=9)	Botafogo (N=7)	Socó lake (N=12)	Andirá (N=7)	Total (N=48)
Human relations (total):							
Sense of collectivity	2	1	3	2	1	1	10
Excitement (*animação*)	1	0	0	0	1	3	5
Norms of solidarity	0	0	1	0	0	2	3
Integration (*entrosamento*)	1	0	0	0	1	1	3
Pleasure	0	0	0	1	0	1	2
Invitation	1	0	0	0	0	0	1
Leadership	0	0	1	0	0	0	1
Conflict resolution	1	0	0	0	0	0	1
Mistrust	0	0	1	0	0	0	1
Utilitarian motivations:							
Income	1	4	4	3	1	1	14
Natural resource conservation	0	1	4	3	2	0	10
Livelihood	0	1	1	0	0	2	4
Management success	1	0	0	1	1	1	4
Legal fishing	0	2	0	0	1	0	3
Reserve	0	0	0	0	0	3	3
Lack of rule compliance	0	0	0	0	1	2	3
Knowledge acquisition	1	0	1	0	0	0	2
Appreciation for fishing	1	0	0	0	0	1	2
Easiness	0	0	0	0	0	1	1
Fish	0	0	0	1	0	0	1
Lakes	0	1	0	0	0	0	1

Table 3-7. continued

Indicator/Management area	Baixio lake (N=6)	Antonina (N=7)	Planeta (N=9)	Botafogo (N=7)	Socó lake (N=12)	Andirá (N=7)	Total (N=48)
Show to Juruá town that reserve is good	0	0	0	0	0	1	1
Involvement with guarding	0	0	0	1	0	0	1
Docked pay due to absence in patrolling	0	0	1	0	0	0	1
Domestic labor	0	0	0	0	0	1	1

Table 3-8. Motivations for engaging in collective action in the LJER.

Indicator/Management area	Baixio lake	Antonina	Planeta	Botafogo	Socó lake	Andirá	Total
Mutirões (N)	7	8	9	7	12	13	56
Human relations	10	17	17	8	13	14	79
Utilitarian reasons	6	2	4	3	6	9	30
Pirarucu management (N)	6	7	9	7	12	7	48
Human relations	6	1	6	3	3	9	28
Utilitarian reasons	4	9	12	10	6	13	54

CHAPTER 4
CO-MANAGEMENT INSTITUTIONS FOR SUSTAINABLE *PIRARUCU* MANAGEMENT

Introductory Remarks

Co-management of extractive reserves shares limited management rights over natural resources to communities, because resource management generally depends on expensive technical studies with little local knowledge input, as seen in Chapter 2. One exception is fisheries management, in which traditional management for single species stocks has shifted to more integrative and participatory ecosystem-based approaches, which are better able to deal with complexity and uncertainty (Berkes 2003, Chapin et al. 2009). Participatory management has decentralized authority and responsibility to local communities under labels of community-based fisheries management or fisheries co-management (Berkes et al. 2001), incorporating local knowledge and practices (Castro 2000, McGrath 2000, McGrath et al. 2005, 2008). Local management of *pirarucu* (*Arapaima* sp.), discussed in this chapter, is a good example of successful application of fisheries co-management.

Fisheries pose major challenges to sustainable management: these are classic examples of common-pool resources (CPRs) for which exclusion is difficult and joint use involves subtractability (Berkes and Farvar 1989). Thus, overexploitation leads to resource depletion (Acheson 2006). Overcoming these challenges involves addressing collective-action dilemmas related to conflicts between individual and collective rationalities determining optimal resource use. Two collective-action dilemmas need to be solved (Acheson 2006). The first involves defining and securing property rights to CPRs, which provide users with incentives to maintain them. The second requires establishing effective governance mechanisms to rule CPR use.

In the co-management of extractive reserves, government gives a degree of autonomy to communities to design local institutions for governing small-scale fisheries. Communities have access, withdrawal and management rights and thus the incentives to maintain these CPRs. However, the conditions for sustainable management vary depending on a complex set of relationships among resources, resource systems, actors, governance systems, and the social, economic and political settings in which these are embedded (Agrawal 2003, Ostrom 2007, 2009).

Small-scale fisheries co-management provides an interesting case to examine the conditions under which communities and government are able to devise successful management institutions for CPRs.In the Amazon floodplains, the conditions under which fisheries are managed vary among areas, offering different scenarios under which different governance arrangements and other factors can be related to sustainable management.

Small-scale Fisheries in the Amazon

The Amazon floodplain or *várzea* is a dynamic landscape encompassing the major river channel, forested natural levees bordering channels, permanent floodplain lakes and seasonally inundated grasslands in the transition between levees and lakes (McGrath et al. 2005). These areas are subject to marked seasonal flooding, with water levels varying about 12m every year. In the wet season, the whole ecosystem is flooded, while in the dry season only the main river, some connecting channels and lakes still have water (Junk 1997). The flood pulse affects temporal and spatial habitat and food availability for aquatic organisms, determining seasonal patterns of fish migration and fishing dynamics (Crampton 1999, Castro 2000).

Floodplains are amongst the most important aquatic systems in the Amazon due to its high biodiversity and economic importance for fisheries (Crampton 1999, Capobianco et al. 2001). Small-scale fishing in the floodplain is a significant component of local livelihoods, holding valuable cultural, economic, and biological meaning (Castro 2000). Fishing has for long been a traditional subsistence activity, and became economically important during the first rubber boom at the end of the 19th century and beginning of the 20th century. Small-scale fishing regained commercial importance after the 1960s when fishing was modernized (Castro 2000).

Development of commercial fisheries combined with their poor regulation led to fish overexploitation and numerous conflicts throughout the Amazon floodplain (Hartmann 1989, Barthem 1999, Castro and McGrath 2001). Conflicts over control of resources and territories motivated the organization of local populations against outsiders and development of local management schemes to protect lake systems (Ruffino 2008), under the influence of the Catholic Church. Lake management was based on the idea of rational use of natural resources and their protection for future generations (Derickx 2007). These management schemes emerged between the 1960s and 1980s and are still in use today in many parts of the Amazon (Castro 2000, McGrath et al. 2005). Lake management consists in lake system zoning: communities define lakes for commercial fishery, subsistence (e.g. limiting fishing technology and effort), and preservation, in which no fishing is allowed. Preservation lakes serve as source-sink, so that they can replenish fish stocks in lakes under use. Lake functions are alternated by communities over time. Rules are decided, monitored and enforced by communities (Castro and McGrath 2001).

The Catholic Church was broadly influential in the process of socio-political organization of rubber tappers and riverine peoples in the Amazon, aggregating sparse households into communities and stimulating the rise of social movements (Castro 2000, Allegretti 2002, Pacheco 2010), which culminated with the creation of extractive reserves (Allegretti 1990). Although not so articulated, the history of organization and control of territories in the floodplains resembles the trajectory of the rubber tappers in the Amazon uplands (Castro 2000).

Within small-scale fisheries, *pirarucu* co-management, hereinafter called *pirarucu* management, is recognized as a successful example of resource management in which shifting management authority from the central government to communities has resulted in better social and environmental outcomes (Castello et al. 2009). It also illustrates the shift from conventional single-species management to ecosystem management in which multiple fisheries and aquatic organisms are conserved.

***Pirarucu* Management**

Pirarucu, the world'slargest scaled freshwater fish, is endemic to the Amazon basin. This top-predator can weigh up to 200 kg and achieve 3 m in length. Although there are some ecological studies on natural populations (Castello 2007, 2008*a*, *b*, Arantes 2009, Arantes et al. 2010, 2013), certain aspects of its biology and ecology are still unknown. It is considered to be relatively sedentary, moving short distances across different habitats in flooded forests (Castello 2008*a*). However, a few individuals were recorded moving long distances, up to 300 km in a year (G.L. Stokes, pers. comm.). When waters are low, *pirarucu* move to lakes and remaining water bodies where their concentration is higher in the dry season. Like other floodplain fish in the Amazon, the *pirarucu* life cycle is regulated by the flood pulse. The *pirarucu* builds nests and

reproduces in flooded forests when the water is rising, where it guards its offspring for three months (Castello 2008*b*). It has relatively late sexual maturity and lays small clutches of eggs. As an obligatory air-breathing fish, the *pirarucu* needs to gulp air at regular intervals (every 5-15 min) making it easy to harpoon by fishers, especially in the open waters of lakes.

The *pirarucu*'s geographic distribution, taxonomic and conservation status are uncertain (Castello and Stewart 2010). The genus *Arapaima* was considered to be monotypic (*A. gigas*) until recently, when studies revealed four species and described a new species of *Arapaima* (Stewart 2013*a*, *b*). *Arapaima gigas* is listed in Appendix II of the Convention of International Trade of Endangered Species (CITES) as data deficient and may be at risk of extinction if no protective measures are taken. The main threat to *pirarucu* is overfishing as its meat is highly prized in the Amazon. It is one of the dominant species in the regional black market, being commercialized either iced or salted and dried for future consumption (Santos et al. 2006).

Conservation strategies for *pirarucu* have shifted in the past few decades from government control and fishing bans to more inclusive management practices that integrate local and scientific knowledge (Castello et al. 2009). Scientists and local fishers in Mamirauá Sustainable Development Reserve in Amazonas state (Brazil) jointly developed a simple count method for *pirarucu* in lakes during the dry season (Castello 2004). Experienced fishers can reliably count juvenile (measuring 1.0 to 1.5 m) and adult *pirarucu* (bigger than 1.5 m) in lakes based on visual or acoustic identification of individuals at the moment of aerial breathing, and through detection of waves of individuals surfacing more or less simultaneously. These knowledge and skills

are acquired from practical experience of artisanal fishing in which fishers observe and listen to *pirarucu* surfacing and catch them immediately after with harpoons. Less experienced fishers can be trained to use these count techniques. *Pirarucu* counts by fishers in closed lakes using these methods were strongly correlated with mark-recapture abundance estimates conducted by scientists (Castello 2004).

Development of this cost-effective count method allowed sustainable harvest levels to be calculated for natural populations. Communities managing *pirarucu* can obtain annual permits from the federal government agency (Brazilian Institute for the Environment and Renewable Natural Resources- IBAMA) to catch up to 30% of adults counted within managed lakes. This harvest quota is considered to be sustainable,based on documented increases in *pirarucu* size and abundance in managed lakes compared to unmanaged lakes in the Mamirauá Reserve (Castello et al. 2009, 2011).

Pirarucu management provides an interesting case for an examination of how governance mechanisms influence the sustainable use and conservation of natural resources in co-management systems. *Pirarucu* is well suited for management in floodplain lakes (McGrath et al. 2005): it is non-migratory and sensitive to disturbance. If management rules are followed and lakes are well protected, overfishing can be avoided and populations will have the opportunity to increase through recruitment or immigration.Some environmental factors, such as lake size and depth, are also known to affect *pirarucu* abundance (Arantes et al. 2013).

This study aimed to investigate how diverse aspects of social-ecological systems, especially the co-management arrangements involving government and communities in

extractive reserves, affect the sustainability of *pirarucu* management. My research question was: *Considering the co-management of* pirarucu*, what are the social-ecological conditions leading to sustainable resource management in Brazilian Amazon extractive reserves?*

Study Area

This study was conducted in the Lower Juruá Extractive Reserve (LJER), a federal protected area managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) covering nearly 188,000 hectares of forests and aquatic systems in central-western Brazilian Amazon (Figure 4-1). The JLER was created in 2001 by demand of local residents represented by the Rural Workers Association of Juruá (ASTRUJ), to guarantee land rights and control over fishing territories (ICMBio 2009).In the LJER there were 15 settlements, hereinafter called communities, where there resided 132 families constituted by 748 people, 643 of which were residents and 105 were authorized users (former residents living in Juruá town; ICMBio 2009). Residents are former rubber tappers from families that had resided in the area for many generations. Their main activities are small-scale agriculture, fishing, forest extractivism, small animal husbandry and small-scale cattle ranching.

Management of *pirarucu* began in the LJER due to demand by local communities and at the joint initiative of ASTRUJ and IBAMA.[25] ASTRUJ and IBAMA organized the visit of community representatives to the Mamirauá Sustainable Development Reserve in 2003, where they learned about the management of the *pirarucu* fishery there from local fishers. In 2004, ASTRUJ decided to invest its money and complement it with a

[25]At that time, IBAMA was responsible for management of federal protected areas. In 2007, this responsibility shifted to ICMBio, but IBAMA remained responsible for licensing*pirarucu* management.

bank loan to purchase three floating houses for community monitoring in strategic locations of the LJER. *Pirarucu* management started in 2006 in three areas and was later expanded to another three, involving a total of eight communities in management of six social-ecological systems: Botafogo, Antonina, Planeta complex, Baixio lake, Socó lake and Andirá river (Figure 4-1). Certified fishers from the Mamirauá Institute conducted *pirarucu* counts at the LJER in the first two years.In 2008, fishers from the LJER were trained and assumed counting responsibilities.

In all six systems, communities had autonomy to design and modify local rules, define membership and control access to resources. They were also responsible for monitoring rule compliance and organizing the *pirarucu* management process in their territories, involving planning, counting and fishing, and making decisions on how benefits should be distributed among members. ASTRUJ coordinated *pirarucu* management in the LJER, being responsible for monitoring *pirarucu* counts and fishing in the six areas. The association also represented communities in their communication with governmental organizations (e.g. communicating local demands, requesting management quotas, and reporting *pirarucu* counts and fishing off-take to IBAMA) and private parties (e.g. applying for bank loans, negotiating prices and the selling of *pirarucu* and other fish species with commercial boats). IBAMA was responsible for setting management quotas based on counts from the previous year, issuing fishing permits, and sanctioning illegal fishing, transporting, and commercialization outside the protected area. Within LJER and its zone of influence, it was ICMBio’s role to monitor and sanction illegal fishing, transporting and commercialization of fishing products and

to support communities in conflict resolution, as well as support ASTRUJ in the coordination of *pirarucu* management.

Methods

Co-management arrangements involving government and communities varied among the six systems implemented for *pirarucu* management in the LJER. I therefore carried out a comparative case study analysis (Yan 2003) to investigate the importance of various factors theorized in the CPR and fisheries literatures and based on previous work on fisheries in the Amazon to account for the sustainability of *pirarucu* management in the LJER. Through an interdisciplinary approach and employing both qualitative and quantitative methods, I collected data on multiple explanatory factors (the independent variables) potentially affecting the sustainability of *pirarucu* management (the dependent variable).

From April 2012 to May 2013, I studied the six social-ecological systems of *pirarucu* management in the LER (Figure 4-1). Three of these systems (Botafogo, Antonina, and Baixio lake) were managed by single communities (Botafogo, Antonina, and Socó, respectively), while in the others, representatives of two or more communities participated in management: a) the Planeta complex of lakes (Planeta) involved some managers from Antonina and Botafogo; b) Socó lake involved managers from FG1 and Socó; and c) Andirá involved managers from five communities inhabiting or using the Andirá river (Forte das Graças 1 – FG1, Cumarú, Escondido, Itaúba and Igarapé do Branco – Ig. Branco). These six different management systems, hereinafter also referred to as social-ecological systems, combined community management of *pirarucu*

in a set of geographically close water bodies[26] in co-management with the government, including the joint definitions of local norms and rules as related to governmental regulations (Salgado 2015).

I determined the sustainability of management systems (management outcome - O) by their overall increase (sustainable) or decrease (unsustainable) in *pirarucu* stocks over time, as measured by annual counts of juvenile and adult individuals carried out by trained fishers from 2006 to 2012. I gathered data on annual counts from ASTRUJ's reports to IBAMA, which serve as the basis for setting official management quotas for the following year, as well as through participant observation of *pirarucu* counts in the six systems in 2012.

Then, I examined numerous potential factors affecting *pirarucu* stocks, based on knowledge of *pirarucu* ecology and on common property theory (Table 4-1). I caracterized each area in terms of its resource system, social actors, governance system, and interactions among them, based on Ostrom's framework for social-ecological systems (Ostrom 2007, 2009, McGinnis and Ostrom 2014). I did not measure the broader external context as the six management systems were relatively close and were subject to similar external drivers in terms of their shared social, economic and political settings.

