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# Socio-ecological assessment for environmental planning in coastal fishery areas: A case study in Brazilian mangroves

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ABSTRACT

Along the world's (sub) tropics mangroves are important coastal ecosystems supporting small-scale fisheries and human populations, highlighting the need to consider participatory approaches in this ecosystem management. We carried out a socio-ecological assessment to characterize the use and perceptions of local populations at Northeastern Brazil (São Francisco River Estuary) on mangrove fisheries and local development, and pointed out strategies for environmental planning. The questionnaire-based results show that the locals are economically dependent on mangrove fisheries, exploring 12 types of fish, 4 types of crabs, 3 types of mollusks and shrimps. All populations indicated a decrease in the fishery yield, mainly due to a high fishery pressure and shrimp farming. We conclude that strategies pointed out by the locals as creation of an protected area of sustainable use (Extractive Reserve), aided by government support to create a local small-scale fishery processing industry, to cultivate oysters and fish and ecotourism are sustainable alternatives for poverty alleviation and mangrove conservation. These alternatives and the socio-ecological assessment should be a guideline for other mangroves areas worldwide with similar environmental problems and where fishery is the base of economic subsistence, in order to guarantees the long term sustainability of mangrove socio-ecological systems.



## 1. Introduction

### 1.1. Conceptual basis

All humanly used resources are embedded in complex, social-ecological systems (SESs), in which subsystems as resource system, resource units, users, governance systems and rules are relatively separable but interact to produce outcomes at the SES level, demanding scientific knowledge that combine ecological and social sciences to enhance efforts to sustain SESs (Ostrom, 2009). Mangroves, coastal ecosystems distributed along the world's (sub) tropics, can be characterized as a good example of SESs, since their resources have been heavily traditionally used for food, timber, fuel, medicine and socio-economic subsistence (Rönnbäck, 1999; Alongi, 2002; Walters et al., 2008). This ecosystem supports diverse local fisheries including fishes, crustaceans (crabs, shrimps) and mollusks, which are source of income for traditional and deprived human communities (Rönnbäck, 1999; Walters et al., 2008; Satyanarayana et al., 2013; Santos et al., 2014). Positive correlations have been demonstrated between mangrove cover and municipal fisheries landings (Rönnbäck, 1999), thus, it is estimated

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that two-thirds of the world's fishing communities depend on the existence of mangroves (FAO, 2003).

Though the importance of mangrove ecosystems for human subsistence has been reported before (Rönnbäck, 1999; Saenger, 2002; Walters, 2003; Wattage and Mardle, 2005; FAO, 2007; Walters et al., 2008; Satyanarayana et al., 2013), research on the extent on which the livelihoods depend on certain resources is still lacking (Satyanarayana et al., 2013). Evaluation of the importance of mangroves for human communities and their knowledge about the ecosystem and fishery resources are important information for the local conservation and coastal management as well as for the maintenance of these communities and fishery stocks (e.g. Souto, 2007; Nordi et al., 2009; Firmo et al., 2011, 2012; Magalhães et al., 2012; Satyanarayana et al., 2013). In this context in which humans and environment are linked and interdependent, socio-ecological assessment is a major tool for coastal management, since it considers this relationship and local knowledge as important information for environmental planning. In this view, ethnozoology studies have been developing a chief importance, aiding in valorization of the regional fauna from an ecological point of view as well as from economic and social standpoints, and subsidize environmental management and species conservation plans that take into account the social and economic realities of the human populations that will be affected (Alves and Nishida, 2003; Alves, 2012; Alves and Souto, 2015). For example, many ethnozoological studies with fisher or harvesters of different mangrove resources as mollusks (e.g. Nishida et al., 2006a,b,c; Rocha et al., 2008), fishes (e.g. Rocha et al., 2008) and crabs (e.g. Alves and Nishida, 2002, 2003; Rocha et al., 2008; Capistrano and Lopes, 2012; Nascimento et al., 2012, 2016), have shown that local populations have a high knowledge of the species they depend upon and the environment, therefore, they can contribute for the establishment of management strategies (Alves and Souto, 2015). In Brasil, this is a really fact for the crab species *Ucides cordatus, Cardisoma guanhumi* and *Callinectes sapidus*, for which local knowledge was fundamental for the elaboration of a National Propose of Management Plan for these crabs (Brasil, 2011).

