

Original Paper

Adaptive Management to Climate Change and Its Barriers in the Brazilian Amazon

Antonio F. P. Oviedo^{1,2*}, Marcel Bursztyn¹, Saulo R. Filho & Diego Lindoso¹

¹ Center for Sustainable Development, University of Brasília, Brasília, Brasil

² Instituto Socioambiental, São Paulo, Brasil

* Antonio F. P. Oviedo, Center for Sustainable Development, University of Brasília, Brasília, Brasil;
Instituto Socioambiental, São Paulo, Brasil

Received: July 18, 2019

Accepted: August 1, 2019

Online Published: August 29, 2019

doi:10.22158/ra.v4n1p10

URL: <http://dx.doi.org/10.22158/ra.v4n1p10>

Abstract

Studies on barriers to climate change adaptation identify many underlying drivers but describe few processes whereby adaptation is implemented. We contribute to the literature by describing how adaptive capacity relates to project cycle in small-scale communities where local stakeholders combine knowledge and barriers affecting adaptive management. Our study focused on two floodplain landscapes in the Brazilian Amazon where fisheries were identified as a current concern, potentially leading to future social conflict if not properly addressed. At both sites, we adopted participatory research to design an adaptive management framework for the analysis of socio-ecological barriers influencing local decision-making by fishermen and farmers. The comparative analysis provided insights into several actions that could support overcoming barriers to the governance of natural resources in each phase of the project cycle. Adaptation actions included fostering local participation and tools to facilitate knowledge generation and revising the role of the central government in natural resource management. We found that due to the slow capacity to adapt their practices, institutions regulating fisheries tend to work as a barrier for adaptation processes.

Keywords

adaptation, adaptive management, barriers, fisheries, Amazon

1. Introduction

Climate change has stood out as a major issue over the last two decades, especially from the perspectives of both the social and the natural sciences. Research studies indicate that developed countries would be less vulnerable due to greater adaptive capacity while developing countries would be more vulnerable

given their lower ability to cope with climate-driven impacts (Adger et al., 2009; Nielsen & Reenberg, 2010). However, the critical events that have occurred in recent years in the developed countries have given rise to critical questioning of the capacity and public policies of these countries to adapt to climate change.

As far as adaptive governance is concerned, previous studies have focused on different managerial scales, from state-level (Engle & Lemos, 2010) to community-level (Agrawal & Perrin, 2009) or both (Lemos & Agrawal, 2006) to identify major barriers to adaptation. This article aims to assess the limitations to adaptation that undermine the ability of traditional communities living in floodplain areas of the Amazon to cope with climate-driven impacts. The main objective is to approach these limitations through an analytical framework that enables their identification and organization within the processes of adaptation in the context of local communities. The identification of the barriers is required for increasing our understanding of adaptation processes and to facilitate decision-making related to public policy design and implementation.

Adaptation appeared along with mitigation in United Nations Framework Convention on Climate Change (UNFCCC) as one of two strategies to tackle human-driven climate change (UNFCCC, 1994). It was a marginal topic in the climate agenda compared to mitigation, which had concentrated most of the international community's efforts from the late 1990s onwards (Schipper, 2006). The setbacks during the Kyoto Protocol along with the failure in reaching a satisfactory mitigation agreement during the Conference of the Parties (UNFCCC, 2010a; UNFCCC, 2010b), in 2009, revealed the complexity of international negotiations. Meanwhile, new and stronger data on climate change risks were provided in IPCC's fourth Assessment Report (2007a) and subsequently created a suitable environment for adaptation to emerge as a paramount strategy as important as mitigation in the political spectrum. In this context, the research community was summoned to produce knowledge to support an efficient adaptive decision-making process.

Adaptation can refer to a system's feature or strategy that makes it more suitable to the changing environment. It can also refer to the condition of being adapted or to describe an action or a process that reduces the system's vulnerability or that takes advantage of an opportunity in a context of a disturbance (Barnett, 2010). There are several definitions in literature for adaptation. For example, the Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007b). Brooks (2003, p. 8) understands it as an "adjustments in a system's behavior and characteristics that enhance its ability to cope with external stresses". Pielke (1998, p. 159) presents adaptation as "adjustment in individual, group and institutional behavior in order to reduce society's vulnerability to climate". From a broad perspective, climate adaptation can be understood as what systems do to prevent and recover from climate stress (Biagini et al., 2014).

Adaptive capacity is a key research topic in the field of climate adaptation. It refers to the ability to manage, cope, and recover from climate disturbances (Smit & Wandel, 2006). At the most general level, it refers to the set of adaptive resources available to the socio-ecological system along with the means to access/plan/manage them (Norberg & Cumming, 2008; Adger, 2006). In resilience literature, adaptive capacity is frequently related to processes such as diversification, learning, innovation, reorganization, and development (Engle & Lemos, 2010; Anderies & Norberg, 2008; Lambin, 2005). Institutions, governance arrays, decision-making process, and adaptive management are constantly under research focus given the importance of understanding how potential conditions and resources are translated in actual adaptation (Barnett, 2010; Lemos & Agrawal, 2006). Monitoring and learning process are fundamental as a managerial approach to help in the process of institutional and social learning (Gunderson & Holling, 2002). In practice, typically, the decision-making process is not so linear and well ordered. Various authors (Mintzberg et al., 1976; Cohen et al., 1972) clearly show how the reality often diverges from the idealized models of the decision-making processes.