In terms of resource system (RS) characteristics, I measured variables pertaining to habitat and food availability for fisheries, as well as management system size and boundaries (based on Agrawal 2003 and Arantes et al. 2013). The RS variables

[26] Not all water bodies (e.g. rivers or lakes, streams, channels) are connected throughout the year; some lakes may be temporarily isolated in the dry season, as connecting channels may get dry or too shallow during this period.

included: water surface area (considering all aquatic environments within the system in the dry season); depth of flooding[27] (measured in the dry season when *pirarucu* is counted and system boundaries are clearer); clarity of system boundaries (defined as within or outside the protected area, which make their limits more or less clear); location of management system in relation to communities responsible for its management, and distance to town, measured from its access point.

In relation to social actors (A), I considered the total set of users who had rights to fish in the management systems (e.g. for subsistence), and whether they were involved in *pirarucu* management, as well as management group size. Users who fished in these systems without permission (outsiders) were not included, as it is hard to measure illegal activities. I characterized actors through variables influencing community organization as predicted by collective action (Olson 1965) and common property theory (Agrawal 2003): size (number of households; number of managers; proportion of users involed in management); socioeconomic attributes measuring group heterogeneity (age class, religion, education, occupation, main livelihood, wealth); leadership (presence of visionary leaders who made efforts to guide the group to sustainable management practices); and social capital (trust and shared norms).

Governance system (GS) characteristics refer to past experience of collective protection of lakes; community enrollment in *pirarucu* management; collective-choice rules defining rights to participate in decision making; institutional arrangements known to affect the success of common property regimes (monitoring, sanctioning and conflict

[27] Following Arantes et al. (2011), it was measured from the bottom of aquatic environment to the maximum level reached by the last flooding shown by a ring-mark in nearby trees. This makes depth of all environments comparable, as lakes usually become disconnected from other water bodies in the dry season and retain water even if these are receding elsewhere.

resolution; Ostrom 1990); and support from governmental and non-governmental organizations (ICMBio and ASTRUJ).

I also assessed variables regarding interactions (I) among factors: the importance of the resource system to users (in terms of subsistence and income); and the overlap between residence and resource location, based on Agrawal (2003).

For measuring resource system characteristics, I conducted participatory mapping and field recognition of lakes with key community informants (Table 4-2). With that information, I was able to identify and characterize lakes and other aquatic environments within management systems. In the field, I mapped all areas with a GPS and took depth measurements at their deepest points as indicated by key informants (fishers). In addition, I measured resource system areas and locations through *Landsat 5 TM*[28] satellite images from the dry season period.

For both actors and governance systems, I employed a variety of methods of data collection (Table 4-2). I held community meetings in the six areas to gather information on past history of resource system governance and on the *pirarucu* management process. In order to characterize communities, governance, and perceptions about *pirarucu* management, I conducted semi-structured interviews with a random sample[29] of people from communities involved in management systems, including both male and female heads of the family when possible. Some people engaged in two management systems (e.g. members of Botafogo community participating in management in Botafogo and Planeta systems; FG1 members involved

[28] Available at http://www.inpe.gov.br; accessed in 2014.

[29] I interviewed both male and female heads of all households in communities that had up to ten houses, and at least 30% of households in larger communities.

in management of Socó lake and Andirá systems) were interviewed twice, using slightly different questionnaires for the two areas. Questionnaires for single- and multiple-community management were almost the same, except for some questions that did not make sense when involving multiple communities and that were suppressed (e.g. With what frequency do you share food in the community?) or adapted (e.g. If you need help, with how many people do you count on in the community/management group?). In addition, I collected data on ICMBio and ASTRUJ through semi-structured interviews with key informants. These interviews focused on how these organizations provided support for *pirarucu* management. I conducted participant observation of communities, ASTRUJ and ICMBio throughout the *pirarucu* management process in the six areas, which included meetings for management organization, planning and evaluation, rule making, counts, fishing, monitoring, commercialization, and profit sharing. During participant observations, I also held informal conversations with leaders and other community members, regardless of whether they were involved in management. Research instruments are presented in Appendix A.

Results were organized into a framework based on the type of explanation (RS, A, GS, and I), permitting an analytical review of the many explanatory variables in order to identify those whose values or categories differed among systems in terms of increased or decreased *pirarucu* stocks over time. Because there were many variables for each concept noted among the explanatory factors listed above, I chose to present only those variables that differed between systems with increased or decreased *pirarucu* abundance, to facilitate interpretation of results.

Results

Of the total 97 households in the eight communities involved in *pirarucu* management, I interviewed a random sample of 48 households, totaling 108 interviews with 88 people. I conducted semi-structured interviews with two representatives of ASTRUJ and two of ICMBio and one meeting with key community/group members with each of the six management systems.

Management Outcomes

Pirarucu management was successful in the LJER as total fish counts increased from 1,300 to 4,498 over six years. From 2006 to 2012, most systems exhibited an increase in *pirarucu* abundance. However, the increases ranged widely, from 26% to 597%, and two systems exhibited a slight to moderate decrease (Figure 4-3; Table 4-3; Table 4-5). A high increase was found in Planeta (O1.1a), whose fish population increased every year beginning with 455 and reaching 3,172 individuals after six years of management. A moderate increase was found in Baixio lake, which started management in 2009. In three years, its fish population increased by 72% (32 to 55 individuals). Botafogo exhibited a low increase, from 131 to only 171 individuals (30%) over time (2007-2012). However, population counts reached a peak of 310 individuals in 2008, so the change was nonlinear. Similarly, Antonina varied from 636 to 800 individuals (26% increase) from 2006 to 2012, achieving its maximum in 2008 (887 individuals). Andirá exhibited a moderate increase (53%) from 2007 to 2011 (307 to 469 individuals); however, in the following year its *pirarucu* population dropped to 260 individuals, 15% less than when management started. Socó lake was the only system with a continuous decrease in *pirarucu* abundance, from 209 to 40 individuals (-81%) from 2006 to 2012.

The findings revealed great variability among the many variables measured for the six management systems (Table 4-5; Table B-1). In the next sections, I present data for numerous explanatory factors for the six management systems, in terms of indicators of their resource systems, social actors, governance systems, and interactions among these. Because there are many explanatory factors, because some vary more than others, and because some vary more systematically with regard to *pirarucu* populations, I focus my comparative analysis on those factors that offer the strongest explanations. I also focus on comparisons between the two management systems with the clearest contrasts in their patterns of fluctuation in *pirarucu* abundance, Planeta (largest increases) and Socó (continued declines).

Characteristics of Resource Systems

Planeta complex comprised ten lakes and their connecting channels, covering an area of 500 hectares. Compared to the other systems, it was of intermediate size (RS1.1) and had the deepest lake (23 m; RS1.2), called Sacado do Planeta. This deep oxbow lake used to be the main channel of Juruá river, but became isolated due to continuous sediment deposition as the river changed its course.This is a common phenomenon in geologically young river systems such as the Juruá.

Botafogo, Baixio and Socó comprised systems with relatively small and shallow lakes, whereas Antonina system consisted of relatively small and moderately deep lakes. In Botafogo, there were three lakes and a deeper stream connecting two of them, in which *pirarucu* concentrated in the dry season and thus where they were counted as well. Baixio and Socó systems comprised one managed lake each, and Antonina system had two managed lakes.

Andirá was the most different system in the LJER: managed environments included lakes, *ressacas* and *remansos*[30] along the Andirá river, which could get as deep as 15 m. It was also the largest system and the only one surrounded by *igapós* (black water flooded forest), which are less productive than *várzeas* (white water flooded forest; Fisher 1978).

Closed systems, such as Antonina, Planeta, Baixio and Socó lake, are more predictable than management systems along streams or rivers, such as Botafogo and Andirá (RS2). Open water bodies with permanent water discharge are more susceptible to a sudden fall or rise in water levels due to excessive drought or rain. Therefore, in Botafogo and Andirá systems it was more difficult to hold *pirarucu* stocks, as these could escape if aquatic environments become connected due to excessive rain (e.g. *repiquete*).

Except for Andirá, all of the management systems had clear boundaries (RS3), as these were located totally within the protected area territory. The Andirá river constitutes the southern limit of the LJER. Its lower portion is completely within the reserve, but its middle course is outside of it, and the management area falls partly outside the reserve boundaries, bordering another contiguous federal protected area.[31]

Planeta was the farthest system from its managing communites (17 to 34 km from Antonina and Botafogo, respectively; RS4.1), but it was also the closest system in terms of distance to town (20 km; RS4.2), making it the most vulnerable to invasions.

[30]*Ressacas* and *remansos* are both areas with slow water currents on the river margins.

[31]Tefé National Forest.

Andirá was the most distant system from town: its beginning and end were located 65 to 110 km from Juruá, respectively.

Characteristics of Actors

Three systems were managed by single communities (Botafogo, Antonina, and Baixio lake), with two others managed jointly by two communities (Planeta, by managers of Botafogo and Antonina; and Socó lake, by managers of FG1 and Socó) and one managed jointly by five communities or small localities (Andirá, comprised managers of Cumarú, Escondido, FG1, Itaúba and Ig. Branco; Table 4-3).

Botafogo community consisted of 11 households (A1.1) and had six other families that moved to Juruá town who were still considered authorized users, so they could fish for subsistence and maintain agricultural activities in the area. However, these six did not actively contribute to *pirarucu* management, as they were not involved in lake guarding and patrolling. Most households in Botafogo (78%) participated in *pirarucu* management within the Botafogo system.

Antonina community had 17 resident households and two other families considered authorized users (former residents) living in Juruá. Of these, most (80%) were involved in *pirarucu* management in the community (A1.2; A1.3).

Planeta was managed by 26 residents and authorized users of Botafogo (belonging to 14 households) and 23 residents and authorized users of Antonina (16 households; A1.2), totaling 49 people.

Baixio lake was managed by the smallest community (Socó), with only sixhouseholds (A1.1), most of which participated in *pirarucu* management in Baixio Lake (83%;A1.2; A1.3). These also participated in management at the Socó Lake, together with part of FG1 community (A1.2; A1.3).

Andirá comprised five communities that lived in the Andirá River (Cumarú, Escondido and Itaúba) or close to it (Ig. Branco and FG1). Some of these were actually localities,[32] with 1 to 4 families only (Itaúba, Escondido, and Ig. Branco). Except for FG1, most households participated in *pirarucu* management (A1.2; A1.3).

Socó lake had the most socially heterogeneous group of communities participating in its management, and Planeta and Antonina the least heterogeneous (A2.1). In terms of religion, Socó lake had people without any religious beliefs, as well as Catholics and Protestants (A2.1.1). However, in Botafogo the proportion of Protestants (27%) to Catholics (73%) was higher. The highest proportion of fisherman occupation (A2.1.2) and wealth disparity (A2.1.3) were also found for Socó lake.

All of the management systems had prominent leaders, although not all of them promoted a vision of long-term fishery sustainability (A3). The key leaders of Botafogo and Antonina communities led the management group in the Planeta management system.These were also founders of ASTRUJ in 1998, and have been involved in its board of directors since then. They shared a common view of *pirarucu* management as a strategy for collective organization as a means of improving livelihoods. In Baixio lake, the community's matriarch was the one who years before rented out the use of Socó lake to outsiders, creating conflicts with FG1 community and reducing fish stocks. The community president was also reported to illegally sell turtles and *pirarucu*, a practice condemned by other leaders, not necessarily because it was illegal, but because they knew those practices were unsustainable. In Socó lake, there were important leaders, but these were not considered to be legitimate by other community members. Finally, in

[32]Communities are bigger and have more infrastructure than localities, such as school, church, soccer field, communitary center, public telephone etc.

Andirá system, a strong leader organized monitoring of the management area. He was the first president of ASTRUJ and was a leader from the Solimões river, linked to the *Movimento de Educação de Base* (MEB)[33] from the Catholic Church. He got married and lived for many years in Cumarú community, bringing ideas of land struggle and lake preservation to this indigenous community. After he passed away in 2011, community members reported they felt less motivated and did not patrol the river that year.

Regarding social capital (A4), most people in Planeta, Baixio lake and Antonina had high trust in their peers, while this was found only for a minority in Botafogo, Andirá and Socó (A4.1). High levels of shared norms regarding reciprocity, solidarity and a sense of collective interest were found for the majority in Planeta, Baixio lake, Antonina and Andirá, and for a minority in Botafogo and Socó lake (A4.2).

Characteristics of Governance Systems

Some communities had a relatively long history of protecting lakes against outsiders (GS1). In Botafogo, families were descended from a landowner[34] who had engaged the community in the collective protection of lakes for more than 40 years before *pirarucu* management began (GS1.1). Lake protection was more recent in Antonina (started in 1995, 11 years before management) and Socó Lake (started in 1992, 14 years before management). In other areas, such as Planeta and Andirá, lakes started to be protected in 2005, only because of *pirarucu* management, two years before the first fishery.

[33] MEB was a political branch of the Catholic Church that was influential in the social and political organization of rubber tappers since the 1960s.

[34] This leader passed away in 2011, as well as the one from Cumarú.

In 2004, ASTRUJ decided to buy floating houses (GS3.1) to guard aquatic systems for management of *pirarucu*. They used their own finances and obtained a bank loan to buy three floating houses, which they installed in strategic positions on the Andirá river and Planeta complex. On the Andirá river, people were initially skeptical (GS1.2), but a key leader convinced people to form groups and guard the river through regular monitoring in the floating house. In Planeta complex, managers decided to guard a vast area of lakes that was close to town and used by urban fishers. Before guarding it, managers said in 2004 there were only 20 *pirarucu* in Sacado do Planeta. After two years guarding, they registered approximately 450 *pirarucu*. The management group also increased in size, from 16 in 2006 to 49 in 2012. In Botafogo, Antonina, and Baixio lake, people were generally in favor and actively supported management, while in Socó they were more reluctant, especially those against management practices (GS1.2). In 2012, there were a total of 95 people involved in *pirarucu* management in the whole LJER.

In all management areas, communities had the freedom to organize and to make their own rules, respecting general rules on *pirarucu* management, including counts by trained fishers to inform management quotas for the following year; a minimum catch size of 1.5 m; a prohibition on catching *pirarucu* over the quota or during the closed fishing season (*defeso*); and a prohibition on the use of gillnets. In addition, communities built their own schemes for monitoring, fishing, and sanctioning offenders. For example, some prohibited motorboats in lakes during the dry season so that *pirarucu* would not feel the noise and escape; some would not allow leaving gillnets alone at night during the *pirarucu* fishery, as young *pirarucu* (*bodeco*) could get trapped

and drowned; or would not allow catch of very big fish on lakes with difficult acccess, because they would not be able to carry them over long distance trails. These rules contributed to sustainability of *pirarucu* management. Rules were informal in all areas except in Planeta complex, where ICMBio incentivized the formalization of rules through an internal regiment (*regimento interno*; GS2.1) based on the experience of the Mamirauá reserve. The regiment at the Planeta complex management area was coordinated by ICMBio and ASTRUJ, and was built collectively by managers of Botafogo and Antonina through several meetings over two years. These institutions started the same process in Andirá, but could not advance as they concluded it was premature. The area still lacked a fishing agreement involving all users in Andirá (e.g. urban fishers, communities from LJER and Tefé National Forest, etc.), which was not developed due to lack of local ICMBio team's capacity to conduct such a process.

Overall, most people participated in decisions regarding *pirarucu* management in the systems I studied at the LJER (GS2.2). However, in Socó almost half of the community did not participate. Meetings were conducted by the community association, which required a small monthly payment to maintain membership. Those that did not pay and were not members were allowed to participate in meetings butcould not vote, nor elect the community's president.