Co-management schemes, involving fishers and government agencies as partners, has been promising in the management of tropical coastal fisheries, as in the Caribbean and Pacific Islands (Warner, 1997; Zann, 1999; Johannes, 2002; Nishida et al., 2006c). The implementation of a successful management strategy fundamentally requires the involvement of the main stakeholders, who must be sensitized to the need for the conservation of the natural resource as a guarantee for its sustainable exploitation (Nishida et al., 2006c).

### 1.2. Question of study

Brazil, with a coastal zone of approximately 8500 km of extent (4° 30′ N to 33° 44′ S), shows the second largest mangrove area in the world (Asmus and Kitzmann, 2004; Spalding et al., 2010). In this country artisanal fishery is fundamentally relevant because this activity produces food, for commercial purposes and a means of economic subsistence (Nishida et al., 2006a). The bulk of Brazilian fishery is based on mangrove ecosystems whose species spend most of their life cycle in those environments (Vannucci, 2002; Nishida et al., 2006a). A diversity of fishery resources are exploited in Brazilian mangroves, such as fish (e.g. Souto, 2008), mollusks (e.g. Nishida et al., 2006a, b; Mendonça and Machado, 2010) and crabs (e.g. Alves et al., 2005; Ferreira et al., 2009; Nordi et al., 2009; Firmo et al., 2012, 2011; Magalhães et al., 2012).

Although various decrees and laws legally enforce the conservation and management of Brazilian mangroves, the ecosystem have been affected by a variety of anthropogenic activities (Santos et al., 2014), resulting in environmental changes and socio-economic impacts on the communities that depends on mangrove resources (e.g. Glaser, 2003). In this view, it is important to consider that the perception of environmental changes by local communities has proven valuable as a background to reconstruct historical use and impact on mangroves (Walters, 2003; Dahdouh-Guebas et al., 2004, 2005; Walters et al., 2008; Nfotabong-Atheull et al., 2011), serving as information and support for the local management and conservation efforts (e.g. Satyanarayana et al., 2013).

In Northeastern Brazil, the São Francisco River Estuary (10° 30′ 27″S, 36° 23′45″W) comprises a significant mangrove area (30 km$^2$) nearby human populations live and use mangrove fishery resources. Despite this, the economic and social importance of these resources and the knowledge and management practices of the local populations are poorly documented. Additionally, even though this area is part of a protected area where sustainable use is allowed (Sergipe, 2004), the poverty, decrease of fisheries resources and deforestation of mangroves for shrimp farming are constraints to achieve sustainability. Similar scenarios are found along Brazilian coast and worldwide wherein mangrove socio-ecological systems face impacts that put in risk its long term sustainability (e.g. Dahdouh-Guebas et al., 2005; FAO, 2007; Firmo et al., 2011; Satyanarayana et al., 2013). This study aims to characterize the use of economic important mangrove fishery resources by the human populations of the São Francisco River Estuary, and their perceptions on the mangrove fisheries shifts and environmental impacts that occurred during the last decade as well as their perspectives for community sustainable development. Our hypothesis is that mangrove fisheries are the unique source for local economic subsistent and this high dependence conducted to a high development of local knowledge on the environment and changes/impacts, which can aid in formulating management strategies for socio-ecological sustainability. Therefore, based on the data generated in this study, we pointed out some strategies important to be considered in the local management. The applicability of these management strategies and socio-ecological assessment were also discussed for the national scale and for mangrove areas worldwide with similar characteristics and environmental problems. Therefore, we contribute with important information and methodology for environmental planning and management in mangrove coastal areas.

## 2. Material and methods

### 2.1. Study area

The São Francisco River is one of the most important and largest Brazilian water resources and is considered the River of National Integration, draining seven states along its 2863 km with a river basin of 636,919 km$^2$ (ANA, 2005, Fig. 1a; b). The estuary of this river is located in the low São Francisco, on the boundary of Sergipe and Alagoas States (10° 30′ 27″S, 36° 23′45″W) in the Northeast of Brazil (Fig. 1b and c). The study area corresponds to the southern part of this Estuary (State of Sergipe) (Fig. 1c) and covers approximately 192.35 km$^2$ and is part of the municipalities of “Brejo Grande” and “Pacatuba”. About 93% of the study area is occupied by natural cover such as: sandy coastal vegetation (77%), mangroves (15.7%) and intertidal flats (0.7%), while 7% is occupied by human activities as aquaculture (2.4%) and agriculture (4.7%) (Santos et al., 2014).

The study area is part of a State Environmental Protected Area (APA “Litoral Norte”), a conservation unit of sustainable use which was created in 2004, but still does not have a Management Plan (Sergipe, 2004; Santos et al., 2014). This area is characterized by a