Adaptive management emerges as an analytical framing for conceptualizing adaptation. It recognizes that the non-linear and complexity of resources management can result in unpredictable scenarios that demand adaptive process to improve through learning, filling the gap between science and practice (Wise et al., 2014). Even though adaptive management is usually related to resources governance, we understand that strengthening adaptive management in indigenous and traditional communities is building resilient communities to climate impact and, as so, it's climate adaptation. In this sense, bottom-up studies on adaptive management cycles can reveal the limitations that hinder adaptation. In literature, this topic has been organized under the umbrella of "adaptive barriers". More commonly, ecological, technological, and economic barriers have been studied, however, since the early 2000s, social barriers (i.e., normative, cognitive, and institutional) have been gaining expression in the scientific agenda (Adger et al., 2009). Cognitive barriers refer to psychological and mental processes' influence on undertaking adaptive action (Lorenzoni et al., 2007). Normative barriers cover the role of norms and cultural values in the scope of adaptive decision in a given social context (Jones & Boyd, 2011). Finally, institutional barriers are related to the influence of organizations and social interaction infrastructures on the adaptation process (Barnett et al., 2015; Barnett, 2010; Ostrom, 2005).

These barriers are paramount in understanding climate adaptive governance, approached here as a frame of stakeholders, processes, management frameworks, and institutional mechanisms that lead to adaptation. It implies flexible governance models, capable of learning and adjusting in context of uncertainties and an ever-changing environment (Folke et al., 2005; Dietz et al., 2003). All of these aspects can be observed in adaptive management projects. Researches looking at the process underlining such projects can reveal common and specific adaptive barriers and provide insights for improvement and better adaptive management.

There is widespread recognition of the role that local perceptions can play in the management of natural resources (Davis & Wagner, 2003; Ahmed & Quack, 2017; Millar et al., 2019) and adaptation

to climate change (Meldrum et al., 2018; Utete et al., 2019). Local perception of climate patterns, life stories of species, and environmental characteristics are nested within management measures (Berkes, F. & Berkes, M., 2009). There is increasing recognition of the need to incorporate local perception into climate and adaptation assessments, as local communities have a significant knowledge of how ecosystems respond to climate change (IPCC, 2014). This article presents a set of case studies within the Amazon floodplain where local perception has contributed to the development of community-based adaptive management. They are typically small but complex social ecological systems, involving a wide range of ecosystems, species and climate patterns. We argue that community members build adaptive management by generating knowledge of a range of management cycles and policy issues. The purpose of this study is to describe how adaptive capacity relates to project cycle in small-scale communities where local stakeholders combine knowledge and barriers affecting adaptive management.

2. Method

This article presents an analytical model focused on barriers faced by riverine communities that may hinder the adaptive management to climate variability in floodplain areas in the Brazilian Amazon. Our analysis aims at predicting major barriers that preclude their adaptation process based on the adaptive management cycle (Margoulis & Salafsky, 1998). The adaptive management represents the process or the rational approach to decision-making in regard to adaptation. The comparative analysis of case studies produces a matrix for identification of drivers that cause certain barriers at the different levels of both decision-making process and adaptive management cycle.

In this article, we define the term barriers as thresholds beyond which current activities, forms of resource use, and ways to support ecosystems can no longer be kept, even under their altered form. Conversely, barriers can be overcome through joint efforts and coordinated changes in ways of thinking, capacity to prioritize actions, changes in the use of natural resources, and performance of institutions.

The proposed analytical model uses two case studies (Figure 1) that developed local adaptive management schemes: (i) fishing community of Igarapé do Costa, state of Pará, and (ii) fishing community of Santo Antonio, state of Acre. The fieldwork was conducted between 2008 and 2013 and aimed at discussing environmental impacts and social adaptations to climate variability at a local scale in view of the ability to implement management measures based on the project cycle (Margoulis & Salafsky, 1998). Participatory methods were applied as part of an inductive and exploratory approach to investigate the community's planning and implementation of adaptive management. The case studies include: (i) a pre-assessment consisting of a two-day meeting with each municipal fishermen's union (Santarém and Manoel Urbano) for preparatory activities in the target communities, and (ii) three-day workshop with community members in each target community. The sample included 50 community members. Each workshop had 25 participants selected according to livelihood strategies (fishermen, farmers, and cattle ranchers). To assess the implementation of adaptive management, informants were

asked for each management cycle: (i) what could hinder the adaptation action, and (ii) how users, the ecosystem, and the governance system contribute to constitution of barriers. Results were then discussed with a panel on adaptive actions that was organized and validated at the community workshop. The community informants built a formal procedure to reach consensus on each topic (Habermas, 1996).



Figure 1. Community of Igarapé do Costa, State of Pará (1), and Santo Antonio, State of Acre (2)

This participatory research used the adaptive management cycle which reflects the decision-making processes involved in understanding the problem, the planning of adaptation actions, and their monitoring (Figure 2). For each phase of the adaptive management, we identified potential barriers that could preclude the progress from one phase to another and those which might constitute a tool for preventing pitfalls during the process. Margoulis and Salafsky (1998) refer to the phases as common phases of a rational decision-making process, including: (i) definition of the conceptual model; (ii) project design, action plan, and monitoring plan; (iii) implementation of the action plan and monitoring plan, training, and partnerships; (iv) analysis and updating of strategies based on the results and monitoring plan; and (v) share lessons learned and feedback in order to cycle each project phase (iteration). The proposed framework considers that decision-making processes are typically less linear in practice and that the adaptive management phases provide a useful heuristic ordering.