The organizational schemes for community monitoring varied, and operated on different levels among management systems. In Planeta and Andirá, management groups were divided in subgroups who regularly took turns[35] in the floating houses to

[35]In Planeta, subgroups involved members of the two communities who stayed in floating houses for five weekdays every five weeks or one weekend every month (in the case of students). In Andirá, all groups mixed members of at least two communities and each stayed for one week every six weeks.

patrol management areas (GS3.1). The former involved ten groups using two floating houses that patrolled the Planeta complex of lakes day and night, 365 days a year, since 2005 (GS3.2). In the latter, six groups rotated turns in guarding the floating house in the dry season only, beginning in 2005. There was no monitoring in the wet season, when the *pirarucu* were spread out in the river and flooded forests. In Planeta, managers were only men, while in Andirá women were also involved in guarding the floating house. In the other areas, women were only involved in cooking during fishing, except in Botafogo where women had a more prominent role in community leadership and in forming groups with men guarding the lake entrance, on which the community built a small house on the other side of the river to protect also the turtle nesting beach. However, the Botafogo community lacked sufficient people to guard it, as some families moved to town because of lack of schooling in the community, and most men from the community were involved in *pirarucu* management at the Planeta complex.Those that remained in Botafogo could not invest much time in patrolling as they were few and had to dedicate their time to their agricultural livelihoods. However, they still conducted regular monitoring on a routine though non-systematic basis, as their agricultural plots were located close to the managed lakes. In Antonina, the entrance to managed lakes was very close to the community and they often fished for subsistence in these areas. So their continued presence did not require structured patrolling of their lakes. In addition, they did not have problems with outsiders as the area was becoming isolated (shallower each year, especially in the dry season)[36] due to change in the course of the Juruá river, such as in Sacado do Planeta lake. However, the management group in

[36]Sometimes it was necessary to walk and push the canoe, as it got stuck in a sand bank or mud in the middle of the river.

Antonina faced free riding problems with other members of the community, despite them all being of the same family. Baixio lake was located very close to Socó community, and managers reported almost no invasions there, so they did not have to regularly monitor it. They only patrolled the lake if they noticed fishing tracks. The same happened in Socó lake, although free riding was mentioned to occur there frequently.

Regarding sanctioning (GS4), Botafogo and Andirá respondents reported that they did not sanction rule offenders, while respondents in Baixio lake said there was no need to do it as there were no rule offenders. The Planeta complex group used to apply fines to those managers who were absent on their patrolling periods, and their money was discounted from the *pirarucu* fishery income at the end of the year. Andirá had the same rule, but did not apply it although absences from monitoring occurred frequently. Antonina used to report rule offenders in the community. Once they applied fines to a rule offender from the community and another time they reported it to ICMBio and the community member was fined, despite kinship relations between accusers and the offender. In Socó lake, community members reported conflicts to ICMBio, as these included physical aggression against one community management leader (who was also the community's president). ICMBio intervened through meetings and informal conversations with those against management, trying to strengthen trust with them, but with little or no success.

Success in resolving conflicts (GS5.1) was reported in three of the management systems: Planeta complex, Baixio lake and Antonina. In Planeta, major conflicts with urban fishers after community monitoring started in Sacado do Planeta were resolved

after it was officially included within the limits of the LJER.[37] In Baixio lake, community managers reported that conflicts with Arati (another community from the LJER) over the use of Baixio Lake were resolved after recognition of the lake as a managed area. In Antonina, community managers reported that conflicts among community members were worse in the beginning, but with continuous dialogue and sanctioning mechanisms applied by the managers, these were reduced.

In the other areas, communities faced difficulties to resolve conflicts that were internal (Botafogo and Socó lake) or external (Andirá). In Botafogo, the community was trying to solve conflicts with members who were free riding. In Socó lake, there were conflicts in the past between members of Socó and FG1 communities, and more recent conflicts within FG1. According to leaders of FG1, in the mid 1990s, the Socó's commmunity matriarch rented out Socó lake to a commercial fishery boat without asking FG1 for permission, as both were users of the lake. According to FG1 community members, the Socó leader had the Mayor's support, and as a result, no sanctions were applied. In 1998, the two communities agreed to reserve the lake for subsistence fishing only, which was recognized by a municipal decree along with other lakes in the region (including Antonina, Botafogo and in Andirá river). Some years later, the two communities agreed to reserve the lake for *pirarucu* management, but this decision was not consensual within FG1 and conflicts started between those in favor and against management. Those against *pirarucu* management decided to fish for commercial sales as well, as they felt they also had fishing rights over the lake. So they disrespected the management rules, which restricted time of the year, number and size of fish caught,

[37] The area was mistakenly left outside in the Decree that created the reserve in the coordinates defining the protected area boundaries. This error was later noticed and corrected by ICMBio.

and fishing with gillnets. Some leaders said rule breakers never complied with rules even before management, when the lake was only for subsistence fishing. In Andirá, the community had not had conflicts with outsiders before management. Actually, most community members used to sell fish to commercial boats coming from cities. The main conflict started when community managers began monitoring the Andirá river, as members from upriver communities in Tefé National Forest were not involved in management and did not respect the rules, illegally catching *pirarucu*. Community managers also had problems with free riders within the management group, whom they could not control.

In terms of institutional support, ASTRUJ coordinated *pirarucu* management in the LJER, organizing *pirarucu* counts and the commercialization process, reporting to IBAMA and asking for management quotas (GS6.1). It was the role of the communities to plan and organize *pirarucu* management in their areas, involving rule making, monitoring, reporting of offenses, and benefit sharing in the community/group. There was little presence of ASTRUJ and ICMBio during fishing in most areas, except in Planeta and Andirá. ICMBio's role was to support communities and ASTRUJ in the *pirarucu* management process (GS6.2).

Overall, communities reported that they had received robust support from ASTRUJ and ICMBio with regard to *pirarucu* management (GS6). The highest perceived level of ASTRUJ support was found in Planeta and Andirá (100%), and the lowest was reported in Socó lake (76%) and Antonina (71%; GS6.1). ICMBio's average level of support, in terms of monitoring, sanctioning, and conflict resolution (GS6.2.1) was reported to be highest in Planeta and Andirá (4 out 5), and lowest in Baixio Lake

(2.8 out of 5). In breaking down those numbers, I found that ICMBio's support for community monitoring was higher in Baixio lake (91%), Planeta complex (87%) and Andirá (85%), and lower in Socó lake (52%). Support in institutional monitoring was higher in Baixio lake (83%) and lower in Socó lake (55%) and Antonina (53%). Finally, respondents reported that ICMBio support to combat invasions in managed lakes was lower for all areas (varying from a high of 64% in Baixio lake to a low of 40% in Antonina). ICMBio managers reported they provided higher support to Planeta complex and Andirá, which consisted of fuel for community monitoring. Although it was available for all communities, no one requested it as they did not systematically patrol their areas. In Socó lake, ICMBio respondents reported that they invested more in social organization and building trust in the community as a means of fostering conflict resolution.

Finally, all managed areas were directly perceived to be important for community subsistence, except for Planeta complex (I1.1) that lay outside community territory (I2). However, this area had the highest economic profitability (I1.2.1), representing almost one third (US$ 1,480; I1.2.2) of their average annual income (US$ 5,366).[38] All areas were generally appraised as being profitable, but with somewhat lower values for Andirá (76%), Socó lake (69%), and Baixio lake (60%). In 2012, income from *pirarucu* management was US$ 175 per person in Botafogo; US$ 975 per family in Antonina; in Baixio lake, it was US$ 190 per family; in Socó lake, fish were divided among all families within the community as they decided not to commercialize it; and in Andirá, managers received an average of US$ 440 (women received less than men as they did

[38]Data from 2012.

not fish, only participated on guarding the area; I1.2.2). In previous years, some communities decided to buy collective materials for their overall benefit. Over the years, the Botafogo community decide to invest their income from management in buying assets for the collective benefit of the community (radio-communication, water pumps, and parts of the engine generator that was broken), sharing the rest of the money equally among them. Socó community bought a water pump in 2011 with income they received from management at Baixio lake.

Discussion

Pirarucu provides an interesting case of a resource that was initially controlled by the government and generally overexploited, but once management rights were shared with communities, there was an overall increase in stocks. In the LJER, the number of *pirarucu* counted increased more than three-fold after six years of management. Successful management has also been documented in other parts of the Amazon. In the middle Solimões river, management of *pirarucu* in the Mamirauá reserve resulted in increased *pirarucu* abundance. After eight years of experimental management, the number of *pirarucu* increased nine-fold overall in managed areas, while in neighboring areas *pirarucu* abundance did not increase (Castello et al. 2009). Campos-Silva and Peres (2016) found an average of 304.8 (±332.5) *pirarucu* in managed lakes in middle Juruá river, compared to only 9.2 (±9.8) in open access lakes. In the Purus river, the number of *pirarucu* counted increased from 2,581 to 12,227 after three years of management (Rabello Neto 2013). In the lower Amazon region, the median density of *pirarucu* was almost two orders of magnitude higher in managed areas (10.02 ind/km^2) than in unmanaged ones (0.55 ind/km^2; Castello et al. 2015). In this region, local extinctions of *pirarucu* in open access lakes were also documented.

Despite the generally successful experience overall, not all areas are equally successful. In the LJER, among the six management systems, a comparison of the extreme cases of increase (Planeta) and decrease (Socó) in *pirarucu* stocks helps to identify conditions for sustainable fisheries management.

Planeta Complex

In Planeta, effective protection of lakes by communities reduced illegal fishing and led its overexploited population to increase fast. The system's large size and profound lake depth provided suitable conditions for population growth. Fishers say that *pirarucu* prefer undisturbed environments; they therefore knew that if lakes were well-protected, *pirarucu* would respond accordingly. The ecological knowledge of community managers about *pirarucu* behavior and population dynamics, along with the high carrying capacity of the Planeta complex of lakes, provided incentives for community engagement in regular monitoring of this overexploited resource system.

Visionary leaders of Botafogo and Antonina communities motivated the organization of *pirarucu* management. For one thing, they had the experience of lake governance, as well as a shared vision that Planeta complex had a high potential for *pirarucu* recovery.They also held the belief that together they could enhance lake protection, thereby increasing fish stocks, with the result that *pirarucu* management could be a significant source of income, as seen in Mamirauá reserve. They participated in the struggle to create the LJER, founded ASTRUJ, and were involved in reserve co-management. In turn, ASTRUJ coordinated the *pirarucu* management process and established the horizontal linkage between communities (defined as 'bridging' by Woolcock 2001) as well as the vertical connection ('linking'; Woolcock 2001) between the communities and outside social actors (e.g. ICMBio, IBAMA, *pirarucu* buyers),

strengthening coordination and communication among parties. ASTRUJ's entrepreneurship had a key role in management of the Planeta complex system: acquisition of floating houses and regular monitoring were essential for the *pirarucu* population recovery.

Overlap between user group residential location and resource location has been previously pointed out as a facilitating condition for sustainable management (Wade 1994, Baland and Platteau 1996). However, this study found the opposite. In contrast to other cases where management sites were close to community residential areas and thus provided *de facto* lake protection, Planeta complex was far from the managing communities, and in that regard, it was not an ideal area for fisheries management. Rather, it had been an open access regime used by urban fishers, and was difficult to monitor and highly vulnerable due to its closeness to Juruá town, its large size, and its easy access through the surrounding flooded forests both in the wet (by canoe) and dry season (by foot). Community proximity is thus not a necessary condition for successful fisheries management, provided other conditions do obtain.

Given the spatial distance between the communities and the lakes, co-management institutions were key for the sustainable management of *pirarucu* in Planeta. The management group involving Botafogo and Antonina was able to design effective common property institutions to control access to the fishery, with ASTRUJ's and ICMBio's support. ASTRUJ provided the means and incentives for management to work: the financial capital to acquire floating houses and the social capital that linked the management group to government organizations (IBAMA and ICMBio) and private parties (*pirarucu* buyers). ICMBio legitimated *pirarucu* management at the Planeta

complex in several ways. First, ICMBio included the Planeta complex of lakes in the LJER's management plan. Second, through official incorporation of Sacado do Planeta within the LJER's boundaries, ICMBio corrected the earlier Decree that created the LJER and by incorporating Planeta, reduced conflicts with urban fishers. Third, ICMBio supported the formalization of rules in the internal regiment.

For their part, the community managers of Planeta were able to overcome their difficulties through investments in monitoring: they acquired two floating houses and installed them in strategic locations at the Planeta complex. They received support from ICMBio that permitted radio communication between patrolling canoes and floating houses, and between floating houses and Juruá town, which was key to improving monitoring and calling in support from ICMBio or ASTRUJ. The moderate size of the management group facilitated face-to-face communication while also allowing multiple groups to take turns monitoring. Despite the high overall investment required for monitoring, their individual level of effort was spread out over time, so that they could keep their livelihoods in the communities.

Another key element for explanation is that managers in Planeta shared collective norms and interests and constituted a relatively homogeneous group. Within-group conflicts were not related to lack of rule compliance by members, but rather to unequal efforts among managers in monitoring and fishing or unequal distribution of non-monetary benefits.[39] Despite these conflicts and the challenges of having two different communities working together, Planeta's management group had strong social capital. Within communities, group members had close kin relations: up to three

[39]Gas for transportation throughout the year between their communities and the floating house and fish for subsistence at the end of the *pirarucu* fishery.

generations of the same family were working together in *pirarucu* management at the Planeta complex. In addition, their common livelihoods based on agriculture demanded a strong labor force, requiring frequent labor sharing groups, which helped to reinforce trust, reciprocity and a sense of collective interest within communities. Between communities, there were some kinship and long-term friendship relations, and members of Botafogo and Antonina occasionally met for leisure or work. Shared ideas and practices of lake governance had deeper roots stemming from the MEB's work in the region in the 1980s and 1990s. Moreover, all users were involved in management in the Planeta complex and they shared similar interests, which facilitated success.

Given that background, in Planeta, managers engaged in effective management practices, such as regularly sharing information about the system during meetings or group conversations. They were the most mature management group, as they had agreed on formal management rules. Formalization made rules more legitimate: the internal regiment was frequently cited by managers during meetings to reinforcethe management group's power to sanction offenders. For example, the internal regiment established fines for those members that were absent in their respective monitoring groups; these were discounted from the money they received from *pirarucu* fishery in the end of the year. Nobody argued against it as these were their official rules.

Socó Lake

Socó lake had the worst management performance: in six years of management, the number of *pirarucu* dropped each year from more than 200 fish to only 40. Although the resource system was small and shallow, offering little space for populations to grow, it included grasses and flooded forests in its surroundings that are favorable habitats to maintain *pirarucu*. Therefore, the system could at least have maintained the population

stable over time. A crucial explanation for the contrast in the change in *pirarucu* populations with Planeta, is that in the Socó lake system, the communities did not invest much in monitoring, despite this lake being geographically close to Socó and FG1, and easy to monitor. This resulted in part precisely due to the fact of proximity of the communities to the lake, and thus the perception that monitoring was unnecessary. Although Socó system had management rules, it functioned in practice as an unregulated common property regime, as free riding was frequent and there was no sanctioning. Proximity to the Juruá river also facilitated access and invasions.

Conflicts within FG1 were complex as the community was relatively large and heterogeneous, involving multiple interests and identities. To make it worse, community members competed over scarce resources as FG1 had few lakes besides the river in which to fish. Since the beginning, community engagement in management was not consensual, and the group in favor of *pirarucu* management faced reluctance by the majority. However, free riders composed only a small number of community members who did not agree with management. They lived on fishing, and felt that they also had rights to catch *pirarucu* for sale. Conflicts were more serious there than in any other area, leading to physical aggression against one management leader who was also the community's president. The aggressor and other rule offenders were not sanctioned, so illegal fishing continued and the *pirarucu* population dropped. As a result, fishing quotas issued by IBAMA also declined. Perceiving these negative management outcomes, the management group decided to suspend fishing for two years (2010 and 2011) despite having authorized quotas, to give the population the opportunity to increase. In 2012, they decided to fish their quota (seven individuals) just for community subsistence,

sharing the fish among all community members, regardless of whether they were involved in management.

