Water Use and User Attitudes

Common-Pool Resources and Longitudinal Change in a Brazilian Community

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Abstract: Common-pool resources (CPRs) are subtractable resources that are physically or institutionally available for many users. The present study sought primary participant observation and focus group data on a Brazilian CPR-dependent community. It analyzes this data through the lens of CPR theory to assess ongoing local natural resource management efforts against longitudinal changes related to large-scale state and private development projects. The findings indicate that real or perceived changes related to the resources, technology, human populations, and decision-making processes in the study area have disrupted social arrangements and resulted in natural resource degradation. The article argues that, in order to achieve sustainability objectives, CPR-guided policy formulation must consider the social embeddedness of community-based actors and resources within their wider historical and social contexts, as well as user attitudes and relations among shifting conditions on multiple scales.

Keywords: coastal development, common property resource, natural resource management, resource user, sustainability, user perspective

Introduction

Common-pool resources (CPRs) are private or public resources, of natural origin or constructed by humans, for which the physical or institutional exclusion of beneficiaries bears a high cost and where resource exploitation by one party reduces availability for others (Ostrom et al. 1999: 278). For Ostrom and colleagues the rational depletion of the very CPRs upon which actors depend, a process pointed to by Garrett Hardin (1968), is not inevitable. Indeed, they contend that many groups around the world have used systems of self-regulation for the successful management of CPRs for hundreds or thousands of years, and in some cases these conditions have improved over time, as with lobster populations in Maine (Ostrom 2008).

Thomas Dietz and colleagues (2003) have identified five preconditions that promote the successful governance of CPRs. These include

the monitoring of natural stocks and extractive practices; moderate change with respect to the resources themselves, human populations, technology, and economic and social conditions; face-to-face social interaction and networking; the ability to exclude outside users; and user cooperation in monitoring and rule enforcement. In addition, these authors contend that when the selective pressures on governance institutions expand from local influences to regional, national, or even global ones, CPR management becomes much more complicated. This is because increased scalar complexity will require governance institutions to make use of much more information concerning CPRs and their use patterns, deal with conflict between more stakeholders and interest groups, find effective ways to promote rule compliance, provide infrastructure, and adapt to changing conditions.

Therefore, according to this framework, when significant levels of social, biophysical, and technological changes occur within a given successfully managed CPR system, one would expect quantitative and qualitative CPR losses to result. The present study set out to test this hypothesis by analyzing a variety of longitudinal changes and user perceptions that have occurred in a remote Brazilian community for whom CPRs have played an important economic role. The findings were then analyzed to identify the strengths and limitations of CPR theory for predicting and offering insight into real-world socioenvironmental configurations. We contend that this exercise offers insight into the understanding of CPR governance dynamics and the effective formulation of sustainable development policies.

The Study Area

Quixaba is a geographically and socially isolated rural village located in a semiarid region near a large river-mouth lagoon and coastal wetland ecosystem in the north of the state of Rio de Janeiro in Southeast Brazil (Figure 1). According to residents, a majority of Quixaba's population participates in one or more of the community's three main economic activities: small-scale fishery, mat weaving from the stalks and fibers of southern cattail (*Typha domingensis*), and the small-scale agriculture of crops such as maroon cucumber, okra, and taro root. Quixaba thus relies to a significant degree on the CPRs available to all residents, including the water, fish, cattail, and other flora and fauna in the lagoons, rivers, and canals of the region, as well as the highly pure water contained in the Emborê Aquifer (Caetano 2000) used to

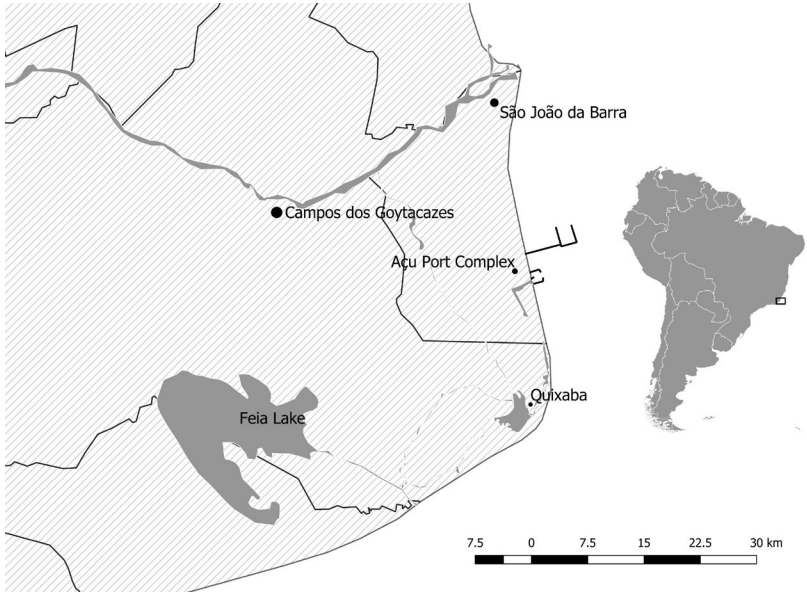

Figure 1 ■ Map of the study area of Quixaba in relation to key municipalities and regional features and within Brazil.

irrigate crops and for all the residents' domestic needs. As the article will discuss below, locally managed and institutional arrangements and relatively static social conditions were instrumental in the preservation of these resources for at least a century.