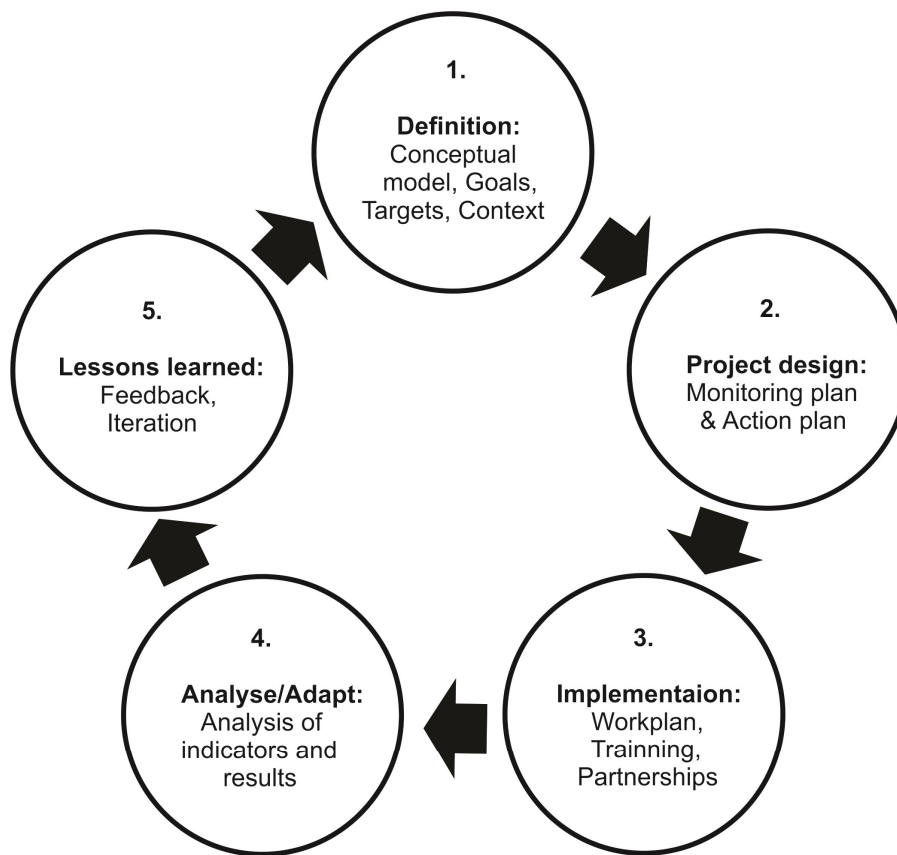


Figure 2. Adaptive Management Cycle

Source: Adapted from Margoulis and Salafsky (1998).

3. Result

3.1 Fishing Community of Igarapé Do Costa, Santarém, Pará

The community of Igarapé do Costa is located in natural levees and seasonally inundated grasslands which are cut by a perennial river channel (except in years of great droughts) in an island dominated by three floodplain lakes (Pacoval, Aramanaí, and Itarim). It is situated in the lower Amazon region where a pilot agro-extractive settlement project (PAE) has gained the power to develop a management plan for the fisheries and natural resources within their boundaries (McGrath et al., 2008).

During the flood period, lowlands are flooded by the waters of the Pacoval and Aramanaí lakes, allowing the access to the Amazon River. In contrast, during dry season, the community loses access to the Amazon River and the lakes shrink significantly. Years of severe drought and shallow lakes generate a high fish mortality due to increasing water temperature. Each year access to clean water is severely compromised at the peak of the dry season compelling the residents to dig water wells (often finding inadequate water for human consumption) or bring water for domestic use from the Amazon River which happens to be three kilometers away.

The geomorphological features of the Igarapé do Costa compromise its potential for economic diversification. The residents spend months surrounded by water followed by months surrounded by soil and mud. According to the residents, they are unable to practice agriculture because of the very short period in which the soil is exposed to the strong summer heat. Alternatively, residents install small raised beds for vegetable gardening. Fishing is the main activity for a majority of the families (IPAM, 2006). Fishermen in the community have reported the decrease in the size of some species, including two of great commercial importance, *Hypophthalmus* sp. (mapará) and *Prochilodus nigricans* (curimatã), and threat to the species of commercial value such as *Arapaima gigas* (pirarucu) and *Colossomacropomum* (tambaqui). The existing community-based management scheme (fishing agreement) prohibits fishing during the drought in site-specific places (i.e., Aramanaí channel and Poção), except artisanal fishing techniques, and regulates fishing efforts in the territory of the community.

Currently, adaptive management measures undertaken by the community involve fishing rules, raise of small animals (pigs and chickens), regulation of cattle ranching, planting of grassland (canarana), and rules for infrastructure and water supply. Management measures involve 70 families. According to the Fishermen Union Z-20, the community association of Igarapé do Costa is one of the most organized local institution in the region of Urucurituba. A set of actors is responsible for implementing policies and management measures: National Institute for Colonization and Land Reform (INCRA), National Environmental Agency (IBAMA), Fishermen Union Z-20, PAE Urucurituba Regional Fisheries Council, Igarapé do Costa Community Association, youth group, local school council, Municipal Secretary of Education in Santarém, State Secretary of Environment and Sustainability (SEMAS), and Amazon Environmental Research Institute (IPAM).

3.2 Fishing Community of Santo Antonio, Acre

Purus River is one of the main tributaries of the Amazon River with floodplains reaching 21.833 km². Purus white waters are highly productive in terms of fisheries and deliver around 30% of the fish landing in Manaus city (about 2.1 million inhabitants) and 70% of the fish landing in Acre's capital, Rio Branco (about 383,400 inhabitants). In the upper Purus River, fisheries are strongly linked to the hydrological regime in the main channel and to the regular flooding of their adjacent floodplains and lakes. The hydrological cycle in the community of Santo Antonio is characterized by a high water season (October to May) and a low water season (June to September). According to the local residents, since 2005, the dry season has extended to the months of October and November. The variation in the water level can reach 12m on average.

Purus River and its oxbow lakes support micro-stocks of different fish species and play a key role in preserving fisheries in conditions of water stress such as those observed during the droughts of 2005 and 2010. Changes in the hydrological cycle and ecosystems rapidly affect the structure of fish landing and may have negative impacts on fishing in the lower region of the basin. Production of commercial and subsistence fishery in the upper Purus has decreased in the last few decades (Oviedo & Crossa,

2011), directly affecting 15,000 families that live along rivers in the upper region.