Large community size made it more difficult to build trust, establish face-to-face communication, reach agreements and ensure rule compliance. While Socó was a small community with high social capital, there was little trust and collective norms between it and FG1 due to past and present conflicts in lake governance, and within FG1. However, a significant portion of the FG1 community was involved in well-organized *mutirões* (collective labor arrangements) for agriculture that were planned in monthly meetings of the community association. These meetings were attended mostly by those who paid association fees, and those who did not were excluded from decision making. Thus, community meetings were not arenas for conflict resolution, and it is not surprising that the management group faced such difficulty to reach agreements and solve conflicts in FG1.

Differences in religious beliefs may also account for divergent perspectives regarding lake protection in the region. While Protestants believed that what God created would never end even in face of overuse, Catholics thought that it might not end but overuse would lead to resource degradation. The Catholic Church has historically supported community organization for the collective defense of lakes against invasions and the sustainable use of natural resources among rural communities in the Amazon (Castro 2000). This support included work in the communities of the Lower Juruá, though mainly the bigger ones: Botafogo, Antonina, FG1 and Cumarú. This is not to say that Catholics do better than Protestants in conserving natural resources, as beliefs do not necessarily translate into practices. However, heterogeneous worldviews about the

sustainability of fishery practices definitely made it more challenging for the management group of Socó lake to find support in their communities in terms of building agreements and complying with management rules.

Socó lake was the management system where respondents reported receiving the lowest level of support from ASTRUJ and ICMBio. As in other areas, ASTRUJ was present in *pirarucu* counting, but in Socó, it was not visible throughout the management process, especially in the last three years of management, in which the group decided not to fish or to commercialize their quotas. ICMBio's attempts to solve conflicts failed, and sanctioning mechanisms were ineffective, as legal punishment can only occur if transgressors are caught in the act, or if they are reported by certified environmental agents. However, ICMBio/IBAMA were present in monitoring actions in the LJER only two to three times a year, and even during these actions it was hard to catch offenders. The situation was aggravated when the voluntary environmental agents (*Agentes Ambientais Voluntários* – AAV) trained by IBAMA lost official recognition by ICMBio,[40] meaning that agents could no longer officially report environmental infractions or seize materials of illegal fishing. Loss of power of community environmental agents led to increased conflicts with outsiders in the reserve as a whole, as they were no longer respected by them.

[40] The AAV Program was created by IBAMA in Amazonas state in 1997, becoming a national program in 2005. In Amazonas, more than 5,000 AAVs were trained (Feitosa 2014). The Program was officially revoked by ICMBio in 2013,alleging lack of judicial security. However, in 2011 local ICMBio teams were oriented by ICMBio's central office not to accept AAV's official reports and to orient agents not to keep seized materials from illegal activities. ICMBio in Juruá publicly announced these changes in meetings at that time, which was considered by most managers as the main cause of increased conflicts with outsiders.

Other Management Areas

The other four management areas presented more complex non-linear fluctuations in their annual counts of *pirarucu*, with both increases and decreases in abundance over time. When comparing the counts in the first and last years of management, I found that three of these systems had increased abundance (Baixio lake, Botafogo, and Antonina) while the other (Andirá) had decreased *pirarucu* abundance. However, fluctuations in population size are common in natural populations (Pianka 1994), and only longer-term series of counts would allow more robust conclusions about the effectiveness of these management systems. Nevertheless, an analysis of diverse characteristics of these management systems allows some inferences about their effects on management performance.

In three years of management, Baixio lake exhibited a rapid increase in its *pirarucu* population. Formal recognition of Baixio as a managed lake in the LJER's management plan granted *de jure* rights to the Socó community and solved disputes with Arati over lake use. Once that conflict was resolved, overuse was probably controlled, leading to the natural increase in *pirarucu* numbers. However, this apparent success must be seen with caution, as this system has properties that may make it difficult to maintain sustainable management through time. On the one hand, this is a very small community with high social capital that may find it easy to engage in collective action,and the lake is very close to the community, making it easy to monitor and less vulnerable to free riding. On the other hand, the lake is small and shallow, thus providing limited space for fish and limited economic return from management. Sustainable management is a new practice for the community, given their past experience of not engaging in lake protection and of leasing the lake to outsiders.

Botafogo system was more unpredictable, as it involved management along the stream in which *pirarucu* found refuge during the dry season. Fish could escape if they felt threatened, or due to sudden increases in water levels. In some years, managers reported fewer *pirarucu* in the stream than counted when they went to fish, so fish might have escaped or been illegally caught. The managers did report frequent illegal fishing of *pirarucu* by outsiders in adjacent flooded forests. While they felt unmotivated to protect fish stocks for others to reap the benefits, they did sustain patrols of the area when possible. Managers had a strong commitment to preservation based on their historical engagement in lake governance. However, the absence of most (male) managers from Botafogo, due to working in the *pirarucu* fishery at Planeta, made the Botafogo system more vulnerable to invasions, as women with young children were less able to patrol the area. Just a few women were involved in guarding at the floating house in Botafogo and no one in fishing.

Antonina presented many favorable conditions for successful management: lakes with moderate depth, in an area with difficult access to outsiders, close to the community, which exhibited high social capital due to shared identities and norms as well as strong leaders, a high economic return from management, and the presence of sanctioning and conflict resolution mechanisms. In fact, Antonina was the area with the highest abundance of *pirarucu* after Planeta complex. Free riding within the community could explain why the number of *pirarucu* did not increase much with time. Interestingly, community managers employed sanctioning mechanisms against members of their own families, which is not expected as kinship is an important factor determining social relations in Amazonian communities (Harris 2006).

Andirá was the most complex management system in the LJER. It involved members from five different communities in the management of a huge area along the blackwater Andirá river. The dominant community was indigenous and practiced different livelihoods compared to communities in the other management systems. They had lower annual incomes, which were based on governmental benefits and the commercialization of extractive products instead of agriculture. They also did not have a culture of preserving fish stocks for future generations as other communities, nor a commitment to monitoring. As observed by one ICMBio manager:

> In Andirá, indigenous culture makes them very different from the others. Everything is from everybody, there is no such thing as “this is mine, that is yours”. Although they try to implement the guarding system, they do not perceive it the way as managers from Planeta do. They do not see daily monitoring as an obligation. When Chicó was alive, he used to go alone [to guard the floating house] because people from his group did not want to go. But when they saw he was alone, the next day one appeared, then the other, because they felt bad. Chicó was a very strong leader. For most people in Andirá, the floating house should be across the river from the community, so that they could go and come back when they wanted. Just the place where it is needed the least, as across from the community everybody is guarding.

Management ofthe Andirá river improved local governance, leading to increased *pirarucu* abundance from 2007 to 2011. However, once the strong leader Chicó passed away in 2011, the community felt unmotivated and did not guard the floating house during the following year. As a result, the *pirarucu* populations dropped by 45% in 2012, reaching a smaller population size than when management started. This confirms the importance of community monitoring for fisheries conservation, and at the same time shows the fragility of fisheries that can be fast depleted if not protected. Despite black waters being acidic and generally nutrient poor, the Andirá system has good potential to increase fish stocks due to its large size and ease of control of access to the river’s

mouth. The difficulty is that anyone can enter, as the whole area is not protected, and by law they cannot prohibit the transit of boats throughthe river. As noted by ICMBio, the area needs a fishing agreement to reduce conflicts among its multiple users. Another difficulty concerns collective action problems, as there are free riders, and most people are not engaged in monitoring. If the economic incentive from fishing were higher, maybe they would be more motivated to monitor and otherwise support *pirarucu* management.

Concluding Remarks

The conditions important for successful common property regimes have been examined for a wide array of resources (e.g. McCay and Acheson 1987, Berkes 1989, Tang 1992, Wade 1994, Ascher 1995, Pinkerton and Weinstein 1995), but have neglected analysis of the influence of resource systems, certain characteristics of resource users, and the broader context in management success (Agrawal 2001). Moreover, studies often assumed rather than tested the relationship between local institutions and sustainable management (Baland and Platteau 1996). The present study sought to contribute to institutionalist literature on resource management by addressing these gaps. I examined relationships between numerous different aspects of local management institutions and sustainable management, taking into consideration the multiple dimensions of social-ecological systems associated with common property regimes that exhibited a range of management outcomes.

Employment of a multifaceted analytical framework stemming from Ostrom's (2009) rendition of the social-ecological systems approach helped to capture the daunting complexity of management systems. The case of *pirarucu* management in the LJER is no exception, and the findings indicated that multiple factors account for fishery

sustainability. Key factors that differentiated growing or declining *pirarucu* populations in the LJER included: visionary leaders engaging the group in sustainable practices; community monitoring effort and enforcement of local rules; local participation in decision making; group homogeneity, with shared interests and strong social capital; conflict resolution mechanisms; and supportive outside institutions, whether grassroots or governmental, legitimating local governance, improving communication and networking with external agencies and private parties. In addition, characteristics of the natural resource itself, such as the predictability of the resource and resource system, and the rapid ecological response of *pirarucu* to environmental protection, were relevant elements that accounted for *pirarucu* management effectiveness.

Overall findings from this study corroborated many of the enabling conditions identified for the sustainability of the commons (Agrawal 2003). However, contrary to expectations, neither community proximity (Wade 1994, Baland and Platteau 1996) nor dependence on resource system (Agrawal 2003) were necessary conditions for successful fisheries management. If the management group has high social capital, appropriate leadership, and supportive institutions, and if the resource system has clear boundaries and is of high storage capacity and potential for biological growth (Pretty 2003), then local groups are able to design effective local management institutions even under complex governance conditions. The opposite is also true: if the community is close to the resource system and has easy access to resources, the management group might not perceive that monitoring is necessary; if the community is highly dependent on the resource and has heterogeneous interests, that might increase

conflicts among members over the use of the resource system, potentially leading to free riding and unsustainable resource management.

Overall, *pirarucu* co-management in the LJER was more effective than relying only on government control as *pirarucu* stocks significantly increased after management started. Local collective action and institutions for aquatic system protection were the basis for fishery sustainability, as government alone cannot control illegal fishing. Government needs communities to constitute use rules, engage in systematic monitoring, and report infractions. That in turn allows outside organizations to provide support for community management initiatives, including by enforcing sanctions against rule offenders, but also by recognizing community practices and confirming community resource counts in order to set quotas for the next year. Co-management can thus be effective if it involves a division of responsibilities that decentralizes decision-making authority to communities and includes local knowledge and skills in management strategies (Castello et al. 2009), while also deploying the capacity of outside organizations in support of community decisions. Thus, where communities were able to identify management goals and form local leadership with member support, ASTRUJ played a key role in supporting and strengthening community management and linking community initiatives with higher levels of governance to legitimate community decisions and their enforcement. In co-management arrangements, it becomes the role of government to provide the legal resources and thus the legitimacy for community initiatives to work effectively (Jentoft 2003).

However, co-management should not be seen as a panacea for solving environmental problems (Carlsson and Berkes 2005). Some communities or groups

may have more difficulty to engage in collective action, to enforce and sanction rule offenders, and to resolve conflicts. If local institutional arrangements at the community level are not robust, co-management might not work effectively even with high support from external agencies. Moreover, co-management can actually reinforce unequal power relations (such as gender inequality in the case of *pirarucu* management) or increase internal conflicts within communities. Notwithstanding, co-management is still more appropriate than single management approaches (either community or government) as it is cross-scale, it is more participatory, it bridges knowledges and techniques, and brings the social and human capital of local communities and external institutions to governance of natural resources.

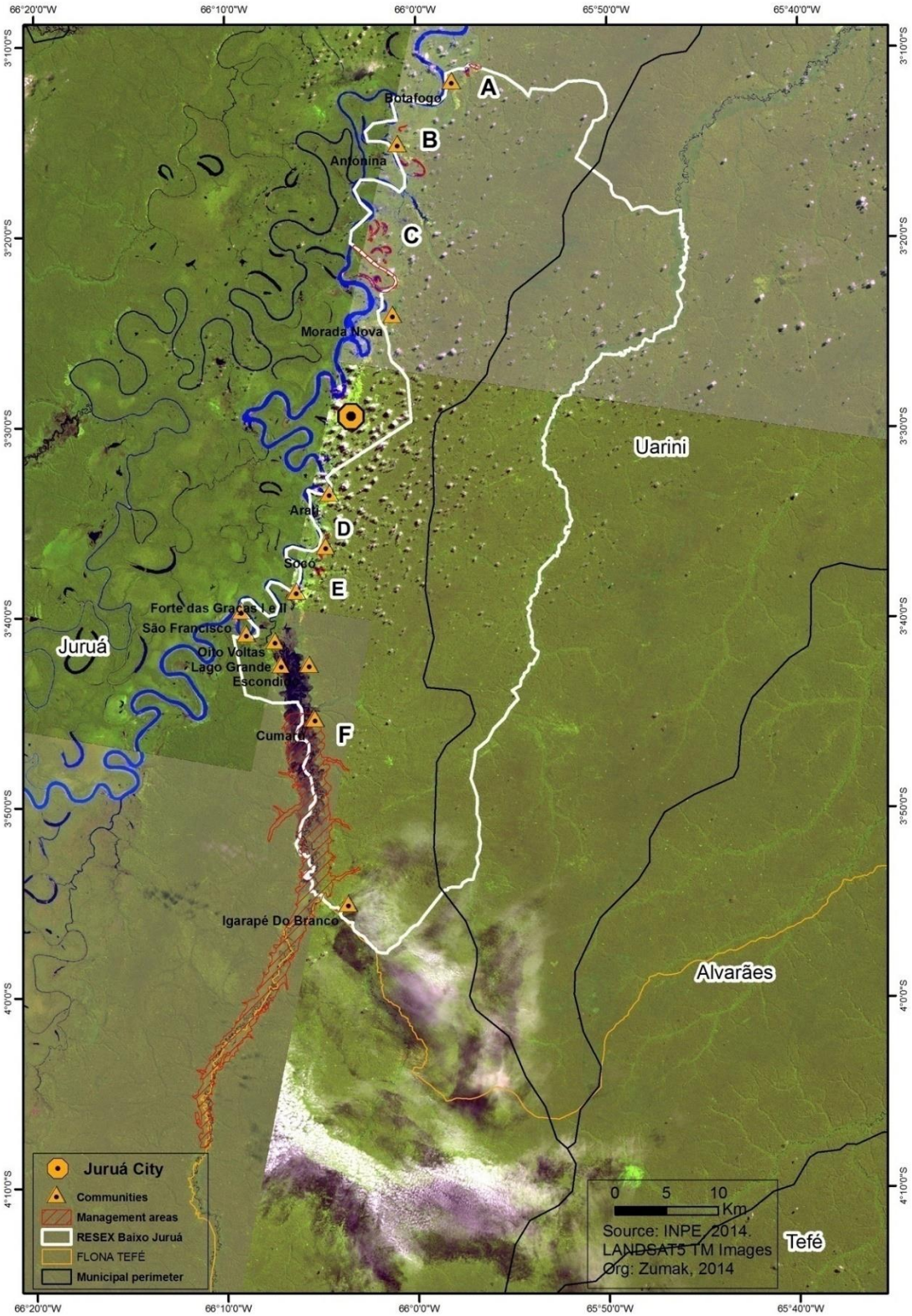

Figure 4-1. *Pirarucu* management systems at LJER: A- Botafogo; B- Antonina; C- Planeta complex; D- Baixio lake; E- Socó; and F- Andirá river.

Table 4-1. Conditions favoring sustainable management according to *pirarucu* ecology and theory on the commons, examined in this study. Adapted from Ostrom (2009) and McGinnis and Ostrom (2014).