Methods

In order to carry out this study, the main author lived in Quixaba and conducted participant observation using the extended case method (Burawoy 2009) for a period of 12 consecutive months beginning in October 2015. This author presented himself to residents as a university researcher writing an academic report on the community. He wrote down research notes immediately after each interaction with residents. Participant observation took place in houses, streets, fishing areas, stores, churches, bars, barber shops, soccer fields, plantations, pastures, and other areas used by residents or relevant to the study.

In addition, this author conducted a focus group interview composed of five male and five female Quixaba residents ranging from

31 to 78 years of age that took place on 5 August 2016. The main author acted as the moderator, used an independent hired facilitator, and made an audio recording of the interview. All related planning, procedures, and data analysis were designed according to the focus group methodology put forth by Denise Côté-Arsenault and Dianne Morrison-Beedy (1999).

The qualitative data derived from this field research, as well as key secondary sources, offer insight into the lives of Quixaba residents and the dynamics of the existing social relations among themselves and with other social groups and actors, relations that have affected their economically important CPRs. In order to fully comprehend and contextualize key events leading to alterations in the socioenvironmental waterscape, however, it is important to consider the broader history of the community's social dynamics and its natural resources. The article, therefore, presents observed situational data derived from extensive firsthand involvement with the community, based on acquired insight and mutual trust, complemented by the shared memories and historical narratives provided by informants and focus group members (all translated from Portuguese), while maintaining contact and dialogue with relevant secondary academic and media sources able to shed light on the investigation. In this way, the following sections offer a brief ethnographic history of Quixaba's transition from almost exclusive reliance on traditional extractive activities to the status of a much more economically diverse community that has become integrated into the wider regional economy and makes use of modern technology and mechanization. Later, we will discuss these findings' relevance as pertaining to CPR theory and policy formulation.

Quixaba: The Origins of a Common-Pool Resource Community

At the beginning of the sixteenth century, Portugal was a world naval and military power that had signed the Treaty of Tordesillas with Spain over the division of newly discovered lands in the Americas. As Portugal had claimed the coastal regions of present-day Brazil in 1500, the country was struggling to protect this coastline from encroachment by other European nations. The Portuguese Crown made an effort to colonize the region now comprising Quixaba in 1534, but the settlement failed due to frequent attacks by local indigenous groups. According to Alberto Lamego (2007), in 1622 there was a community of Portuguese

fishers living near the mouth of the Paraíba do Sul River, approximately 30 kilometers from the present location of Quixaba. A decade later colonization of the region began in earnest when a group of seven officially authorized owner-administrators arrived to survey and divide the lands now under their control. In the years that followed, the chief economic activities of the Portuguese settlers of the region involved cattle raising and sugarcane cultivation and processing.

The coastal plains comprising this area contained large areas of wetlands, and the hydrologic and geologic features of the region of the future municipalities of Campos dos Goytacazes and São João da Barra affected the settlement patterns of the individuals and groups that occupied it. The original seven owner-administrators who came to survey the region, for example, arrived by horseback from the south before continuing their journey by boat along the Furado River, the Feia Lake, and the Iguaçu River. While the vast majority of sugarcane plantations and cattle farms were established over the more fertile *tabuleiro* grasslands areas, the region in the immediate vicinity of Quixaba is classified as *restinga*, a type of tropical forest occupying sandy, acidic, nutrient-poor soil and characterized by small to medium-sized trees and shrubs. In addition, the village of Quixaba itself was not one of the locations permanently or seasonally inundated in Campos dos Goytacazes (Soffiati 2015). Therefore, the village's settlers may have been part of a phenomenon described by Rinaldo Arruda (1999: 82), whereby "populations separated from the dynamic centers of the national economy, throughout Brazil's history [occupied] the less populated spaces where the land and the natural resources were still abundant" (our translation).

The oldest informants contacted in the present study were born in Quixaba between 1935 and 1940. They described an extremely isolated community, unconnected to the region's electrical grid and public transportation network, composed of between 15 and 20 houses spread sparsely through the *restinga*. These informants used average family sizes to estimate a population of between 100 and 150 people living in Quixaba in 1950. During this period, small-scale agriculture, fishing, and hunting provided the only sources of nutrition and were the basis of all economic activity. People considered the water, flora, and fauna of the Iguaçu River system the property of all residents. Likewise, although there were locally managed agreements conferring private land ownership (sans formal titles), people could generally hunt and trap wherever they wanted and grow crops in unused areas of land.