In the community of Santo Antonio, a set of two fishing agreements is coordinated by the state government, the municipal fishermen's union, and the Arapaima Fishermen's Association since 2005 where the major objectives are to manage *Arapaima gigas*, conserve micro-stocks of fish species and ecosystems, and provide greater benefits to local users. Adaptive management measures involve fishing rules, crop calendar in river banks and upper lands, controlling aquatic vegetation in managed lakes, and rules for infrastructure and access to lakes. Fishing agreements involve 13 families and a group of managers with 12 members. However, internal conflicts between the two local institutions undermine the participatory and decision-making process. The efficiency of management measures is limited by weak monitoring practices. Consequently, the municipality of Manoel Urbano, where the community is located, experienced a decline in arapaima stocks (Oviedo et al., 2015). A set of actors is responsible for the fishing and farming activities: IBAMA, Santo Antonio Community Association, municipal fishermen's union, Arapaima Fishermen's Association, State Secretary of Environment (SEMA), and State Secretary of Agroforestry and Family Production (SEAPROF).

During the workshops in the two case studies, around 82.5% of the community participants perceived a change in climate particularly an increasing trend in temperature and variability, prolonged dry season and decreasing trend of rainfall in their lifetime. Almost all respondents (91%) responded that climate change has become a challenge for their fishing and farming system. The percentage of participants who agreed that climate change can be adapted was 65.4%. Having early warning information about environmental changes also affected the extent of adaptive management. Regarding the cause behind climate change, 76.1% of respondents stated anthropogenic processes (i.e., deforestation, urbanization, overharvesting of natural resources) as the major factor. Moreover, 18.3% of respondents did not know the reason behind the changing climate.

Table 1 presents the barriers reported throughout the adaptive management process in the studied communities. Two key characteristics underlie the analytical model of barriers to climate adaptation. The first one is a description of rational choices to allocate power and decision-making with respect to climate adaptation. The second shows a set of institutional elements that include the users, the local context, and the cultural values (the knowledge of ecosystem changes) related to barriers to avoid making trade-offs. Results identify barriers in each phase and therefore may impact progress from one phase to another. Some barriers were reported by community members to occur in more than one phase of the management cycle (i.e., community leadership, legal framework supporting local governance, ability to document, organize, and translate information). However, this table aims to emphasize the key management cycle where the barrier is most influential.

Table 1. Barriers Found in the Adaptive Management Cycle in Both Amazonian Communities

| Phases | Governance aspects in which barriers emerge |
|---|--|
| 1. Definition of the conceptual model | <ul style="list-style-type: none"> (i) Community leadership (ii) Ability of users and institutions to detect environmental changes (iii) Preliminary delineation of the problem (iv) Sensitivity of users to environmental changes (v) The need of response and viability threshold (vi) Site-specific context and translated information at an appropriate scale |
| 2. Project design | <ul style="list-style-type: none"> (i) Level of governance of local actors over management measures (ii) Local capacity to define a set of conservation targets and adaptation options/actions (iii) Availability of supporting data/information to establish adaptation actions (iv) Social conflicts between local users and/or institutions impacting decision-making and proposed adaptation actions (v) Celerity on legal regulation (vi) Government and funding agencies with fragmented vision (community-based adaptation, ecosystem based adaptation, risk reduction, food security, forest value chains) different from the integrated vision of rural communities |
| 3. Implementation | <ul style="list-style-type: none"> (i) Willingness for implementing adaptation actions (ii) Growing knowledge and necessary skills for the implementation of the adaptation action (iii) Legality and authorization of the competent governmental agencies (iv) Legal framework supporting local governance (v) Existence of sufficient resources (financial, technical, etc.) and working time (vi) Roles and responsibilities defined among users and/or institutions (vii) Collective action to overcome institutional delay and behavioral barriers |
| 4. Analysis/Adaptation | <ul style="list-style-type: none"> (i) Level of implementation of monitoring plan with indicators (ii) Threshold of need and feasibility of monitoring and evaluation (iii) Accessibility of methods to evaluate adaptation actions (iv) Level of consensus on relevant data interpretation (v) Financial resources for monitoring (vi) Limitations of governmental bodies in monitoring natural resources at a local scale |
| 5. Sharing lessons learned and cycle the conceptual model | <ul style="list-style-type: none"> (i) Trade-offs in the allocation of adaptation actions (ii) Decision-making process to revise/adjust earlier decisions (iii) Legal and environmental restrictions on revising regulatory constraints (iv) Limitations of tools and mechanisms for communication (options/actions, results, indicators) among the different actors involved (v) Ability to document, organize, and translate information to community members |

4. Discussion

During the *definition of the conceptual model*, users and institutions produce a larger set of possible options and these are analyzed in the light of criteria and goals agreed upon by the group; in the end, one or more of the options and/or adaptation actions are considered viable and are, then, selected. Cultural values influence how people generate knowledge related to climate variability and natural resource management to determine what information and knowledge they value, and which subjects are important. Community users should examine climate variability and natural resources through the facts of their livelihoods, territorial arrangements, local rules, and empirical consequences.

Cognitive psychology studies suggest that these cultural facts dye our general ideas about society and environmental regulation (Kahan & Braman, 2006). Preliminary findings on the fishing communities studied show that these cognitive filters shape the perceptions of climate variability and influence the decision-making processes (Oviedo et al., 2016). During this step, the presence of leadership with authority and ability to positively influence the process can be crucial. The leaderships in the community of Igarapé do Costa (i.e., health agents, members of the community association, representatives of fishermen's union, and Urucurituba PAE's council) were relevant in the management of actions and projects. Information provided by these leaderships permit users to concentrate their deliberations only on those options that they deem possible to control or on options that improve governability. At this point, the inability to identify and reject targets could become a significant barrier. As in the case of Santo Antonio, local leaderships played a limited role in this phase because the coordination of the project agenda and procedures was done by the state government.