Variable code	Variables	Condition
Resource systems (RS)		
RS1	System size (area, depth)	Large and deep lakes provide more habitat and food availability for *pirarucu* in the dry season than small and shallow lakes.[1] Large systems are harder to be monitored, and small systems are less productive; thus, moderate size is more conducive to self-organization.[2]
RS2	Predictability	In the dry season, lakes are more predictable than river or streams as water levels do not change so fast (due to sudden rain, for example), preventing *pirarucu* from escaping to other areas
RS3	Clarity of system boundaries	Well-defined boundaries are key to success of common property regimes,[3] facilitating monitoring and rule enforcement.
RS4	Location (distance to community and to town)	Systems located closer to community are easier for community monitoring; systems located far from urban areas are less prone to invasions.
Actors (A)		
A1	Group size (management group, community and users involved in management)	Groups should be small enough to facilitate getting users together and agreeing on rules, while still being able to effectively monitor resource systems against outsiders. Thus, group size depends on other SES variables and management tasks.[2]
A2	Socioeconomic attributes (group heterogeneity)	Group heterogeneity may affect collective action in diferent ways; both homogeneous and heterogeneous groups may account for the success of collective action and sustainability of the commons.[4]
A3	Leadership	Groups with respected local leadersare more likely to self-organize.[2] Local leaders are relevant in conflict management, and in bridging communities to external agencies.[5]
A4	Social capital (trust and shared norms)	Groups with higher social capital are more likely to engage in collective action, reach agreements and face lower transaction costs of monitoring.[2,6]

Table 4-1. continued

Variable code	Variables	Condition
Governance systems (GS)		
GS1	History or past experience (collective protection of lakes; community engagement in management)	Groups with history of successful collective action are more able to succeed in other collective efforts. Decisions to manage resources that emerged from the bottom-uphave higher chances of rule compliance than if these were imposed on communities.
GS2	Collective-choice rules (participation in management decisions)	Rules defining rights by which most authorized users can participate on decisions regarding resource use.[3,7]
GS3	Monitoring (technology and frequency of monitoring)	Regular monitoring, reduced illegal fishing.
GS4	Sanctioning	Regular sanctioning, reduced illegal fishing
GS5	Conflict resolution	Present, reduced conflicts
GS6	Organizations (governmental and non-governmental)	Supportive organizations establishing intra- or inter-community/group connections or linking community/group with external actors facilitate agreements, information sharing, learning etc.
Interactions (I)		
I1	Importance of resource system to actors (subsistence and economic value)	Users substantially depend on resource system for their livelihoods or highly value its sustainability.[2,4,8]
I2	Overlap between residential location and resource location[4,5]	Resource system located within use area of community
Outcomes (O)		
O1	Ecological performance (sustainability)	If management rules are followed and systems are effectively protected, *pirarucu* stocks will increase or become stable (in case it achieves system's carrying capacity) over time.

Source: [1]Arantes et al. (2013),[2]Ostrom (2009),[3]Ostrom (1990),[4]Agrawal (2003),[5]Rahman et al. (2015),[6]Baland and Platteau (1996),[7]Schlager and Ostrom (1992), [8]Murphree (1993).

Table 4-2. Methods of data collection for the different variables employed in this study.

Variable code	Variables	Method of data collection								
		Field measures	Sattelite images	Participatory mapping	Secondary data	Comm. meeting	Semi-structured interview (random N)	Semi-structured interview (key informants)	Informal conversation (key informants)	Participant obs.
Resource System (RS)										
RS1	System size	x	x							
RS2	Clarity of system boundaries				x	x				
RS3	Predictability			x		x				
RS4	Location			x	x					
Actors (A)										
A1	Group size					x				
A2	Socioeconomic attributes						x			
A3	Leadership						x		x	x
A4	Social capital						x		x	x
Governance system (GS)										
GS1	History or past experience					x			x	
GS2	Collective-choice rules					x	x			
GS3	Monitoring					x		x	x	x

Table 4-2. continued

Variable code	Variables	Method of data collection								
		Field measures	Sattelite images	Participatory mapping	Secondary data	Comm. meeting	Semi-structured interview (random N)	Semi-structured interview (key informants)	Informal conversation (key informants)	Participant obs.
GS4	Sanctioning					x		x	x	
GS5	Conflict resolution					x		x	x	
GS6	Organizations						x	x	x	x
Interactions (I)										
I1	Importance of resource system to actors					x	x			
I2	Overlap between residential location and resource location[4,5]			x						
Outcomes (O)										
O1	Ecological performance				x					x

Table 4-3. *Pirarucu* counts from 2006 to 2012 for each management system of LJER, showing absolute and relative variation in abundance when comparing the first and last years of management.

Management system	Communities involved	2006	2007	2008	2009	2010	2011	2012	Variation in abundance ($t_0 – t_1$)
Planeta complex	Botafogo and Antonina	455	1,047	1,214	1,695	1,959	2,053	3,172	+2,717 (597%)
Baixio lake	Socó	-	-	-	32	58	46	55	+23 (72%)
Botafogo	Botafogo	-	131	310	288	212	230	171	+40 (30%)
Antonina	Antonina	636	649	887	747	825	824	800	+164 (26%)
Andirá	FG1, Escondido, Cumarú, Itaúba and Ig. Branco	-	307	444	381	429	469	260	-47 (-15%)
Socó lake	FG1 and Socó	209	137	110	98	66	69	40	-169 (-81%)
Total	-	1,300	2,271	2,965	3,241	3,549	3,691	4,498	+3,198 (246%)

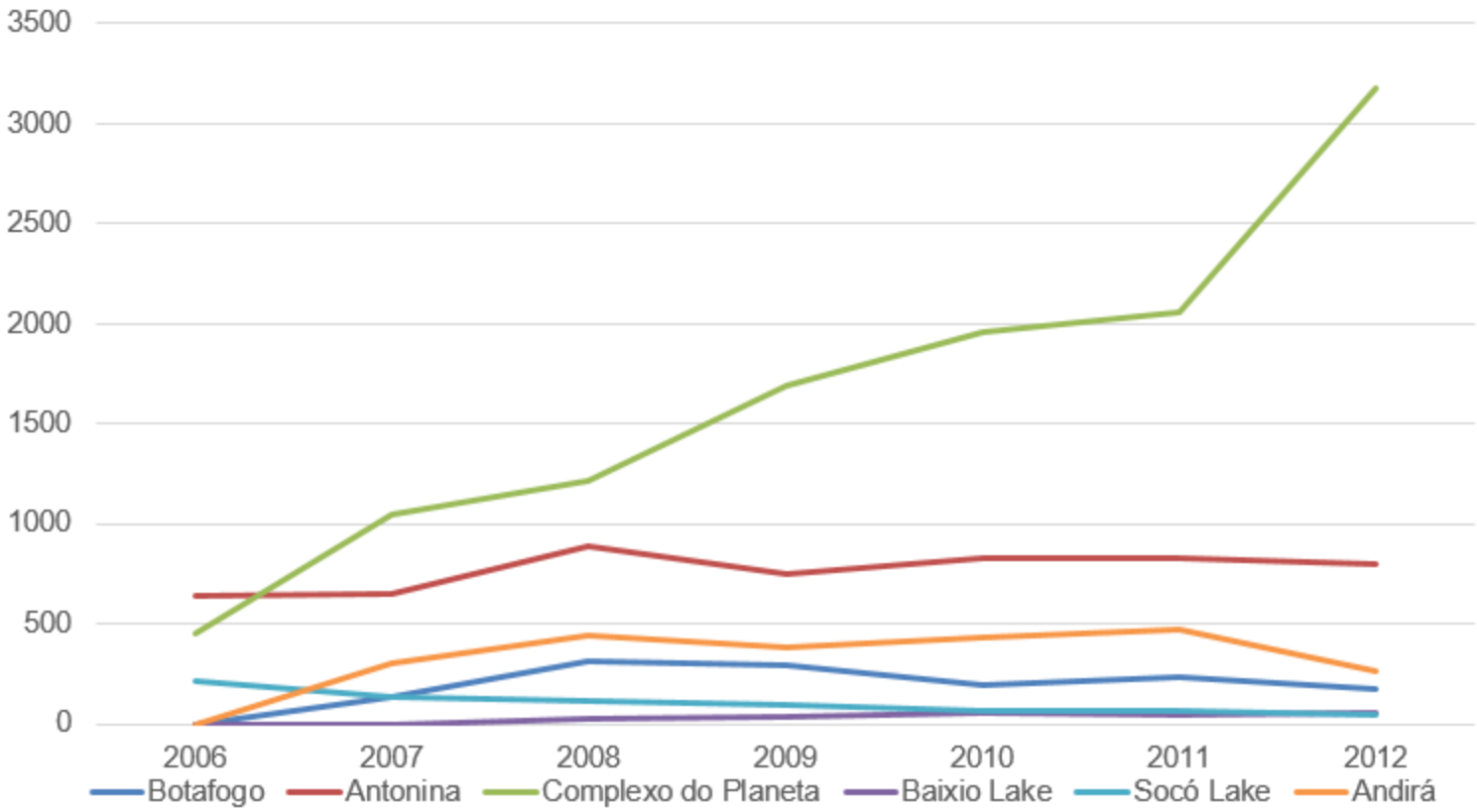

Figure 4-2. Annual *pirarucu* counts from 2006 to 2012 in management systems of LJER.

Table 4-4. Data on commercialization of *pirarucu*, *tambaqui* and other fish from management areas of LJER, extracted from ASTRUJ's reports from 2007 to 2012. NI: Not Informed.

Data on commercial fisheries	2007	2008	2009	2010	2011	2012
Total revenue (US$)[1]	35,500	42,000	17,370	36,050	63,400	99,100
Number of fishers involved	74	94	89	ca. 90	ca. 95	95
Income from fishery management (US$)	130–690	150–1,040	35–433	180-700	113-900	175-1,480
Pirarucu						
Authorized quota (N)	229	310	424	327	352	371
Fished quota (N)	222	291	188	315	345	348
Price/kg (US$)	1.63-2.5 (whole fish)	2.13-2.5 (whole fish)	2.25-2.5 (whole fish)	3–3.25 (whole fish) 2.5-5 (fillet)	2.25-3 (whole fish)	3 (whole fish)
Revenue (US$)	28,000	34,500	17,370	36,050	45,970	NI
Tambaqui						
Kg (total)	2,744	2,593	-	-	8,600	NI
Price/kg (US$)	2.5 – 3	2.75 - 3	-	-	2.75-4	2.75-4
Revenue (US$)	15,000	15,000	-	-	ca. 25,000	NI
Other fish (*pirapitinga, pescada*, catfish)						
Kg (total)	-	-	-	-	3,250	NI
Price/kg (US$)	-	-	-	-	1-1.5	2.75
Revenue (US$)	-	-	-	-	4,475	NI

[1] Net income. Prices and revenues are in dollars, calculated as 2:1 in relation to Brazilian Real at the time of study.

Table 4-5. Comparison of *pirarucu*management systems of LJER in terms of management outcomes, characteristics of resource systems, actors, governance systems, and interactions among factors. NA: Not apply.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
Outcomes (O)							
O1- Ecological performance							
O1.1- Sustainability							
O1.1a- *Pirarucu* stocks over time	Increase Decrease (low, moderate, high)	High increase	Moderate increase	Low increase	Low increase	Low decrease	Moderate decrease
Resource systems (RS)							
RS1- System size							
RS1.1- Area (ha)	Small (<100) Moderate (100-1000) Large (>1000)	Moderate	Small	Small	Small	Large	Small
RS1.2- Depth of flooding (m)	Shallow (<8) Moderate (8-15) Deep (>15)	Deep	Shallow	Shallow	Moderate	Deep	Shallow
RS2- Predictability	Yes No	Yes	Yes	No	Yes	No	Yes
RS3- Clarity of system boundaries	Yes No	Yes	Yes	Yes	Yes	No	Yes

Table 4-5. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
RS4- Location							
RS4.1- Distance to community (km)	Close (<10) Moderate (10-30) Distant (>30)	Moderate	Close	Close	Close	Close/ Distant	Close
RS4.2- Distance to town (km)	Close (<20) Moderate (20-50) Distant (>50)	Close	Moderate	Distant	Moderate	Distant	Moderate
Actors (A)							
A1- Group size							
A1.1- Community size (N of households)	Small (<15) Moderate (15-30) Large (>30)	Small/ Moderate	Small	Small	Moderate	Small/ Moderate/ Large	Small/Large
A1.2- Management group size (N of managers)	Small (<10) Moderate (10-30) Large (30-50)	Large	Small	Moderate	Moderate	Large	Moderate
A1.3- Proportion of users involved in management (%)	Minority (<50) Majority (≥50) All	All	Majority	Majority	Majority	Minority	Minority
A2- Socioeconomic atributes							

Table 4-5. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
A2.1- Group heterogeneity index	Index (3-9): Religious diversity (1-3) + Fisherman occupation (1-3) + Wealth disparity (1-3)	4	5	5	4	6	9
A2.1.1- Religious diversity (N of types)	Number of religions	1	2	2	1	2	3
A2.1.2- Fisherman occupation (%)	None Few (<20%) Some (20-50%)	Few	None	None	None	Few	Some
A2.1.3- Wealth disparity							
A2.1.3.1- Variation in annual income - US$ (average ± standard deviation)	Variation: Low (<3,000) Moderate (3,000-4,000) High (>4,000)	Low	Moderate	Moderate	Moderate	Moderate	High
A3- Leadership	Present Absent	Present	Absent	Present	Present	Present until 2011	Present, lack representativeness
A4- Social capital							
A4.1- Trust (% that trust most people)	Minority (<50) Majority (≥50)	Majority	Majority	Minority	Majority	Minority	Minority

Table 4-5. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
A4.2- Shared norms							
A4.2.1- Reciprocity, solidarity, and/or collectivity (%)	Minority (<50) Majority (≥50)	Majority	Majority	Minority	Majority	Majority	Minority
Governance systems (GS)							
GS1- History or past experience							
GS1.1- Duration of collective protection of lakes before management (N of years)	Long-term (>10) Short-term (<10)	Short	Short	Long	Long	Short	Long
GS1.2- Nature of community engagement in *pirarucu* management	Proactive Reluctant	Proactive	Proactive	Proactive	Proactive	Reluctant	Reluctant
GS2- Collective choice rules							
GS2.1- Nature of rules	Fomal Informal	Formal	Informal	Informal	Informal	Informal	Informal
GS2.2- Most people participate in decision making	Yes No	Yes	Yes	Yes	Yes	Yes	No
GS3- Monitoring							

Table 4-5. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
GS3.1- Technology of monitoring	Present Absent	Present, throughout the year	Absent	Present, but with few monitors	Absent	Present, part of the year	Absent
GS3.2- Frequent monitoring	Yes No	Yes	Yes	Yes	No	Yes	No
GS4- Sanctioning	No Yes NA	Yes	NA	No	Yes	No	No
GS5- Conflict resolution							
GS5.1- Success in solving conflicts	No Yes	Yes	Yes	No	Yes	No	No
GS6- Organizations							
GS6.1- Non-governmental organization							
GS6.1.1- Perceived high support of ASTRUJ (%)	Some people (50-80) Many people (>80)	Many	Many	Many	Some	Many	Some
GS6.2- Governmental organization							

Table 4-5. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
GS6.2.1- Perceived support of ICMBio (index: monitoring, meeting complaints, sanctioning, conflict resolution)	Little (<3) Moderate (3-4) A lot (>4)	Moderate	Little	Moderate	Moderate	Moderate	Moderate
Interactions (I)							
I1- Importance of resource system to users[4,5]							
I1.1-Subsistence value	Weak Strong	Weak	Strong	Strong	Strong	Strong	Strong
I1.2-Economic value							
I1.2.1- *Pirarucu* management perceived as economically profitable (%)	Majority (50-80) Great majority (≥80)	Great majority	Majority	Great majority	Great majority	Majority	Majority
I1.2.2. Income from *pirarucu* management in 2012	US$	1,480/person	190/family	175/person	975/family	440/person (on average)	none
I2- Overlap between residential location and resource location[4]	Yes No	No	Yes	Yes	Yes	Yes and beyond	Yes

CHAPTER 5
CONCLUSION

This research investigated different aspects of natural resource governance in Brazilian Amazon extractive reserves (ERs): the share of rights to communities in decisions involving natural resources, and how participation in decision making affects rule compliance; in the context that communities have *de jure* rights, I examined the role of social capital in fostering collective action for resource management, and the multiple factors affecting the sustainable management of natural resources.