The rivers teemed with snook, pearl cichlid, black acara, trahira, *marobá*, *saúba*, *carapeba*, South American catfish, white shrimp, and

freshwater shrimp and crab. Residents hunted capybara and other large wild rodents of the cavy family, otter, caiman, opossum, canids, and fowl as food sources. A wide range of fruits, grasses (such as sugarcane), leafy vegetables, and root vegetables, notably manioc, were cultivated on land; others, such as cashew, genipap, mango, Suriname cherry, and the fruit for which the town was named, grew wild. Residents used many wild and cultivated plant varieties for their medicinal properties. The stalks and fibers of the cattail plant taken from the rivers were an important building material, providing roping, roof and wall materials for houses, and matting used on beds, chairs, and floors. (Residents did not use manufactured mattresses for most of the twentieth century.) Sand, clay, mud, and wood were other important materials used for construction, and people used wood and charcoal as fuel for cooking. This wide availability of diverse vital naturally occurring resources may have given rise to a saying heard several times during field observations. Residents humorously proclaimed, "The only thing Quixaba lacks is money."

Fishers employed small, rudimentary nonmotorized boats to catch fish with nets dragged along the bottoms of the region's shallow bodies of water. The *cutuca* is an important traditional fishing technique still in use today (albeit on a very limited scale). Fishers thrust logs, branches, and twigs into the sand or silt of the lake or river bottom, not far from the shore, forming an inviting habitat for fish. After a certain number of days or weeks, the fisher returns to the *cutuca* and surrounds it with a net to capture the fish that have gathered. Quixaba fishers report that although *cutucas* are located in the water, an area considered the property of all residents, those who fish the area dutifully recognize the exclusive rights of each builder to the fish contained in the *cutuca*.

Quixaba was essentially a peninsula bordered by the Quitingute and Iguaçu (or Açu) Rivers with easy access to the large Boa Vista Marsh. This estuary system received waters from the Imbé Mountains via the Imbé River, the de Cima Lake, the Feia Lake, and many other watercourses, lakes, and ponds. Both the literature and local residents highlight an important aspect of the Iguaçu River (later known as Açu Lake) during this period; namely, that a beach barrier would form at Barra do Açu every winter during the dry season, but that every rainy season high water levels caused the river to spill into the ocean, eroding the barrier (Figure 2). Residents contended that this dynamic cyclical process was important for regulating water salinity and allowing the entrance of fish, shrimp, and crab from the ocean, promoting the health and reproduction of several key species.

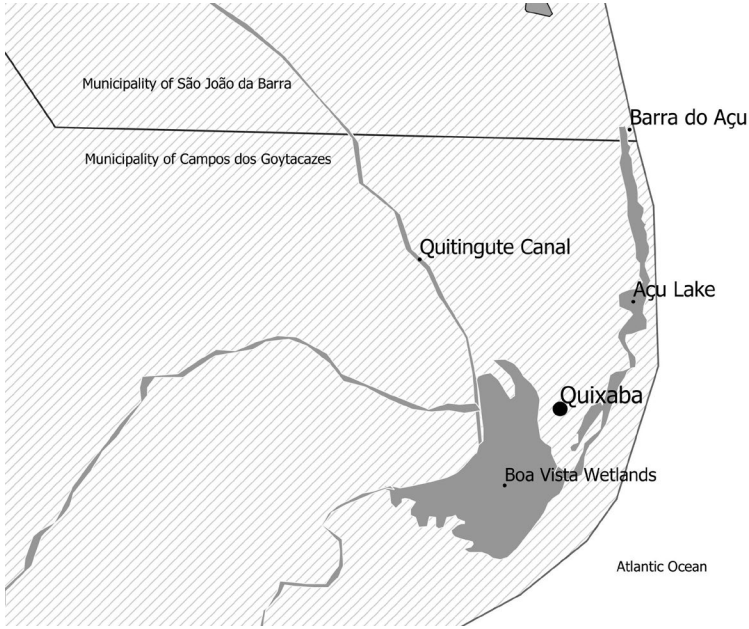

Figure 2 ■ Map of the principal hydrological features surrounding Quixaba.

Land Use Changes, Outcomes, and Changing User Expectations

Later, the National Department of Works and Sanitation (NDWS), a Brazilian federal agency, began to execute land reclamation projects affecting the natural resources in the Quixaba region. Between 1940 and 1960 the NDWS built 1,300 kilometers of canals, dikes, and floodgates to drain wetlands in Campos dos Goytacazes, effectively cutting the Iguaçu River off from its source. As a consequence, significantly lower quantities of freshwater flowed into the Boa Vista/Iguaçu estuary, and the water that did came from the Paraíba do Sul River (a more polluted water source) and flowed southwest instead of northeast, as before. Residents saw river and marsh levels fall, and the waters became more saline from reduced freshwater inflow. As breaches of the sandy barrier at its mouth became rare, residents began to call their former Iguaçu River "Açu Lake."