Although the ecosystem and natural resources used are able to signal some of the change or alteration, users and their institutions, and the system of governance will determine the detection of these signals and the degree of their interpretation. The existence of a signal of change of the ecosystem can go unnoticed if, for example, communities do not register, or users are too busy, or if the institutions are distant and unprepared in terms of infrastructure to monitor such a signal. An important aspect to note is that biological systems often respond more rapidly to climate variability than demonstrated by the climate variables. Therefore, it is important that users are aware of permanent changes in biological systems of any nature. The case study of Santo Antonio showed that the absence of leadership working inside of local institutions can weaken the capacity of the community and reduce their willingness to make decisions regarding environmental change. In turn, government agencies may fail to record and transmit a signal of environmental change. The communication of changes in the ecosystem and its natural resources may fail because of the lack of site-specific mechanisms and language adapted for the target audience.

Barriers to adaptation arise from an inability of institutions (i.e., lack of methods and technology) to record a signal of change and adjust in time to avoid crossing environmental thresholds. In this case, the schools and their teachers play an important role in community engagement for knowledge generation. In Igarapé do Costa, schoolteachers and students had a significant role in participating in the projects and

producing information for the local residents. Similarly, the nature of the ecosystem and its interaction with climate variability can be pervaded with uncertainty that hampers the signal distinction. If users and institutions do not demonstrate a minimum level of concern regarding the problem identified or if they do not see the need for a response, the adaptation measure will find it difficult to follow the cycle of adaptive management. In both the studied cases, users and institutions implemented adaptive management projects that included natural resources inventories, diagnosis of problems, and the schedule of activities and/or actions.

Barriers often arising from the project *design phase* are related to local actors who control the management schemes. For example, if a local organization and a government agency, both linked to the environmental sector, develop their management plans, it is very likely that their adaptation options may differ one from another because their priorities and scales (regarding environmental thresholds) are divergent. If the ecosystem and the management measures in question involve multiple levels of governance, then overcoming the barriers will require institutional agreement and cooperation between such levels to effectively implement the adaptation actions. As different actors (i.e., the community, NGOs, state, and federal governments) focus on different scales and political interests and as different actors can be involved at various levels of governance, barriers to climate adaptation should also be analyzed from a multilevel perspective. In the cases of Santo Antonio and Igarapé do Costa, collective fishing agreements involved the local organizations, and federal, state, and municipal governments for the implementation of management measures. The adaptation actions defined in these fishing agreements reinforce ongoing management measures (i.e., building corrals far from the river channel, using sodium hypochlorite, and breeding small animals in captivity) and define activities to be implemented at different scales of governance. Additionally, in Igarapé do Costa, adaptation actions embrace and amplify an idea that has been successfully introduced by some community residents (i.e., planting of grassland—canarana, and forest restoration). Municipal government promoted teachers' training and made available the local school building as headquarters for training and planning activities; NGOs provided technical assistance for up scaling actions; and federal and state governments provided financial resources, technical assistance, and legal regulation.

Adaptive management during the phase of project design was also hindered by insufficient local capacity. In Igarapé do Costa, the existing legal framework (i.e., fishing agreements and community meetings) supported local participation by providing participatory meetings to engage local users in designing the adaptive management. Therefore, the community had the opportunity to plan for their water and fisheries, as well as discuss conservation goals and adaptation options with government agencies and NGOs. On the other hand, in Santo Antonio, the inability to identify and agree upon conservation goals reflected a significant barrier at this phase. Conflicts between the two local institutions responsible for the fisheries management undermined the participatory and decision-making process. There was no regular attendance to sessions of either institution. State government agents did not align with local managements priorities as the state's emphasis was

aquaculture while the local users wanted to manage natural lakes. Also, local leaders and government agents were not accountable to the local users.

The transition from the design phase to the *implementation phase* is strongly influenced by the decision-making and regulation of adaptive management, partly because of its impact on user's perceptions and partly due to their impact on the ecosystem. While implementation of an adaptation action is to be involved into the legal framework, it sometimes indicates the need for revision in regulatory constraints. For example, strengthening community organization and management practices of subsistence fishing in floodplain lakes against the changes of the flooding cycle (which alters the biology and the reproduction of species) may be in conflict with the existing legislation that regulates access and use for licensed fishermen. It would then be necessary to formulate specific legislation to regulate the access and use of fishery resources (i.e., the creation of a protected area for sustainable use or an agro-extractive settlement project). This is the case of Santo Antonio, where law-enforcement of regulated fishing agreements was unable to maintain fisheries management measures leading to illegal access and fishing (Oviedo et al., 2015). The monitored impact on *Arapaima gigas* (pirarucu) stocks also demanded urgent revisions to declare a moratorium on its fishery. Additionally, in Igarapé do Costa, fishermen reported that the *Hypophthalmus* sp. (mapará) length was still very small at the end of the closed season (*defeso*) when it starts the fishing season, and that the prohibition period should be longer. As this regulation needs to be issued each year, it can be revised or even discontinued. In this case, the knowledge of local fishermen can provide an important subsidy for the revision of regulatory constraints.

The *implementation phase* might involve multiple users, institutions, and field operations and therefore, it is both time and resource consuming. Users have a fundamental influence on whether to deploy a certain adaptation action as well as an implementation mode. Fostering willingness to deploy an adaptation action is the first limitation to be surpassed. In addition, it is necessary that users have acquired knowledge and necessary skills for the implementation of the action. The case study of Santo Antonio found hesitation and even resistance to the implementation of adaptation actions among farmers since they were unaware of a shifting trend in the rainy season related to climate change and therefore preferred maintaining the traditional planting method (i.e., planting season in September rather than postponing it to November). After the regulation of the fishing agreement in lake Santo Antonio, there was an increase in the number of illegal fishing techniques by 20%. On the other hand, community fishermen of Igarapé do Costa showed a high level of engagement and coordination for implementing adaptation actions, especially collective actions on mapping areas, planting grasslands, and water use (96% of the population adopted practices of water treatment).