Research findings indicate that the co-management of ERs decentralizes few rights to communities over natural resources. Communities have access and withdrawal rights, but in some cases inadequate legislation impede them from fully operationalizing those rights, such as in the case of timber. As argued in Chapter 2, communities have rights to extract timber for subsistence but they cannot transport it to process the wood for building a house, for example, without a document that is emitted only for authorized timber management plans, thus impeding them to use it. Decisions over timber management, as well as those related to other higher ecological impact or large-scale economic activities are bureaucratic, centralized on the federal government, and scientific-based with little local knowledge input. Thus, communities have few management rights over resources in the co-management of ERs, which restricts local livelihoods to subsistence farming and to a few extractivist products for commercial purpose.

The legal apparatus of co-management of ERs poses contradictions to the objectives institutionalized by the federal legislation to this model of protected area. According to the National System of Protected Areas in Brazil (SNUC), “the ER is an

area used by traditional extractive populations, whose subsistence is based on extractivism, complemented by subsistence farming and small animal husbandry. Its basic objectives are to protect the livelihoods and culture of these populations, and to ensure the sustainable use of the area's natural resources" (Brasil - MMA 2000). However, communities have shifted to non-extractive livelihoods in ERs due to the lack of policies (e.g. economic subsidies) to leverage extractivism after the end of the rubber boom (Salisbury and Schmink 2007). Moreover, the co-management arrangements involving government, communities, and other parties in governance of ERs have failed to provide alternatives to boost extractivism in these areas. It has failed to bridge scientific and local knowledges, and to bring expert solutions to local problems and demands. The centralization of management decisions by the federal government in ER co-management makes it complicate for communities to engage in market-based wildlife management (e.g. caymans, turtles), timber management, and even some NTFPs such as *andiroba*.

Timber and turtles provide evidence for the above arguments. In the case of strong co-management, co-management institutions (ICMBio and ASTRUJ) could have powers to jointly issue small-scale permits to attend local demands over the use and transport of timber to town, under justified circumstances such as the need to move to town while children are studying. Or, to process the wood required for reforming the floating houses used for guarding lake systems in *pirarucu* management. The Deliberative Council could work as a supervisory body to control for such permits. However, in the absence of local mechanisms to deal with inadequacies of the federal legislation, communities are sometimes forced to risk themselves to be criminalized for

illegally transporting timber to town. Or, they are compelled to buy illegal timber extracted from areas close to town, where law enforcement is lax. Regarding turtles, communities protect turtle nesting beaches for decades, with researchers' and ICMBio's support, and for long have expected to manage turtles for commercial purposes. Community protected beaches have much higher number of female turtles spawning than non-protected ones (Miorando et al. 2013). Although communities have designed common property regimes to control for poaching, free riding is frequent, both by outsiders and insiders. Community free riders say that they protect turtles for others to reap the benefits of it, thus they take out eggs or turtles as well. Command-and-control is inefficient, populations are overexploited and turtles species are threatened by illegal trade. The federal government alleges that cannot authorize management quotas for commercial purposes because of the low number of turtles recorded. However, evidence from *pirarucu* management shows that, once people have rights to organize and economically benefit from management, they have more incentives to engage in conservation practices, and co-management does increase fisheries. Thus, ICMBio could authorize the experimental management of turtles by some communities involved in protection of turtle nesting beaches in ERs, under close supervision of ICMBio, local associations, and research institutions, as a strategy to improve local governance and conserve turtle stocks.

The ERs management planning does incorporate local knowledge. Most rules in the LJER management plan were brought by communities or built with them. Indeed, community participation in rule making was key for rule compliance. I found that the least respected rules were the ones imposed by governmental regulation. However, co-

management decentralizes more responsibilities than rights to communities in resource governance. The management planning should move beyond that and focus on identifying the conditions under which communities, their knowledge, practices, and beliefs contribute to the sustainable management of resources.

Communities have much to add to natural resource governance in ERs. Social norms and networks are important elements of their social organization, and contribute to the emergence of collective action. In this study, I found that communities with higher social capital participated more in *pirarucu* management (Chapter 3). Different than other forms of collective action in communities, motivations for engaging in *pirarucu* management involved more pragmatic thinking related to income, subsistence, and fishery conservation. However, their rationale was not always self-centered and motivated solely by individual income. Indeed, some communities used to invest financial resources resulting from management of *pirarucu* in the collective benefit of the community, including also members that did not participate in management. This sense of collectivity and solidarity characterizes community livelihoods and is one main ingredient for successful resource management.

The *pirarucu* fishery is one exceptional case of management right that has been decentralized to communities. In the LJER, community rights to develop their own management schemes, with ASTRUJ and ICMBio support, resulted in better environmental outcomes (Chapter 4). *Pirarucu* counts documented an increase by almost 350% in the LJER in six years, resulting from the improved governance of management systems. However, management outcomes differed among areas due to multiple factors stemming from characteristics of resource systems, actors, governance

systems, and interactions among these. Employment of the SES framework proposed by Ostrom (2009) helped to capture the complexity of social-ecological systems and identify the conditions underlying sustainable *pirarucu* management. I found that leadership, community monitoring, participation in decision making, group homogeneity, and social capital were key factors accounting for differences between growing or declining *pirarucu* populations.

This study was the first in investigating how co-management involving government and communities operates in the governance of multiple natural resources in ERs. Moreover, it was pioneer in providing an in-depth examination of community's social capital and how it fosters collective action for *pirarucu* management, as well as in analyzing the multiple factors of social-ecological systems affecting the sustainability of *pirarucu* management. Research findings furnish insights relevant to scholarship on extractive reserves, common property theory, social capital, and fisheries co-management. It confirms that government holds authority over natural resources in the co-management of ERs. Yet, it brings evidence on the importance of community participation, local knowledge, institutions and governance for the effective management of natural resources, confirming principles for sustainability of common property regimes raised by Ostrom (1990) and others (Agrawal 2003). However, co-management worked better when communities had external support, evidencing the role of government and local associations in fisheries co-management.

Nonetheless, it is important to recognize the limitations of this study. In order to identify and understand the social and governance mechanisms operating at*pirarucu* management systems (Chapters 3 and 4), I had to choose depth over breadth. Thus, it

has implications for the generalization of results. In addition, it is important to note that results from Chapter 3 and 4 are context-specific and are not intended to provide a recipe for successful management of fisheries.

Research findings are valuable for policy making, serving both government and grassroots organizations. It could provoke debates and base decisions over decentralization of management rights to communities, and improve local governance of natural resources in ERs. If the government expects that regulations are followed in ERs, then it should improve community participation in decision making, not only providing them with rights to design operational rules but also to participate on collective-choice rights. Policies should seek to decentralize management rights to communities in ERs, and incentivize the identification of conditions of resources, resource systems, actors, and governance that affect management sustainability. Government, grassroots organizations, and natural and social scientists could work together to develop mechanisms to incorporate local knowledge and local practices into management plans of ERs and of resources, to facilitate decentralization of rights to communities and improve natural resource governance. The conditions of resources, resources systems, actors and governance potentially affecting management sustainability are context-specific and could be addressed by Deliberative Councils and co-management institutions on the ground. Recognizing the key role of community participation in decision making is important for bringing greater empowerment and democratization in these protected areas, and to help these achieve their main objectives of reconciling conservation and development in the Brazilian Amazon.

APPENDIX A
QUESTIONNAIRES

QUESTIONÁRIO 1.1 – GRUPO DE DISCUSSÃO COM INFORMANTES-CHAVE DAS COMUNIDADES Data: ____/____/_____

PARTE 1. DADOS BÁSICOS - Para iniciar, vou fazer algumas perguntas sobre vocês e sua comunidade:

Nome da comunidade: _____ *Número de famílias:* _____

Código do informante	*Sexo*	*Religião*	*Idade*	*Tempo de moradia na comunidade*	*Função na comunidade*	*Participou do processo de criação da RESEX?*	*Participou da elaboração do Plano de Uso/Manejo da RESEX?*
1.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
2.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
3.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
4.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
5.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim

Código do informante	*Sexo*	*Religião*	*Idade*	*Tempo de moradia na comunidade*	*Função na comunidade*	*Participou do processo de criação da RESEX?*	*Participou da elaboração do Plano de Uso/Manejo da RESEX?*
6.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
7.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
8.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
9.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
10.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
11.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim
12.	( ) homem ( ) mulher	( ) católica ( ) evangélica ( ) nenhuma ( ) _____			( ) presidente ( ) vice-presidente ( ) _____	( ) Não ( ) Sim	( ) Não ( ) Sim

1. Há quantos tempo existe a comunidade?
2. A comunidade tem agente de saúde?

   ( ) não ( ) sim, da própria comunidade ( ) sim, de outra comunidade
3. Que tipo de infraestrutura a comunidade possui?

   ( ) escola (qual nível?) ( ) campo de futebol
   ( ) centro comunitário ( ) posto de saúde
   ( ) poço artesiano ( ) motor de luz
   ( ) telefone ( ) luz elétrica
   ( ) igreja ( ) outra – qual?
   ( ) bomba d´água
4. A comunidade tem algum tipo de organização formal, como:

   ( ) diretoria ( ) time de futebol
   ( ) associação comunitária ( ) outra - qual?
   ( ) associação religiosa
5. A comunidade tem algum tipo de organização informal, como mutirão para:

   ( ) abertura de roçado ( ) construção de benfeitorias
   ( ) farinhada ( ) festejo
   ( ) limpeza da área da comunidade ( ) outra - qual?
6. Quais são as principais atividades econômicas da comunidade?

   ( ) agricultura ( ) pecuária
   ( ) manejo de pirarucu ( ) extrativismo - qual produto?
   ( ) pesca ( ) outra - qual?
7. Com que frequência a comunidade se reúne?

   ( ) Uma vez por semana ( ) Uma vez a cada dois meses
   ( ) Uma vez ao mês ( ) outra
   ( ) Duas vezes ao mês
8. Nos últimos cinco anos, a frequência das reuniões:

   ( ) aumentou ( ) permaneceu a mesma
   ( ) diminuiu

   Por que?

9. Quantos moradores costumam participar das reuniões?

( ) menos da metade da comunidade ( ) mais da metade da comunidade

( ) metade da comunidade ( ) todos da comunidade

10. Nos últimos cinco anos, a participação dos moradores nas reuniões comunitárias:

( ) aumentou ( ) permaneceu a mesma

( ) diminuiu

Por que?

11. Todos os moradores são convidados para as reuniões da comunidade?

( ) não ( ) sim

Por que?

12. Quando foi a última eleição da diretoria da comunidade?

PARTE 2. GOVERNANÇA

Agora, gostaria de saber sobre as regras de uso de recursos e uso da terra da comunidade.

Primeiro, vamos fazer uma lista das regras da comunidade, para cada tipo de uso de recurso. Em seguida, farei perguntas sobre quem criou estas regras e se a comunidade pode mudar as regras se quiser. Também, gostaria de saber se as regras são ou não cumpridas.

Ocupação da terra

a. Quem pode morar na comunidade
b. Quem pode ser usuário dos recursos da área da comunidade
c. Restrições para novos moradores ou usuários
d. Divisão de roçado com pessoas de fora (“fazer de meia”)
e. Critérios para arrendamento da terra (roça, capoeira, lago, outro – qual?)
f. Critérios para venda da terra (lote, benfeitorias)
g. Outro – qual?

Desmatamento

a. Quem pode abrir roçado na área da comunidade
b. Abertura de roçado em mata bruta
c. Abertura de roçado na margem de rios/igarapés
d. Abertura de campo
e. Uso do fogo

f. Tamanho de roçado por família
g. Venda do roçado
h. Outro – qual?

Retirada de madeira

a. Quem pode tirar madeira
b. Quantidade de madeira
c. Tipo de árvore que pode ser derrubada
d. Locais de retirada de madeira (ex. mata bruta, roçado)
e. Tipo de uso (canoa, remo, casa, etc.)
f. Transporte de madeira até a cidade
g. Venda de madeira
h. Outro – qual?

Retirada de PFNM

a. Quem pode tirar PFNM
b. Cuidados ao tirar PFNM (p. ex. trado; não derrubar açaí verde; não tirar palha do olho da palheira)
c. Derrubada de plantas (p. ex. açaí, murumuru)
d. Locais de extração de PFNM
e. Quantidade de produtos a ser extraída
f. Venda de produtos
g. Outro – qual?

Pesca

a. Quem pode pescar nos lagos
b. Apetrechos de pesca
c. Técnicas de pesca
d. Época do ano
e. Locais de pesca
f. Tipos de peixe
g. Quantidade de peixe
h. Presença de barcos de pesca
i. Tamanho de embarcação ou número de canoas
j. Venda do peixe
k. Outro – qual?

Caça

a. Quem pode caçar na área da comunidade
b. Tipos de animais que podem ou não ser caçados
c. Locais de caça
d. Época de caça
e. Técnicas de caça (armadilha, uso de cachorro, etc.)
f. Quantidade permitida
g. Transporte até a cidade
h. Venda
i. Outro – qual?

Apanha de quelônios

a. Quem pode apanhar ovos de quelônios na área da comunidade
b. Quem pode pegar quelônios na área da comunidade
c. Quantidade de ovos
d. Quantidade de quelônios
e. Espécies de quelônios
f. Local de apanha (tabuleiro, praia, boca de igarapé, remanso, boiador etc)
g. Emprego de malhadeira no tabuleiro ou na costa da praia
h. Horário de pesca (dia/noite)
i. Transporte de ovos/quelônios até a cidade
j. Venda de ovos
k. Venda de quelônios
l. Outro – qual?

PARTE 3. GOVERNANÇA: APOIO DO ICMBIO

Nesta última parte, farei perguntas sobre o apoio do ICMBio para a comunidade.

7. O ICMBio dá apoio para a comunidade fazer o trabalho de preservação e vigilância?

   ( ) não ( ) sim

   Como?

8. Caso sim, como você avalia o apoio do ICMBio?

   ( ) Insuficiente ( ) Suficiente

   Por que?

9. No ano passado, houve algum conflito pelo uso da terra ou dos recursos naturais na área da comunidade, envolvendo os moradores ou pessoas de fora, que necessitasse de apoio do ICMBio para resolvê-lo?

( ) não ( ) sim

Qual?

Caso sim, que tipo de apoio foi dado e como você avalia o apoio?

( ) Insuficiente ( ) Suficiente

( ) Não houve apoio

Por que?

10. Como você avalia a fiscalização feita pelo ICMBio/IBAMA na área da comunidade?

( ) Não atende às necessidades de fiscalização

( ) Atende parcialmente às necessidades de fiscalização

( ) Atende bem às necessidades de fiscalização

Por que?

11. Os infratores que são pegos na fiscalização voltam a fazer irregularidades na área?

( ) Não ( ) Sim

( ) Não sabe responder

Por que?

QUESTIONÁRIO 2.1 – ENTREVISTA INDIVIDUAL COM MEMBROS DAS COMUNIDADES MANEJADORAS DE PIRARUCU

Nome da comunidade: _____ *Data:* _____

Código do informante: _____ ( ) homem ( ) mulher *Idade:* _____

PARTE 1. DADOS BÁSICOS

Para começar, farei perguntas sobre você e sua família:

1. *Onde você nasceu*?
2. *Há quanto tempo mora na comunidade?*
3. *Você participou do movimento pela criação da reserva?*

   ( ) não ( ) sim
4. *Você participou das oficinas de elaboração do plano de uso/manejo da RESEX?*

   ( ) não ( ) sim
5. *Você estudou*?

   ( ) não ( ) sim

   Até que série?