Using synchronous life events, older interlocutors estimated that Quixaba was connected to the electrical grid in 1960, and houses soon began to cluster near the power lines on the main road. In addition, people gradually began substituting electric water pumps for the manual pumps they had been using until then. It is important to note that to date the region has no community water supply system and that the townspeople pump groundwater from the water table for all domestic, commercial, and agricultural needs. Maria Lubatti (1979) wrote that during the 1970s younger farmers were making extensive use of motorized irrigation in their plantations, much to the criticism of older family members and neighbors. During the present work, residents said that farmers also began using chemical fertilizers during the 1970s and 1980s, a practice that was extremely widespread during the study period.

In 2006, developer Eike Batista and the Rio de Janeiro governor announced the construction of the Açu Port Complex (APC) in a sparsely populated agricultural region 11 kilometers from Quixaba. When construction concluded in 2014, the APC had a 6.5-kilometer artificial navigation canal, a shipyard, and facilities for the storage, processing, and ship loading and unloading of iron ore, crude oil, bauxite, and other materials. This included the terminus and filtering plant of the 529-kilometer Minas-Rio slurry pipeline, with an annual transport capacity of 26.5 million tons of iron ore. The APC was promoted as the largest industrial port complex in Latin America, occupying 90 square kilometers, and appraised at 3.7 billion US dollars (Martins 2012).

During the construction phase of the APC, beginning in 2007, many Quixaba residents got jobs as truck drivers, pump operators, pipeline and construction workers, and security guards. When it became operational, however, many of these residents were laid off or quit due to difficult working conditions, and only five residents still worked at the APC in 2016. In the words of a 34-year-old male resident, "When the port first came many people who couldn't even read got good jobs there. But now, not even those [from Quixaba] with degrees can get jobs." A woman of 39 added, "When there was hard work to be done, they got people from here. But now that they want educated people, they get people from other regions." Residents reported observing a significant migration of job seekers from other regions of Brazil into the municipality of São João da Barra coupled with rising property values and living costs there. Several APC companies built and rented temporary and permanent housing facilities in the communities of Açu, São João da Barra, and Pipeiros.

Quixaba's first fish processing facility (*frigorífico*) appeared in 2011, and residents built three more over the following four years. These were small, rudimentary, locally owned buildings equipped with walk-in storage freezers and areas for the weighing, cleaning, and packaging of fish. Interlocutors said these facilities had an impact on the area's fishery because while before fishers only took what they could eat or quickly sell, they now knew they could sell all fish directly to the *frigorífico* owners, including small ones they had formerly returned to the water. During this study's fieldwork, residents reported that the Quixaba fisheries only contained pearl cichlid, black acara, trahira, *marobá*, and *saúba* and that catch rates and fish size had fallen dramatically. Because of this, in 2014 some *frigorífico* owners began sending fishing crews to other freshwater lakes and rivers in neighboring municipalities, notably the Imboassica Lake in Macaé, and buying fish from fish farmers. In addition to obtaining, processing, freezing, and packaging fish, *frigorífico* operators transported the product by car, selling it to restaurants, shopkeepers, and supermarkets as far as 150 kilometers from Quixaba.

Interlocutors said the appearance of *frigoríficos* in Quixaba had coincided with impacts related to the construction of the APC. They reported that Iquipari Lake, adjacent to the grounds of the APC, had been contaminated by an unidentified chemical and that its forested areas had been destroyed. "Now it [the lake] doesn't even have fish. The caimans and cattail are all dead!" said one fisher of 53 years. Residents complained that Prumo, the APC's construction management company, had erected fences restricting the access of local residents to Iquipari Lake. A year or two before the fieldwork was conducted, they said, it was possible to gain access to the lake and fish on weekends by showing a photo ID, but that in early 2016 the company had declared the area completely off-limits to the public. Focus group participants speculated that Prumo had enacted this policy to hide the environmental degradation said to have occurred there.

A majority of Quixaba residents also believed that the APC was responsible for other direct and indirect forms of environmental impact. One small-scale farmer of 52 years named Heraldo said that after the APC's construction his agricultural yields fell significantly. He reported that the area's predominant southwestern winds brought large quantities of sand from the APC to the Quixaba region during the months and years of its construction. "Now I can't plant anything. Everything I plant fails. I drilled three wells deeper than six meters, but the water is salty," he said. His maroon cucumbers would sprout and begin growing, reaching about 20 centimeters in height, at which point the leaves

dried out. An engineer who visited the plantation reported the plants were exhibiting symptoms of saline contamination.