In both the cases, the existing regulations (i.e., fishing agreements) supported local governance by providing a structured process to involve local communities in the *implementation phase*. However, this divergence between the case studies likely derives from contrasting institutional efforts deployed for the organizational development of these communities. In the case of the community of Igarapé do Costa,

a co-management project of fisheries in the region had been working on the development of communities over the past 17 years (McGrath et al., 2008). However, in the community of Santo Antonio, investments are reduced and a low-profile presence of the state for technical assistance led to a lower level of community participation and engagement in the implementation of actions.

The *phase of analysis* could lead to adapting and adjusting and demands the consideration of mechanisms that allow for monitoring of the effects of the adaptation actions and the assessment of signals of environmental change. Not reaching consensus on relevant data interpretation may limit the ability to evaluate the effects of the adaptation actions or the degree of success achieved. At a short-term scale, Santo Antonio and Igarapé do Costa have been coordinating community-based monitoring to deal with current threats such as illegal fishing and climate variability (Oviedo et al., 2016). Nevertheless, the success of some actions has been undermined by the weakening of collective action and engagement. For example, in Santo Antonio, to increase the effectiveness of local monitoring and to improve fishery management, the state government has granted an annual fishing quota and legal harvest permits for *Arapaima gigas* extraction. Although the government increased opportunities for community participation, the annual fishing quota and legal harvest permits led to an increase in illegal fishing by fishermen acting in self-interest because the sanctions were not effective. Such a behavior resembles the case narrated by Hardin (1968) in his Tragedy of the Commons. The absence of community assessment meetings in Santo Antonio made it difficult to interpret the results of adaptive management which resulted in communities' barrier in revising rules to reduce illegal fishing.

The *learning phase* of the adaptive management requires participatory approaches that include building and sharing perceptions (and solutions applied) on the issue among multiple users and institutions as well as the construction of trust as a basis for engagement in collective decision and learning processes. The community of Igarapé do Costa highlighted the importance of participatory meetings for the social learning process and knowledge generation. By interacting with neighbors and observing their behavior and the outcomes of their decisions (e.g., planting of grassland, rules for the use of infrastructure, and water supply), fishermen and farmers complement and reconsider the knowledge obtained from their own experiences through the revision and expansion of the adaptation action. In Santo Antonio, the local group of *Arapaima gigas* managers has used biological indicators to demonstrate the extent to which the adaptive management has been successful. Case studies of Santo Antonio and Igarapé do Costa presented a potential tool for studying situations where users could fail.

Results reported in this article have supported other studies, which found that trade-offs in the allocation of adaptation action in response to climate variability are seen as barriers (Eisenack et al., 2014; Barnett et al., 2015). For example, in a drying climate, there will be increased competition for fisheries and water supply. Where fisheries are scarce, decisions about levels of capture, as an adaptation action, will necessarily require trade-offs. Further, in creating demands of infrastructure and water supply, the economic value of water is given preference over its ecological and cultural dimensions. Therefore, adaptation actions that relate to water are also traded-off. In Santo Antonio,

there are emerging trade-offs between fishermen, which may adapt for some time by limiting the harvest level and enhancing enforcement that would be positively affected by these actions. In Igarapé do Costa too, there are trade-offs between the variability of water resources and adaptation action by community users.

During the *learning phase*, communication and information about the climate (or the environment) variability, adaptive actions, and their implications are constantly needed. A growing literature points out to the importance of effective communication in relation to climate change (Moser & Dilling, 2007; CRED, 2009). The limitations regarding the problem of information are related to the vocabulary used and the format of communication pieces. The case study of Santo Antonio showed that any misinterpretation of information, regarding its scale of incidence, or even the lack of it was able to bewilder or interrupt the social interactions of users engaged in the adaptation process. In Igarapé do Costa, the produced communication pieces with the appropriate language for community residents and students (i.e., booklets, charts identifying ecosystem and biodiversity existing in the community, panels of adaptive actions, timeline of the history of the community, and community land use maps) promoted effective dissemination and sharing of knowledge acquired during the process of adaptive management. The description of these cases provides an opportunity to: (i) raise details about the experience of a traditional community on extreme weather events and/or climate variability; (ii) raise awareness of local residents and leaders about climate variability, bringing the debate to the context of their reality; and (iii) generate local knowledge and informative material to be used by community members and partner institutions. As in the case study of Igarapé do Costa, the Municipal Secretary of Education in Santarém adopted this analytical model of climate change assessment and adaptation measures as an activity in the pedagogical project of municipal schools in rural areas. Research team involved in the fieldwork of Igarapé do Costa have promoted training courses to municipal teachers and school directors who replicated the workshops in their rural schools. This regional effort produced a huge environmental education forum in 2009 at the city's headquarters entitled Climate Witnesses.

Barriers were identified according to specific adaptive management phases so that corresponding interventions could be suitably addressed. The combination of analytical constructs, such as the nature of barriers and the adaptive management cycle, constitutes a guideline to design adaptation actions and plans. Rather than proposing a normative approach, the adaptive management cycle is descriptive in detecting barriers at different phases of a planned adaptation action. Most of the barriers identified during specific phases of the adaptive management cycle are related to competing values, which implies trade-offs in prioritizing adaptation actions. Identification of trade-offs associated with adaptation actions requires community and institutional choices regarding climate adaptation.