   ( ) 1ª série ( ) 5ª série ( ) 9ª série

   ( ) 2ª série ( ) 6ª série ( ) 1ª ano (ensino médio)

   ( ) 3ª série ( ) 7ª série ( ) 2ª ano (ensino médio)

   ( ) 4ª série ( ) 8ª série ( ) 3ª ano (ensino médio)

   ( ) Outro – Qual?
6. *Qual é sua religião?*

   ( ) católica ( ) nenhuma

   ( ) evangélica ( ) Outra – Qual?
7. *Qual é seu estado civil?*

   ( ) solteiro ( ) separado/desquitado

   ( ) casado ( ) viúvo

   ( ) amigado
8. *Tem moradia própria?*

   na comunidade:

   ( ) não ( ) sim Tamanho da casa:

   na cidade:

   ( ) não ( ) sim Tamanho da casa:

9. *Contando com você, quantas pessoas moram na sua casa e qual é a relação de parentesco entre vocês?*

Total famílias: Total pessoas:

( ) cônjuge ( ) sogro(a)

( ) filho(s) ( ) nora/genro

( ) neto(s) ( ) cunhado(a)

( ) pai ( ) enteado(s)

( ) mãe ( ) outro – Qual?

10. *Entre os itens que falarei a seguir, quais e quantos você possui em casa?*

Item	Quantidade	Item	Quantidade
( ) televisão	_____	( ) computador	_____
( ) aparelho de som	_____	( ) celular	_____
( ) aparelho DVD	_____	( ) máquina fotografica	_____
( ) máquina de lavar roupa	_____	( ) barco	_____
( ) freezer	_____	( ) motor rabeta	_____
( ) geladeira	_____	( ) motosserra	_____
( ) cama	_____	( ) espingarda	_____
( ) outros – quais?			

11. *Você é afiliado a alguma organização?*

( ) não ( ) sim

Quais?

( ) ASTRUJ ( ) SINDIPESCA

( ) STTR ( ) COLPESCA

( ) outra – Qual?

12. *Você é beneficiário(a) de programas sociais?*

( ) não ( ) sim

Quais?

( ) bolsa família ( ) seguro-defeso

( ) bolsa cidadão ( ) aposentadoria

( ) bolsa verde ( ) crédito INCRA

( ) outro – Qual?

13. *Você tem alguma função na comunidade?*

( ) não ( ) sim

Qual(is)?

( ) presidente ( ) catequista

( ) vice-presidente ( ) vigia de praia

( ) conselheiro ( ) vigia de tabuleiro

( ) agente de saúde ( ) contador de pirarucu

( ) parteira ( ) agente ambiental voluntário

( ) outra

14. *Qual é a sua ocupação principal?*

( ) agricultura ( ) serrar madeira

( ) criação de gado ( ) trabalho assalariado

( ) pesca ( ) aposentado

( ) extrativismo ( ) outra

15. *Você tem criação de animais? (Caso não,* pular para questão 17)

( ) não ( ) sim

Quais e quantos?

( ) galinha ( ) porco

( ) pato ( ) gado

( ) outro – Qual?

16. *Quantos animais foram vendidos ou consumidos nos últimos doze meses?*

Animal	Quantidade para consumo	Quantidade para venda	Valor unit.	Valor total

17. Q*uais são os principais produtos que vocês comercializam?*

1. _____ 4. _____

2. _____ 5. _____

3. _____ 6. _____

18. *Quais são os principais produtos que vocês usam para subsistência?*

1. _____ 4. _____
2. _____ 5. _____
3. _____ 6. _____

19. *Considerando os animais e produtos citados anteriormente, como foi sua produção para comercialização e subsistência na última safra:*

Produto	Meses	Produção total	Unid	Prod. consumo	Unid	Prod. venda	Unid	Preço unit.	Valor total

20. *Qual é a renda mensal da sua família (casa)?*

PARTE 2. COOPERAÇÃO NA COMUNIDADE – *Agora, farei perguntas sobre cooperação na comunidade:*

21. *No último ano, de quantas reuniões comunitárias você participou?*

( ) nenhuma ( ) metade ( ) todas
( ) menos da metade ( ) mais da metade

22. *Como você fica informado(a) das reuniões comunitárias?*

( ) não é informado ( ) através de vizinhos ( ) outra
( ) através do líder comunitário ( ) através de familiares

23. *Você participou da última eleição da diretoria da comunidade (presidente, vice, etc.)?*

( ) não ( ) sim

Caso não, por que?

24. *Você participa de algum mutirão na comunidade? (C*aso não, pular para questão 28)

( ) não ( ) sim

Quais?

( ) abertura/limpeza do roçado ( ) trabalho em ponte/trapiche

( ) farinhada ( ) abertura de furos

( ) limpeza da comunidade ( ) vigilância de lago

( ) roçar campo de futebol ( ) outro

25. *Como se organiza(m) o(s) mutirão(ões) do(s) qual(is) você participa?* (ao marcar X, identificar os tipos de mutirão)

( ) grupo familiar ( ) grupo religioso

( ) grupo de amigos ( ) turma (rodízio)

( ) outro

26. *Com que frequência você participa de mutirões?*

( ) raramente ( ) quase sempre

( ) geralmente ( ) sempre

27. *Por que você participa de mutirões?*

28. *Na comunidade, com que frequência os moradores vizinham comida?*

( ) nunca ( ) quase sempre

( ) raramente ( ) sempre

( ) geralmente

29. *Você vizinha comida?*

( ) não ( ) sim

Caso sim, com quem você costuma vizinhar? (não necessariamente em ordem)

	Nome/apelido	Parente?
1.		( ) não ( ) sim
2.		( ) não ( ) sim
3.		( ) não ( ) sim

30. *Quando precisa de ajuda, com quantas pessoas você pode contar na comunidade?*

( ) ninguém ( ) mais da metade da comunidade

( ) menos da metade da comunidade ( ) todos da comunidade

( ) metade da comunidade

31. *Quando precisa de ajuda, p. ex. no caso de problema de saúde ou de dinheiro, quem são as pessoas da comunidade com as quais você mais pode contar?* (não necessariamente em ordem)

	Nome/apelido	Parente?
1.		( ) não ( ) sim
2.		( ) não ( ) sim
3.		( ) não ( ) sim

32. *Quando tem tempo livre, com quem você costuma conversar na comunidade?*

	Nome/apelido	Parente?
1.		( ) não ( ) sim
2.		( ) não ( ) sim
3.		( ) não ( ) sim

33. *Quem são as lideranças na sua comunidade?*

34. *Se você tivesse que escolher uma das duas opções, qual você escolheria?*

( ) ter e cultivar uma roça com 10.000 covas sozinho(a)

( ) ter e cultivar uma roça de 25.000 covas junto com outra pessoa da comunidade

Por que?

35. *Para quantas pessoas na comunidade você emprestaria os seguintes itens:*

Item	Ninguém	Menos da metade da comunidade	Metade da comunidade	Mais da metade da comunidade	Todos da comunidade
a) Paneiro	( )	( )	( )	( )	( )
b) Espingarda	( )	( )	( )	( )	( )
c) Malhadeira	( )	( )	( )	( )	( )
d) Motor rabeta	( )	( )	( )	( )	( )
e) Dinheiro	( )	( )	( )	( )	( )
f) Haste de pirarucu	( )	( )	( )	( )	( )

36. *Em quantas pessoas da comunidade você confiaria a vigilância do lago de subsistência da comunidade?*

( ) ninguém

( ) menos da metade da comunidade

( ) metade da comunidade

( ) mais da metade da comunidade

( ) todos da comunidade

PARTE 3. RELAÇÕES EXTERNAS

Gostaria agora de fazer perguntas sobre as relações da comunidade com instituições de Juruá.

37. *Entre as instituições que falarei a seguir, numere cada uma de 1 a 5 de acordo com o apoio que dão à comunidade, sendo 1 = menos apoio e 5 = mais apoio.*

Instituição	Menos---Mais	Instituição	Menos ---Mais
Prefeitura de Juruá	1 2 3 4 5	Colônia de pescadores	1 2 3 4 5
Secretaria de Saúde	1 2 3 4 5	Sindipesca	1 2 3 4 5
Secretaria de Educação	1 2 3 4 5	ASTRUJ	1 2 3 4 5
Secretaria de Ação Social	1 2 3 4 5	ICMBio	1 2 3 4 5
Secretaria de Produção	1 2 3 4 5	IBAMA	1 2 3 4 5
Paróquia	1 2 3 4 5	INCRA	1 2 3 4 5
Pastoral da Criança	1 2 3 4 5	Delegacia de Polícia	1 2 3 4 5
IDAM	1 2 3 4 5	Outra – Qual?	1 2 3 4 5

38. (Apenas para comunidade que tem tabuleiro) *Dê um número de 1 a 5 (1=muito ruim - 5=muito bom) para o apoio que o ICMBio/IBAMA dá ao trabalho de preservação de tabuleiros pela comunidade, em termos de:*

Situação	Ruim ---------- Bom
Incentivar a vigilância comunitária	1 2 3 4 5
Atender às denúncias da comunidade	1 2 3 4 5
Fazer fiscalização quando necessário	1 2 3 4 5
Combater a apanha ilegal de quelônios/ovos	1 2 3 4 5
Ajudar a resolver conflitos	1 2 3 4 5

39. *Dê um número de 1 a 5 (1=muito ruim - 5=muito bom) para o apoio que o ICMBio/IBAMA dá ao trabalho de preservação de lagos pela comunidade, em termos de:*

Apoio	Ruim ---------- Bom
Incentivar a vigilância comunitária	1 2 3 4 5
Atender às denúncias da comunidade	1 2 3 4 5
Fazer fiscalização quando necessário	1 2 3 4 5
Combater as invasões de lago	1 2 3 4 5
Ajudar a resolver conflitos	1 2 3 4 5

40. *Nos últimos cinco anos, houve mudança no apoio que o ICMBio/IBAMA vem dando ao trabalho de preservação de lagos pela comunidade,em relação a:*

Situação	Aumentou	Diminuiu	Permaneceu igual	Não sabe responder
Incentivar a vigilância comunitária				
Atender às denúncias da comunidade				
Fazer fiscalização quando necessário				
Combater as invasões de lago				
Ajudar a resolver conflitos				

PARTE 4. MANEJO DE PIRARUCU

Nesta última parte do questionário, farei perguntas sobre o manejo de pirarucu:

41. *Você participa do manejo de pirarucu?* (caso não, pular para pergunta 43)

( ) não ( ) sim

42. *Há quanto tempo?*

Porque participa (ou não) do manejo?

43. *A seguir, vou ler algumas frases relacionadas ao manejo de pirarucu feito pela comunidade. Quero saber se você concorda ou não com estas afirmações. Não há resposta certa ou errada, o que importa é a sua opinião.*

Afirmação	Concorda totalmente	Concorda em parte	Discorda em parte	Discorda totalmente	Não sabe responder
a) O manejo de pirarucu aumentou a quantidade de pirarucus no(s) lago(s) da comunidade.	( )	( )	( )	( )	( )
b) Com o manejo de pirarucu, ficou mais fácil da comunidade conseguir peixe pra comer.	( )	( )	( )	( )	( )
c) Com o manejo de pirarucu, minha renda melhorou.	( )	( )	( )	( )	( )
d) A comunidade investe muito tempo cuidando dos lagos de manejo de pirarucu.	( )	( )	( )	( )	( )
e) A comunidade investe muito tempo na pesca do pirarucu manejado.	( )	( )	( )	( )	( )
f) O manejo de pirarucu trouxe muitos conflitos com pessoas da comunidade.	( )	( )	( )	( )	( )
g) O manejo de pirarucu trouxe muitos conflitos com pessoas de fora.	( )	( )	( )	( )	( )
h) O manejo de pirarucu traz mais prejuízo do que lucro.	( )	( )	( )	( )	( )
i) A comunidade faz vigilância do lago com frequência.	( )	( )	( )	( )	( )
j) Há pessoas na comunidade que investem muito mais em cuidar do lago de manejo do que outras.	( )	( )	( )	( )	( )
k) Há frequentes invasões no(s) lago(s) da comunidade.	( )	( )	( )	( )	( )
l) Há pessoas da comunidade que não cumprem com as regras do manejo de pirarucu.	( )	( )	( )	( )	( )
m) A comunidade não consegue controlar os moradores que descumprem com as regras do manejo.	( )	( )	( )	( )	( )
n) A comunidade se reúne, quando necessário, para tomar decisões em relação ao manejo de pirarucu.	( )	( )	( )	( )	( )
o) Eu costumo participar das reuniões de tomada de decisão em relação ao manejo de pirarucu na comunidade.	( )	( )	( )	( )	( )

Afirmação	Concorda totalmente	Concorda em parte	Discorda em parte	Discorda totalmente	Não sabe responder
p) A divisão dos lucros da pesca do pirarucu na comunidade é justa.	( )	( )	( )	( )	( )
q) Com o manejo de pirarucu na comunidade, minha vida melhorou.	( )	( )	( )	( )	( )
r) Com o manejo de pirarucu, os manejadores passaram a se preocupar mais com a preservação dos recursos.	( )	( )	( )	( )	( )

QUESTIONÁRIO 2.2 – ENTREVISTA INDIVIDUAL COM MEMBROS DO MANEJO DE PIRARUCU NO COMPLEXO DO PLANETA / ANDIRÁ

PARTE 1. DADOS BÁSICOS

Idem ao Questionario 2.1

PARTE 2. COOPERAÇÃO NO MANEJO – *Agora, farei perguntas sobre cooperação no grupo de manejo:*

21. *No último ano, de quantas reuniões de elaboração do regimento interno do manejo do Sacado você participou? (exclusivo para Complexo do Planeta)*

    ( ) nenhuma ( ) metade ( ) todas

    ( ) menos da metade ( ) mais da metade

22. *No último ano, de quantas reuniões do grupo de manejo você participou?*

    ( ) nenhuma ( ) metade ( ) todas

    ( ) menos da metade ( ) mais da metade

23. *Como você fica informado(a) das reuniões do grupo de manejo?*

    ( ) não é informado ( ) através do líder comunitário ( ) outra – Qual?

    ( ) através da ASTRUJ ( ) através do grupo de vigilância

24. *Além do trabalho conjunto de vigilância de lagos, você participa de mutirões com moradores ou usuários da outra comunidade: _____? (Planeta: se for da Antonina, perguntar sobre o Botafogo e vice-versa; No Andira, perguntar sobre as comunidades envolvidas)*

    ( ) não ( ) sim

    Caso sim, quais?

    ( ) abertura/limpeza do roçado ( ) reforma do flutuante

    ( ) farinhada ( ) abertura/limpeza de furos

    ( ) roçar campo de futebol ( ) outro – qual?

25. *Com que que frequência você visita a comunidade _____? (idem questão 24)*

    ( ) nunca ( ) quase sempre

    ( ) raramente ( ) sempre

    ( ) geralmente

26. *Caso visite a comunidade _____ (idem questão 24), qual costuma ser o motivo da visita?*

( ) visitar parente(s) ( ) jogar futebol

( ) visitar amigo(s) ( ) festejo

( ) trabalho de mutirão ( ) prestar serviço (ex. serrador, carpinteiro)

( ) outro – Qual?

27. *Já houve conflitos (no presente ou no passado) entre moradores/usuários das comunidades _____? (citar comunidades do grupo de manejo, idem 24)*

( ) não ( ) sim ( ) não sabe responder

Caso sim, que tipo de conflito?

28. *Se precisar de ajuda, com quantas pessoas do grupo de manejo você pode contar?*

( ) nunca ( ) quase sempre

( ) raramente ( ) sempre

( ) geralmente

29. *Quando precisa de ajuda, p. ex. no caso de problema de saúde ou de dinheiro, quem são as pessoas do grupo com as quais você mais pode contar?* (não necessariamente em ordem)

	Nome/apelido	Parente?
1.		( ) não ( ) sim
2.		( ) não ( ) sim
3.		( ) não ( ) sim

30. *Em relação à pesca do pirarucu manejado no Sacado/Andirá, se você pudesse escolher, qual destas opções você escolheria:*

a. *Cotas individuais para os pescadores, onde cada um pesca individualmente a mesma cota e recebe o lucro proporcional ao peso dos pirarucus que capturou (como é feito em Mamirauá);*

b. *Cotas coletivas para os pescadores, onde todos se juntam para pescar a cota do grupo e ao final dividem os lucros igualmente entre todos (como é feito no Planeta/Andirá);*

c. *Cotas coletivas por comunidade (proporcional ao número de pescadores), onde os pescadores da mesma comunidade pescam juntos e dividem igualmente entre si os lucros da pesca;*

Por que?