The present study's first author observed other cases of sudden unexplained crop failure, including that of a large field of maroon cucumbers located next to the house rented for participant observation. Likewise, many residents reported tasting unprecedented high salt levels in the rivers and lakes and contended that these levels had affected the richness, size, and distribution of the flora and fauna inhabiting them. A fisherman of 43 years said, "In the past we used to get cattail downriver from the Maria Rosa bridge. Now how many kilometers [upriver] do we need to go to find it? It's because cattail can't take all that salt." Mangrove forests, in turn, had spread farther upriver due to their higher saltwater tolerance. All contacted during the study reported record low water levels in the wetlands, and many believed that the proliferation of water hyacinth (*Eichhornia*) in the rivers and canals was further restricting the entrance of freshwater into the wetlands near Quixaba and restricting access to fish. Many were angry that someone had been burning large stands of cattail, presumably to flush out cava rodents hiding among them when hunting. However, in the words of one fisherman, "Cattail only burns when there's no water!" During the focal group meeting, a woman presented a cell phone video showing a man cutting down cattail on a dry lakebed. Focal group participants justified their astonishment to this video, saying, "Cattail only grows in water!" Many focus group participants expressed concern that in the near future their groundwater would no longer be suitable for human consumption, or would disappear altogether. One man of 57 said, "In the past, you drilled down three meters and got water. Today, you have to go down seven, eight, nine meters." He continued, "The way things are going, a year from now salty [ground]water is going to arrive here . . . What can you do with saltwater? This place won't even exist."

In 2012, Rio de Janeiro State authorities announced the creation of the Açu Lake State Park (ALSP), or Parque Estadual da Lagoa do Açu. The ALSP comprises 8,251 hectares and includes the entire Açu Lake and Boa Vista Estuary. A Unidade de Conservação Integral, the ALSP was designated a protected area slated for conservation, research, and education, from which the removal or alteration of any natural resources would be prohibited by law. The ALSP resulted as a stipulation in the APC's environmental licensing process when authorities required LLX, the erstwhile controlling company of the APC, to provide the ALSP with initial and operational funding as an environmental compensation measure. Authorities, however, failed to engage in dialogue of any kind

with local residents. According to the president of the Quixaba Fishers' and Residents' Association, a representative of the state environmental agency, INEA, informed him that fishery would only be permitted for registered local fishers who obtained a special fishing license. However, because he said that INEA would only provide the licenses one time and would not replace lost ones, fishers in effect were exempted with a grandfather clause from the fishery prohibition stipulated in the ALSP's creation. During this study's fieldwork, the majority of Quixaba residents had never heard of the ALSP and demonstrated outrage upon learning of the project. One focal group member exclaimed, "Just look at that! A place that belonged to us. Nobody else ever even knew about it. It has *our* natural resources, and now they come and do this?"

During the participant observation, the APC and the Rio de Janeiro State government were experiencing severe liquidity and fiscal crises, respectively, leading to budget cuts that hampered INEA's ability to manage the ALSP. Nevertheless, this period saw conflict between INEA's forestry officers and Quixaba residents. In late 2015 high surf conditions destroyed an economically important unpaved ALSP road connecting Quixaba to the much larger community of Farol de São Tomé. As public authorities had taken no action to repair it, residents contributed their own money, land-moving equipment, and landfill material and began to clear a detour through the sandy *restinga*. INEA agents ordered construction to stop, threatening to arrest anyone who defied the order. Residents then returned after midnight and completed the repair over four days during the dawn hours. In addition, INEA agents on other occasions confiscated fishing nets, applied fines related to fishery, and ordered the removal of plantations and buildings close to rivers and lakes. Once in 2015 residents burned tires in protest on the only road into Quixaba, blocking INEA agents from leaving.

Discussion

The data presented above make clear the historical dependence of the Quixaba community on the natural resources that occur nearby, such as water, fish, and cattail. As residents considered them the property of all who lived in Quixaba, these resources represent common-pool resources (CPRs).

The results of the present study, therefore, are rife with examples of technological and social change related to an expansion of influences stemming from an increase in scalar complexity. According to Quixaba

residents, the decision to build a 1,300-kilometer network of canals, dikes, and floodgates by the NDWS beginning in 1940 significantly affected their coastal wetlands system because these works transformed the former Iguaçu River into a lake by cutting it off from freshwater inflows. In this case and others discussed below, residents' local ecological knowledge is supported by the scientific literature, as this modification essentially transformed it from a flow-through system receiving freshwater inflows and flood pulses from rainwater to a terminal system characterized mainly by recharge and discharge between surface water and groundwater (Jolly et al. 2008). In addition, while Peter Bayley (1991) reported a direct correlation between flood pulse loss and decreased multispecies fishery production in river floodplains, another author has extended the relationship between flood pulses and species diversity to other types of wetlands (Middleton 2002). Seasonable water level variability has been shown to positively influence environmental cycles related to fish reproduction (Gomes and Agostinho 1997) and recruitment and feeding (Goulding 1980). Finally, the transformation of a flow-through hydrologic regime into a terminal one has been associated with rising salinity, a process that tends to reduce species richness and overall wetland diversity (Nielsen et al. 2003).