As adaptation actions advance, lessons learned may reveal a general protocol of procedures applicable in overcoming specific barriers. This article proposes that adaptive actions demand site-specific context in relation to climate variability and institutional arrangement. The proposed analytical model shows that programs and projects based only on project design and implementation phases are inadequate to address

this wide range of barriers regarding adaptation. In contrast, there are several mechanisms and operations that could help overcome barriers affecting the adaptation actions, notably in each phase of the adaptive management cycle. Strategies of intervention included enhancing community organization and management to support knowledge generation and strengthening the partnership with government agencies.

Working jointly with community associations in shaping this research proved effective in increasing awareness about climate change and involving not only management measures and political aspects of natural resources but also organizational processes. A question for future investigations refers to the performance analysis of each adaptive management phase as an indicator of adaptability. For example, a group of fishermen could compensate the lack of financial resources because they have a good capacity for collective actions that facilitate potentially difficult processes. In the near future, research in this direction should investigate the various patterns that users and institutions have found to overcome the barriers faced.

References

- Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16(3), 268-281. <https://doi.org/10.1016/j.gloenvcha.2006.02.006>
- Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., ... Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climate Change*, 93(3), 335-354. <https://doi.org/10.1007/s10584-008-9520-z>
- Agrawal, A., & Perrin, N. (2009). Climate adaptation, local. Institutions and rural livelihoods. In W. N. Adger, I. Lorenzoni, & K. L. O' Brien (Eds.), *Adapting to climate change: Thresholds, values, governance* (pp. 350-367). Cambridge University Press, Cambridge. <https://doi.org/10.1017/CBO9780511596667.023>
- Ahmed, M. N. Q., & Haq, S. M. A. (2017). Indigenous people's perceptions about climate change, forest resource management, and coping strategies: A comparative study in Bangladesh. *Environ Dev Sustain.*, 21(2), 679-708. <https://doi.org/10.1007/s10668-017-0055-1>
- Anderies, J., & Norberg, J. (2008). Theoretical Challenges: Information Processing. In J. Norberg, G. S. Cumming (Eds.), *Complexity theory for a sustainable future* (pp. 155-179). New York: Columbia University Press.
- Barnett, J. (2010). Adapting to climate change: Three key challenges for research and policy-An editorial essay. *WIREs Climate Change*, 1(3), 314-317. <https://doi.org/10.1002/wcc.28>
- Barnett, J., Evans, L. S., Gross, C., Kiem, A. S., Kingsford, R. T., Palutikof, J. P., ... Smithers, S. G. (2015). From barriers to limits to climate change adaptation: Path dependency and the speed of change. *Ecology and Society*, 20(3), 5. <https://doi.org/10.5751/ES-07698-200305>
- Berkes, F., & Berkes, M. K. (2009). Ecological complexity, fuzzy logic and holism in indigenous knowledge. *Futures*, 41, 6-12. <https://doi.org/10.1016/j.futures.2008.07.003>

- Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S., & McNeeley, S. M. (2014). A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. *Global Environmental Change*, 25, 97-108. <https://doi.org/10.1016/j.gloenvcha.2014.01.003>
- Brooks, N. (2003). *Vulnerability, Risk and Adaptation: A Conceptual Framework*. Working Paper 38, Tyndall Centre for Climate Change Research.
- Center for Research on Environmental Decisions—CRED. (2009). *The Psychology of Climate Change Communication: A Guide for Scientists, Journalists, Educators, Political Aides, and the Interested Public*. Columbia University, New York.
- Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A garbage can model of organizational choice. *Administrative Science Quarterly*, 17, 1-25. <https://doi.org/10.2307/2392088>
- Davis, A., & Wagner, J. R. (2003). Who knows? On the importance of identifying “experts” when researching local ecological knowledge. *Human Ecology*, 31(3), 463-489. <https://doi.org/10.1023/A:1025075923297>
- Dietz, T., Ostrom, E., & Stern, P. (2003). The struggle to govern the commons. *Science*, 302(5652), 1907-1912. <https://doi.org/10.1126/science.1091015>
- Eisenack, K., Moser, S. C., Hoffmann, E., Klein, R. J. T., Oberlack, C., Pechan, A., ... Termeer, C. J. A. M. (2014). Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change*, 4, 867-872. <https://doi.org/10.1038/nclimate2350>
- Ekstrom, J. A., Moser, S. C., & Torn, M. (2010). Barriers to climate change adaptation: A diagnostic framework. In *Public Interest Energy Research (PIER) Program final project report CED-500-2011-004*. Sacramento: California Energy Commission.
- Engle, N. L., & Lemos, M. C. (2010). Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change*, 20(1), 4-13. <https://doi.org/10.1016/j.gloenvcha.2009.07.001>
- Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, 30(1), 441-473. <https://doi.org/10.1146/annurev.energy.30.050504.144511>
- Gunderson, L., & Holling, C. S. (2002). *Panarchy: Understanding Transformations in Systems of Humans and Nature*. Island Press, Washington, DC.
- Habermas, J. (1996). *Between facts and norms: Contribution to a discourse theory of law and democracy*. MIT Press, Cambridge. <https://doi.org/10.7551/mitpress/1564.001.0001>
- Hardin, G. (1968). The Tragedy of the Commons. *Science*, 162, 1243-1248. <https://doi.org/10.1126/science.162.3859.1243>
- Instituto de Pesquisa Ambiental da Amazônia-IPAM. (2006). *Censo estatístico comunitário: Comunidade Igarapé do Costa, região do Urucurituba*. Cartilha. Santarém, IPAM.