31. *Quem são as lideranças do grupo de manejo?*

32. *Com quem você prefere trabalhar durante a pesca, em que o grupo de manejo está todo reunido?*

	Nome/apelido	Parente?
1.		( ) não ( ) sim
2.		( ) não ( ) sim
3.		( ) não ( ) sim

33. *Para quantas pessoas do grupo de manejo você emprestaria os seguintes itens:*

Item	Ninguém	Menos da metade do grupo	Metade do grupo	Mais da metade do grupo	Todos do grupo
a) Paneiro	( )	( )	( )	( )	( )
b) Espingarda	( )	( )	( )	( )	( )
c) Malhadeira	( )	( )	( )	( )	( )
d) Motor rabeta	( )	( )	( )	( )	( )
e) Dinheiro	( )	( )	( )	( )	( )
f) Haste de pirarucu	( )	( )	( )	( )	( )

34. *Na sua opinião, quantas pessoas do grupode manejo levam o trabalho de vigilância a sério?*

( ) ninguém
( ) menos da metade do grupo
( ) metadedo grupo
( ) mais da metade do grupo
( ) todos do grupo

PARTE 3. RELAÇÕES EXTERNAS

Gostaria agora de fazer perguntas sobre as relações do grupo de manejo com instituições de Juruá.

35. *Entre as instituições que falarei a seguir, numere cada uma de 1 a 5 de acordo com o apoio que dão ao manejo no Planeta/Andirá, sendo 1 = menos apoio e 5 = mais apoio.*

Instituição	Menos---Mais	Instituição	Menos ---Mais
Prefeitura de Juruá	1 2 3 4 5	Colônia de pescadores	1 2 3 4 5
IDAM	1 2 3 4 5	Sindipesca	1 2 3 4 5
Secretaria de Produção	1 2 3 4 5	ASTRUJ	1 2 3 4 5

Paróquia	1 2 3 4 5	ICMBio	1 2 3 4 5
Instituição	Menos---Mais	Instituição	Menos ---Mais
Delegacia de Polícia	1 2 3 4 5	IBAMA	1 2 3 4 5
Outra – Qual?	1 2 3 4 5		

36. *Dê um número de 1 a 5 (1=muito ruim - 5=muito bom) para o apoio que o ICMBio/IBAMA dá ao trabalho de vigilância noPlaneta/Andirá, em termos de:*

Apoio	Ruim ---------- Bom
Incentivar a vigilância comunitária	1 2 3 4 5
Atender às denúncias do grupo de manejo	1 2 3 4 5
Fazer fiscalização quando necessário	1 2 3 4 5
Combater as invasões	1 2 3 4 5
Ajudar a resolver conflitos	1 2 3 4 5

37. *Nos últimos cinco anos, houve mudança no apoio que o ICMBio/IBAMA vem dando ao trabalho de vigilância no Planeta/Andirápelo grupo de manejo, em relação a:*

Situação	Aumentou	Diminuiu	Permaneceu igual	Não sabe responder
Incentivar a vigilância comunitária				
Atender às denúncias do grupo				
Fazer fiscalização quando necessário				
Combater as invasões				
Ajudar a resolver conflitos				

PARTE 4. MANEJO DE PIRARUCU

Nesta última parte do questionário, farei perguntas sobre o manejo de pirarucu:

38. *Há quanto tempo participa do manejo no Complexo do Planeta/Andirá?*

39. *Porque participa do manejo?*

40. *Na sua opinião, quais são os maiores problemas do manejo de pirarucu no Complexo do Planeta/Andirá?*

41. *A seguir, vou ler algumas frases relacionadas ao manejo de pirarucu no Complexo do Planeta/Andirá. Quero saber se você concorda ou não com estas afirmações. Não há resposta certa ou errada, o que importa é a sua opinião.*

Afirmação	Concorda totalmente	Concorda em parte	Discorda em parte	Discorda totalmente	Não sabe responder
a) O manejo de pirarucu aumentou a quantidade de pirarucus no(s) lago(s) do Planeta/Andirá.	( )	( )	( )	( )	( )
b) Com o manejo de pirarucu, ficou mais fácil de conseguir peixe pra comer.	( )	( )	( )	( )	( )
c) Com o manejo de pirarucu, minha renda melhorou.	( )	( )	( )	( )	( )
d) O grupo investe muito tempo cuidando dos ambientes de manejo de pirarucu.	( )	( )	( )	( )	( )
e) O grupo investe muito tempo na pesca do pirarucu manejado.	( )	( )	( )	( )	( )
f) O manejo de pirarucu no Planeta/Andirá trouxe muitos conflitos com os comunitários da reserva.	( )	( )	( )	( )	( )
g) O manejo de pirarucu no Planeta/Andirá trouxe muitos conflitos com pessoas de fora.	( )	( )	( )	( )	( )
h) O manejo de pirarucu traz mais prejuízo do que lucro.	( )	( )	( )	( )	( )
i) O grupo de manejo faz vigilância do Planeta/Andirá com frequência.	( )	( )	( )	( )	( )
j) Há pessoas no grupo que investem muito mais em cuidar dos lagos de manejo do que outras.	( )	( )	( )	( )	( )
k) Há frequentes invasões no(s) ambientes(s) de manejo do Planeta/Andirá.	( )	( )	( )	( )	( )
l) Há pessoas no grupo que não cumprem com as regras do manejo de pirarucu.	( )	( )	( )	( )	( )
m) O grupo não consegue controlar os manejadores que descumprem com as regras do manejo.	( )	( )	( )	( )	( )
n) O grupo se reúne, quando necessário, para tomar decisões em relação ao manejo de pirarucu.	( )	( )	( )	( )	( )

Afirmação	Concorda totalmente	Concorda em parte	Discorda em parte	Discorda totalmente	Não sabe responder
o) Eu costumo participar das reuniões de tomada de decisão em relação ao manejo de pirarucu no Planeta/Andirá.	( )	( )	( )	( )	( )
p) A divisão dos lucros da pesca do pirarucu no Planeta/Andirá é justa.	( )	( )	( )	( )	( )
q) Com o manejo de pirarucu no Planeta/Andirá, minha vida melhorou.	( )	( )	( )	( )	( )
r) Com o manejo de pirarucu no Planeta/Andirá, os manejadores passaram a se preocupar mais com a preservação dos recursos.	( )	( )	( )	( )	( )
s) A maior parte das reuniões do grupo é organizada pelo ICMBio.	( )	( )	( )	( )	( )

QUESTIONÁRIO 2.3 – ENTREVISTA COM INFORMANTES-CHAVE DO ICMBIO SOBRE APOIO AO MANEJO DE PIRARUCU

Data: _____ *Código dos informantes*: _____

1. *Há quanto tempo e de que forma você(s) vêm acompanhando o manejo de pirarucu na RESEX do Baixo Juruá?*
2. *Comparando os diferentes sistemas de manejo de pirarucu da RESEX, que tipo de apoio institucional do ICMBio foi ou tem sido dado para cada área, em termos de:*

Sistema de Manejo	Vigilância e fiscalização	Punição de infratores	Resolução de conflitos	Outras formas de apoio ao manejo
Botafogo				
Antonina				
Planeta				
Lago do Baixio				
Lago Socó				
Andirá				

3. *O que você(s) identifica(m) como chave para o sucesso do manejo?*
4. *Quais as principais limitações do manejo na RESEX?*

APPENDIX B
ADDITIONAL TABLE

Table B-1. Comparison of *pirarucu* management systems of LJER in terms of management outcomes, characteristics of resource systems, actors, governance systems, and interactions among factors. NA: Not apply; PA: Protected Area.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
Outcomes (O)							
O1- Ecological performance							
O1.1- Sustainability							
O1.1a- *Pirarucu* stocks over time	Increase Decrease (low, moderate, high)	597% (+2,717 fishes in 6 years)	72% (+23 fishes in 3 years)	26% (+164 fishes in 6 years)	30% (+40 fishes in 5 years)	-15% (-47 fishes in 5 years)	-81% (-169 fishes in 6 years)
Resource systems (RS)							
RS1- System size							
RS1.1- Area (ha)	Small (<100) Moderate (100-1000) Large (>1000)	500.4	21.4	52.5	82.7	9,971.3	37.1
RS1.2- Depth of flooding (m)	Shallow (<8) Moderate (8-15) Deep (>15)	5.7 to 22.6	5.8	4.8 to 7.8	5.2 to 10.8	6.6 to 15.3	7.3
RS2- Predictability	Yes No	Yes	Yes	No	Yes	No	Yes

Table B-1. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
RS3- Clarity of system boundaries	Yes No	Clear (within PA)	Clear (within PA)	Clear (within PA)	Clear (within PA)	Not clear (part outside PA)	Clear (within PA)
RS4- Location							
RS4.1- Distance to community (km)	Close (<10) Moderate (10-30) Distant (>30)	16.7 to Antonina; 33.7 to Botafogo	1.6 to Socó	3.5-4.2 to Botafogo	1.3-7.9 to Antonina	0-45 to Cumarú 14-59 to FG1	1.5 to Socó 3.4 to FG1
RS4.2- Distance to town (km)	Close (<20) Moderate (20-50) Distant (>50)	20	44.6	56.6-57.2	35.1-44.9	65-110	48
Actors (A)							
A1- Group size							
A1.1- Community size (N of households)	Small (<15) Moderate (15-30) Large (>30)	Botafogo – 14 Antonina – 16	6	11	17	Cumarú – 12 Escondido – 3 Ig. Branco – 4 Itauba – 1 FG 1 – 38	FG – 38
A1.2- Management group size (N of managers)	Small (<10) Moderate (10-30) Large (30-50)	49	9			33	
A1.3- Proportion of users involved in management (%)	Minority (<50) Majority (≥50) All	Total 30 Botafogo – 14 Antonina – 16	5	13	14	Total 25 Cumarú – 10 Escondido – 2 Ig. Branco – 1 Itauba – 1 FG 1 – 11	FG – 9

Table B-1. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
A2- Socioeconomic atributes							
A2.1- Group heterogeneity index	Index (3-9): Religious diversity (1-3) + Fisherman occupation (1-3) + Wealth disparity (1-3)	4	5	5	4	6	9
A2.1.1- Religious diversity (N of types)	Number of religions	1 Catholic (100%)	2 Catholic (92%) None (8%)	2 Catholic (73%) Protestant (27%)	1 Catholic (100%)	2 Catholic (92%) Protestant (8%)	3 Catholic (83%) Protestant (13%) None (4%)
A2.1.2- Fisherman occupation (%)	None Few (<20%) Some (20-50%)	7%	0%	0%	0%	13%	21%
A2.1.3- Wealth disparity							
A2.1.3.1- Variation in annual income - US$ (average ± standard deviation)	Variation: Low (<3,000) Moderate (3,000-4,000) High (>4,000)	5,365 ±2,627	6,411 ± 3,294	5,574 ± 3,854	5,932 ± 3,161	5,529 ± 3,309	5,904 ± 4,622

Table B-1. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
A3- Leadership	Present Absent	Present	Absent	Present	Present	Present/ Absent (passed away in 2011)	Present, lack representativeness
A4- Social capital							
A4.1- Trust (% that trust most people)	Minority (<50) Majority (≥50)	60	83	47	61	33	25
A4.2- Shared norms							
A4.2.1- Reciprocity, solidarity, and/or collectivity (%)	Minority (<50) Majority (≥50)	73	75	33	72	53	42
Governance systems (GS)							
GS1- History or past experience							
GS1.1- Duration of collective protection of lakes before management (N of years)	Long-term (>10) Short-term (<10)	2	0	44	11	2	14
GS1.2- Nature of community engagement in *pirarucu* management	Proactive Reluctant	Proactive	Proactive	Proactive	Proactive	Reluctant	Reluctant
GS2- Collective choice rules							

Table B-1. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
GS2.1- Nature of rules	Fomal Informal	Formal	Informal	Informal	Informal	Informal	Informal
GS2.2- Most people participate in decision making	Yes No	100	100	100	78	95	52
GS3- Monitoring							
GS3.1- Technology of monitoring	Present Absent	Two floating houses in different access points	No	One floating house in front of access point (dry season), but few people to guard	No	One floating house in the dry season	No
GS3.2- Frequent monitoring	Yes No	Day and night monitoring, all year round; 10 groups of 4-5 monitors in alternate guarding every week	Unfrequent, when notice tracks of invaders	Routinely/daily throughout the year, as agricultural plots are close to lake;	No need, lake entrance is close to community; no invasion by outsiders (only by community members); go there if notice something strange	Day and night monitoring during the dry season only; 6 groups of 5 monitors in alternative guarding every week	4-6 people monitor lake during dry season
GS4- Sanctioning	No Yes NA	Absent monitors are fined; Gillnets from illegal fishing are seized by managers	NA (no rule breaking)	No	Community members caught in rule breaking pay fines	No	No

Table B-1. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
GS5- Conflict resolution							
GS5.1- Success in solving conflicts	No Yes	Solved conflicts with urban fishers	Solved conflict with other community	Conflict with community members	Reduced conflict among community members	Conflict with users from other communities along Andirá river	Conflict increased with management
GS6- Organizations							
GS6.1- Non-governmental organization							
GS6.1.1- Perceived high support of ASTRUJ (%)	Some people (50-80) Many people (>80)	100	83	92	71	100	76
GS6.2- Governmental organization							
GS6.2.1- Perceived support of ICMBio (index: monitoring, meeting complaints, sanctioning, conflict resolution)	Little (<3) Moderate (3-4) A lot (>4)	4	2.8	3.5	3.2	4	3.4
Interactions (I)							

Table B-1. continued.

Indicator/Variable	Categories	Planeta	Baixio lake	Botafogo	Antonina	Andirá	Socó lake
I1- Importance of resource system to users[4,5]							
I1.1-Subsistence value	Weak Strong	Managed lakes are within communities' areas; exert only indirectly influence	Managed lake is used for community's subsistence	Managed lakes are used for community's subsistence	Managed lakes are used for community's subsistence	Managed areas are used for communities' subsistence	Managed lake is used for community's subsistence
I1.2-Economic value							
I1.2.1- *Pirarucu* management perceived as economically profitable (%)	Majority (50-80) Great majority (≥80)	100	60	87	89	76	69
I1.2.2. Income from *pirarucu* management in 2012	US$	1,480/person	190/family	175/person	975/family	440/person (on average)	none
I2- Overlap between residential location and resource location[4]	Yes No	Outside communities' use area	Within community's use area	Within community's use area	Within community's use area	Managed area is very big and includes communities' use areas	Within community's use area

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BIOGRAPHICAL SKETCH

Paula Soares Pinheiro was born and raised in Rio de Janeiro, Brazil, where she graduated in biological sciences in the Federal University of Rio de Janeiro, and got a master's degree in ecology in the State University of Rio de Janeiro. She has worked with the creation and management of protected areas in the Brazilian Amazon for the past 14 years. From 2004 to 2006, she worked in the Secretariat of Environment and Sustainable Development of Amazonas, conducting studies for the creation of nearly four millions of hectares of state protected areas. In 2006, she got a permanent position as environmental analyst at the federal governmental agency responsible for protected areas management in Brazil (IBAMA - Brazilian Institute for the Environment and Renewable Natural Resources, which later shifted to ICMBio - Chico Mendes Institute for Biodiversity Conservation). From 2006 to 2015, she worked as manager of the Middle Juruá Extractive Reserve, and since 2016 she works in the Anavilhanas National Park. In 2018, she received a doctoral degree in interdisciplinary ecology from the School of Natural Resources and Environment of University of Florida.