It is important to recognize that the works projects carried out by the NDWS not only promoted the interests of regional, state, and national actors at the expense of those of local ones, but also reflected a global trend of the period. On the one hand, Brazil's economy during the 1940s had not yet fully transformed into an industrialized one and governmental economic policy was still reflecting a mind-set resulting from a centuries-old dependence on sugarcane production. Indeed, authorities routinely touted sugarcane as a tool for promoting industrialization, and the federal program Pró-Álcool would foster the production of thousands of automobiles running on sugarcane-based ethanol a few decades later. Policy makers and landowners thus considered large flooded areas unproductive. On the other hand, according to Andrey Martin and Leonardo Carvalho (2015), Brazilian officials were using the public works projects carried out by the Tennessee Valley Authority (TVA) in the southern regions of the United States in the 1930s as a model for economic stimulus. Like the TVA, NDWS projects were publically promoted using job creation and malaria eradication narratives. While the land reclamation in Campos dos Goytacazes dramatically reduced the influx of nitrate-free freshwater into a significant river and wetlands complex, contributing to its degradation, wider economic and public health considerations effectively supplanted the interests related

to the existing subsistence fishery and small-scale agriculture practiced in the Quixaba region.

Changes related to agriculture and fishery also reflect the introduction of new technologies and Quixaba's newfound interaction with regional markets. In the case of agriculture, electricity and motorized pumps appeared around 1960; less than 20 years later the younger generation was making extensive use of irrigation in the region (Lubatti 1979). During the present study, all plantations observed made use of irrigation, often for over six hours per day during the period of maximum insolation, a fact corroborating a study whose results indicate that 98 percent of farmers in the Quixaba region irrigated their fields (Burla et al. 2014). Irrigation is responsible for 72 percent of Brazil's water consumption (Alves 2016), and Manjula Guru and James Horne (2001) documented the depletion of groundwater by irrigation at more than ten times faster than recharge rates in the Ogallala Aquifer in Oklahoma in the United States. Moreover, while the use of intensive irrigation has been associated with a tendency to cultivate crops with higher hydric demands (Hornbeck and Keskin 2011), further accelerating groundwater use (Barlow 2003), the depletion of groundwater reduces discharge to streams, wetlands, and coastal estuaries. Because irrigation water contains small quantities of salt, this compound tends to accumulate over time, leading to the potential saline contamination of soil and bodies of water (Goudie 1990), a process that Waldir Marouelli and colleagues (2011) contend intensifies in arid and semiarid regions, such as the *restinga* of Quixaba. The symptoms related to the crop failures of maroon cucumber obtained in the results of the present study are consistent with those associated with saline stress (Zhu 2007), and Elzira Oliveira and colleagues (2013) obtained results indicating a low salt tolerance for the plant.

Rogerio Burla and colleagues (2014) found that 95 percent of farmers were using chemical fertilizers in Mato Escuro and Água Preta, two of Quixaba's neighboring communities, which is consistent with the present study's results indicating the use of fertilizers in virtually all the growing fields of the Quixaba region. Because the use of synthetic fertilizers replaced the more traditional practice of spreading organic ground cover around plants, a technique that can reduce evapotranspiration by 50–80 percent (Allen et al. 1998), fertilizer use may be related to the study's findings of intensive agricultural irrigation and high groundwater use. Fertilizer use has been associated with the proliferation of water hyacinth and eutrophication and the silting up of waterways via runoff (Villamagna and Murphy 2010), related processes observed during the

present study. Finally, according to Alexandre Viana and colleagues (2001), the use of fertilizers causes chemical alterations in agricultural soil that inhibit the absorption of nutrients, an outcome that may lead to an upward spiral in fertilizer use (Goudie 1990).

The results of the study indicate a process of increasing and generalized salinization of the land and wetlands complex in the Quixaba region. Scientific studies have reported the intensification of natural seawater intrusion in coastal aquifers through groundwater extraction, potentially resulting in the saline contamination of aquifers (Werner et al. 2013). Alexandre Cruz and colleagues (2006) and Monique Barcelos and colleagues (2011) found evidence of saltwater intrusion in two aquifers of Southeast Brazil possessing geological conditions similar to those of the Emborê Aquifer of the study area; that is, nonconfined aquifers surrounded by highly porous, arenaceous materials located under *restinga* forests.