- Intergovernmental Panel on Climate Change—IPCC. (2007a). *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, & H. L. Miller (Eds.)). New York and Cambridge, UK: Cambridge University Press.
- Intergovernmental Panel on Climate Change—IPCC. (2007b). *Contribution of Climate Change Working Group II: Impacts, Adaptation and Vulnerability to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, & H. L. Miller (Eds.)). New York and Cambridge, UK: Cambridge University Press.
- Intergovernmental Panel on Climate Change—IPCC. (2014). *Climate Change 2014: Impacts, adaptation, and vulnerability-Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, ... L. L. White (Eds.)). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- Jones, L., & Boyd, E. (2011). Exploring social barriers to adaptation: Insights from Western Nepal. *Global Environmental Change*, 21(4), 1262-1274. <https://doi.org/10.1016/j.gloenvcha.2011.06.002>
- Kahan, D. M., & Braman, D. (2006). Cultural Cognition and Public Policy. *Yale Law & Policy Review*, 24, 147.
- Lambin, E. F. (2005). Conditions for sustainability of human-environment systems: Information, motivation, and capacity. *Global Environmental Change*, 15(3), 177-180. <https://doi.org/10.1016/j.gloenvcha.2005.06.002>
- Lemos, M. C., & Agrawal, A. (2006). Environmental Governance. *Annual Review of Environment and Resources*, 31(1), 297-325. <https://doi.org/10.1146/annurev.energy.31.042605.135621>
- Lorenzoni, I., Nicholson-Cole, S., & Whitmarsh, L. (2007). Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change*, 17(3), 445-459. <https://doi.org/10.1016/j.gloenvcha.2007.01.004>
- Margoulis, R., & Salafsky, N. (1998). *Measures of success*. Island Press, Washington.
- McGrath, D. G., Cardoso, A., Almeida, O., & Pezzuti, J. (2008). Constructing a policy and institutional framework for an ecosystem-based approach to managing the Lower Amazon floodplain. *Environ Dev Sustain*, 10, 677-695. <https://doi.org/10.1007/s10668-008-9154-3>
- Meldrum, G., Mijatović, D., Rojas, W., Flores, J., Pinto, M., Mamani, G., ... Padulosi, S. (2018). Climate change and crop diversity: Farmers' perceptions and adaptation on the Bolivian Altiplano. *Environ Dev Sustain*, 20(2), 703-730. <https://doi.org/10.1007/s10668-016-9906-4>
- Millar, J., Robinson, W., Baumgartner, L., Homsombath, K., Chittavong, M., Phommavong, T., & Singhanouvong, D. (2019). Local perceptions of changes in the use and management of floodplain fisheries commons: The case of Pak Peung wetland in Lao PDR. *Environ Dev Sustain*, 21(4),

- 1835-1852. <https://doi.org/10.1007/s10668-018-0105-3>
- Mintzberg, H., Raisinghani, D., & Theoret, A. (1976). The structure of “unstructured” decision processes. *Administrative Science Quarterly*, 21, 246-275. <https://doi.org/10.2307/2392045>
- Moser, S. C., & Dilling, L. (2007). *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*. Cambridge Univ. Press, Cambridge, UK. <https://doi.org/10.1017/CBO9780511535871>
- Nielsen, J. O., & Reenberg, A. (2010). Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. *Global Environmental Change*, 20(1), 142-152. <https://doi.org/10.1016/j.gloenvcha.2009.10.002>
- Norberg, J., & Cumming, G. S. (2008). *Complexity theory for a sustainable future*. New York: Columbia University Press.
- Ostrom, E. (2005). *Understanding institutional diversity*. Princeton: Princeton University Press.
- Oviedo, A. F. P., & Crossa, M. N. (2011). *Manejo do pirarucu-sustentabilidade nos lagos do Acre*. WWF-Brasil, Brasília.
- Oviedo, A. F. P., Bursztyn, M., & Drummond, J. (2015). Now under new administration: Fishing agreements in the Brazilian Amazon floodplains. *Revista Ambiente & Sociedade*, 18(4), 113-132. <https://doi.org/10.1590/1809-4422ASOC985V1842015>
- Oviedo, A. F. P., Mitraud, S., McGrath, D. G., & Bursztyn, M. (2016). Implementing climate variability adaptation at the community level in the Amazon floodplain. *Environmental Science & Policy*, 63, 151-160. <https://doi.org/10.1016/j.envsci.2016.05.017>
- Pielke, R. A. (1998). Rethinking the role of adaptation in climate policy. *Global Environmental Change*, 8(2), 159-170. [https://doi.org/10.1016/S0959-3780\(98\)00011-9](https://doi.org/10.1016/S0959-3780(98)00011-9)
- Schipper, E. (2006). Conceptual History of Adaptation in the UNFCCC Process. *Review of European Community & International Environmental Law*, 15(1), 82-92. <https://doi.org/10.1111/j.1467-9388.2006.00501.x>
- Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3), 282-292. <https://doi.org/10.1016/j.gloenvcha.2006.03.008>
- United Nations Framework Convention on Climate Change—UNFCCC. (1994). *Resolution adopted by the General Assembly, 20 January*. A/RES/48/189. Retrieved January 4, 2019, from <http://www.refworld.org/docid/3b00f2770.html>
- United Nations Framework Convention on Climate Change—UNFCCC. (2010a). *Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009 - Part One: Proceedings*. FCCC/CP/2009/11.
- United Nations Framework Convention on Climate Change—UNFCCC. (2010b). *Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009-Part Two: Action taken by the Conference of the Parties at its fifteenth session*. FCCC/CP/2009/11/Add.1.

- Utete, B., Phiri, C., Mlambo, S. S., Muboko, N., & Fregene, B. T. (2019). Vulnerability of fisherfolks and their perceptions towards climate change and its impacts on their livelihoods in a peri-urban lake system in Zimbabwe. *Environ Dev Sustain.*, 21(2), 917-934. <https://doi.org/10.1007/s10668-017-0067-x>
- Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Archer Van Garderen, E. R. M., & Campbell, B. (2014). Reconceptualizing adaption to climate change as part of pathways of change and response. *Global Environmental Change*, 28, 325-336. <https://doi.org/10.1016/j.gloenvcha.2013.12.002>