While the present study documented the widespread, intensive use of crop irrigation through groundwater extraction, the presence of the APC has significantly increased the potential for saline contamination through marine intrusion in the region. According to its environmental impact report (Ecologus 2011), the APC project required the use of 10 cubic meters of water per second, or roughly the equivalent of a Brazilian city of 2.8 million people, and stipulated that this water would be provided by the Paraíba do Sul River. Construction, however, was never finished on the water supply pipeline, and the APC was not authorized to receive water from the local water utility in São João da Barra. Although INEA has not published any official documents regarding the use of the Emborê Aquifer by the APC, the authors of this study received an internal INEA memo confirming that the APC's operational requirements were being met exclusively through the pumping of water from the aquifer. Therefore, scalar reconfiguration of the study area region, characterized by the introduction of pressures and influences reflecting the interests of diverse regional, national, and global social groups on an area that previously received no external assistance or interference, has affected its natural resources. The fact that the APC is using significant quantities of water from the aquifer interacting with the waterscape of Quixaba is consistent with the data obtained in this study; namely, that the water table is dropping, rivers and lakes are in danger of drying up, and a widespread process of salinization is underway.

In addition, other aspects of the APC's construction may have exacerbated this process. Workers dredged 44 million metric tons of ocean sand and pumped it onto the continent with saltwater as landfill

material; they later excavated 65 million metric tons of continental material in order to form a 6.5-kilometer navigation canal connected to the Atlantic Ocean (Ecologus 2011). During construction at least one known spill resulting in the saline contamination of freshwater resources took place, leading to a fine of approximately US$400,000 for the developers (Hoffmann 2013). Besides the removal of large quantities of ocean sand, the APC project called for the construction of an offshore terminal composed of a three-kilometer caisson breakwater pier and two one-kilometer jetties protecting the navigation canal. The results of this study indicate that over a three-year period following their completion, beach sediment accretion occurred on the up-drift side of these structures, accompanied by erosion on the down-drift side, conditions consistent with recognized sedimentation pattern changes resulting from barrier construction (Vaidya et al. 2015). As Adrian Werner and colleagues (2013) and others have observed, coastal hydrogeologic processes are extremely complex, thus complicating attempts to identify controlling factors related to salinity. Nevertheless, it is reasonable to conclude that large-scale construction on the continent-ocean interface and the resulting modification of the coastal morphology related to the APC may have generated significant impact to the salinity of the waterscape in question, especially through widely recognized processes such as surface deposition and runoff of saline contaminants and groundwater intrusion by seawater.

Alterations in the social fabric of the region also have bearing on changes in use patterns related to Quixaba's CPRs. Ethnographic data from the present study indicate a population of 100–150 residents in the community in 1950, while according to Oliveira (2012) Quixaba had a population of 500 in 2012. Thus, the community's growth rate over this period of just over 300 percent was proportional to Brazil's overall population growth, which increased from 52 million to 194 million over the same period. Regionally, however, the installation of the APC created expectations of a dramatic increase in population. Before construction began, the project's proponents made public statements predicting the creation of 50,000 jobs, directly or indirectly, a number superior to the entire population of the São João da Barra municipality. Over eight years later, however, residents believed that the actual number of jobs created was significantly lower, and the present study found evidence of conflict between local residents and migrating workers over these jobs. In addition, the results showed the resentment voiced by many residents over unfulfilled economic stimulus negatively affected the social relations underpinning the region's CPR use, especially after

municipal and state lawmakers quickly and surreptitiously passed eminent domain legislation to forcibly remove more than two thousand landowners from acreage slated for the APC on 31 December 2008 (Associação dos Geógrafos Brasileiros 2011; Pedlowski 2013). During the study's participant observation, many residents reported that drug use and crime rates in the region increased after the APC's arrival. They expressed concern that their region could become "another Macaé," a reference to a nearby city that experienced rapid population increases, the appearance of shantytowns, urban crime, spatial segregation, and natural resource degradation resulting from petroleum exploration development (Santafé 2011).

According to Ostrom and colleagues (1999), the effective governance of CPRs requires a high degree of trust among users, stating that "groups of people who can identify one another are more likely than groups of strangers to draw on trust, reciprocity, and reputation to develop norms that limit use" (279). Interlocutors of the present study described the system of *cutucas* in which residents refrained from "stealing" the fish contained in the habitats constructed by other users in the lake commons near Quixaba, a practice that had functioned effectively for generations. In addition, Ostrom and colleagues (1999) emphasized the need for CPR user autonomy in the development and application of rules as well as a commitment to the future sustainability of the resources, while pointing to the challenges to effective governance posed by large and complex systems. In stark contrast, however, when speaking about the creation of the ALSP, a top-down reconfiguration scheme affecting the use and management of Quixaba's hydric resources, one community leader said, "Almost no one has heard of this project. They never scheduled a meeting here to explain it."

According to the present study's results, while local user groups successfully managed their common-pool natural resources for over a century, the quality and quantity of these resources was falling during the study period. In addition, the study found evidence that expectations of extensive human migration, technological changes (motorized pumps, synthetic fertilizers, and motor vehicles), large-scale construction, and the industrial-scale use of natural resources altered the socioenvironmental relations in the region enough to undermine the recuperative capacities of its CPRs. At the same time, the study obtained results indicating that newly created conditions helped corrode the belief that all users would respect norms of conduct designed to preserve the CPRs and weakened the authority of local stakeholders. Specifically, these conditions included the arrival of unknown actors

and the transfer of decision-making processes to distant authorities, restricted access locations, as well as the creation of new institutional arrangements, such as the ALSP. With respect to another type of common-pool resource, one Quixaba resident stated, "[At the time] they promised that the jobs would be for the community. Now the jobs are for outsiders and community residents have none." Thus, it is likely the nonfulfillment of agreements and perceived false narratives expressed at the beginning of the APC's implantation contributed to local residents' suspicion of the social groups associated with the complex while disrupting existing rules of conduct that helped maintain the health of the natural systems. This scenario is consistent with analyses linking the creation of Brazilian conservation areas to changes in local user conduct characterized by a sudden overexploitation of resources, often stemming from the belief that the local community has been permanently dispossessed of the area in question (Arruda 1999). The point here is that changes in user expectations and perceptions can produce real outcomes affecting the CPRs they manage.

James Fairhead (2012) has discussed a phenomenon in which powerful actors reconfigure power relations in order to appropriate natural environments. This approach can offer insight into the results of the present study, especially when one recognizes that alterations to power relations in this context simultaneously reconfigure and multiply the spheres of influence and interests affecting the socioenvironmental systems in question. This is an important point for consideration, for it carries implications for the formulation of policies designed to promote the sustainability of natural ecosystems. Although the CPR framework is useful for recognizing that changes to resources, technology, and user groups can affect the health of a given common-pool resource area, one must consider that user groups may be those exploiting the resources in obscure ways and whose effects can present temporal and/or spatial variation. Such exploitation can take the form of the surreptitious use of vast quantities of aquifer water within the grounds of an industrial port enclave and the "reclamation" of land for sugarcane cultivation, as in the present study. In addition, because the use of natural resources can take even more complex and hidden forms, such as when commodities contain embedded water (Allan 1996) and investment firms trade lucrative ecological credits (Smith 2007), identifying all relevant user groups can be a difficult task. The crucial point here is that the transition from a sustainable CPR scheme to an unsustainable one may well involve not only the easily discernible kinds of change outlined above, as when more people are fishing in a given lake, but

change involving transformations of scale, which inevitably engender power inequalities. Therefore, systematic efforts to elucidate or limit scalar and power dynamics alterations must form an important part of any successful policy involving CPR management.

Conclusion

The study's participant observation and focus group interactions revealed ongoing losses in species abundance and richness in the river and lake commons accompanied by decreased agricultural productivity in the Quixaba environs. As fishery, the weaving of mats from the southern cattail found in the wetlands, and farm produce are the three most important sources of income for the village, these changes have created hardship for local residents. Those contacted during the study believe that land reclamation intervention altering the hydrological regime of the local wetlands has been a chief cause of species losses and reduced crop productivity by limiting the inflow of freshwater pulses, leading to increased salinization of the ecosystem. However, other factors directly related to the APC project may also be driving environmental degradation in the region. These include changes to coastal morphology, the mining of large quantities of water from the coastal aquifer, and institutional changes to the governance of the local natural resources through the creation of the ALSP. However, whether the relationship between large public and private intervention projects and reduced natural system health is causal or correlational, changes in the expectancy attitudes of the CPR users themselves seem to be exacerbating degradation.

Common-pool resource theory helps bring the complex social and environmental processes at play in Quixaba into focus by highlighting the correlational-causal nature of changes in resource availability, use, technology, and various other economic and social conditions directly affecting ecosystem health. The drivers of ecological impact in this region, however, are embedded in larger economic and historical processes related to land use change. In effect, the interests of local CPR users' interests were supplanted by those of regional landowners and policy makers during the period of systematic wetland eradication; many decades later, Quixaba residents believed they were dispossessed of their resources by regional and global developers, entrepreneurs, and politicians during the planning of the APC. The authors contend that the lessons provided by the present study also apply to other common-pool

systems. Therefore, meaningful analysis into CPR planning and dynamics must consider that, due to the inherent complexity of CPR systems, user perceptions and attitudes may or may not be related to factual conditions, but that these attitudes can affect CPRs in real ways. In addition, especially when hydrologic dynamics play a key role, planning and analysis must transcend immediate scalar and temporal factors and consider power inequities between diverse social groups.

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