Journal of Environmental Management 128 (2013) 274–282

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Behavioral and environmental influences on fishing rewards and the outcomes of alternative management scenarios for large tropical rivers

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ARTICLE INFO

Article history:
Received 14 October 2012
Received in revised form
13 May 2013
Accepted 17 May 2013
Available online 10 June 2013

Keywords:
Human ecology
Fisheries management
Fishery economics
Small-scale fisheries
Brazilian Amazon

ABSTRACT

Identifying the factors that influence the amount of fish caught, and thus the fishers' income, is important for proposing or improving management plans. Some of these factors influencing fishing rewards may be related to fishers' behavior, which is driven by economic motivations. Therefore, those management rules that have less of an impact on fishers' income could achieve better acceptance and compliance from fishers. We analyzed the relative influence of environmental and socioeconomic factors on fish catches (biomass) in fishing communities of a large tropical river. We then used the results from this analysis to propose alternative management scenarios in which we predicted potential fishers' compliance (high, moderate and low) based on the extent to which management proposals would affect fish catches and fishers' income. We used a General Linear Model (GLM) to analyze the influence of environmental (fishing community, season and habitat) and socioeconomic factors (number of fishers in the crew, time spent fishing, fishing gear used, type of canoe, distance traveled to fishing grounds) on fish catches (dependent variable) in 572 fishing trips by small-scale fishers in the Lower Tocantins River, Brazilian Amazon. According to the GLM, all factors together accounted for 43% of the variation in the biomass of the fish that were caught. The behaviors of fishers' that are linked to fishing effort, such as time spent fishing (42% of the total explained by GLM), distance traveled to the fishing ground (12%) and number of fishers (10%), were all positively related to the biomass of fish caught and could explain most of the variation on it. The environmental factor of the fishing habitat accounted for 10% of the variation in fish caught. These results, when applied to management scenarios, indicated that some combinations of the management measures, such as selected lakes as no-take areas, restrictions on the use of gillnets (especially during the high-water season) and individual quotas larger than fishers' usual catches, would most likely have less impact on fishers' income. The proposed scenarios help to identify feasible management options, which could promote the conservation of fish, potentially achieving higher fishers' compliance.

1. Introduction

Fisheries use diversified gear, target different species and perform at different scales, each of which requiring specific management measures (van Oostenbrugge et al., 2002; Castilla and Defeo, 2005; Anticamara et al., 2011). Typical management measures tend to disregard small-scale fisheries characteristics and focus on the conservation of stocks through effort limitation, gear control, seasonal fishing closures and no-take areas (Gewin, 2004; MacCord et al., 2007; Muallil et al., 2011). However, many fishery managers lack information about fishing effort (Anticamara et al., 2011), a case most common in small-scale fisheries (Salas and Gaertner, 2004; Hallwass et al., 2011).

Management plans aimed at regulating the use of natural resources, such as in fisheries, should consider the interaction between social and economic factors (Cinner and Aswani, 2007; Hilborn, 2007; McClanahan et al., 2009), as it has already been demonstrated that these are key factors in management success (Salas and Gaertner, 2004). Fishers' behaviors, which are motivated

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http://dx.doi.org/10.1016/j.jenvman.2013.05.037

by a number of drivers including economic incentives (Begossi et al., 2011; Kawata, 2012), may be a major source of uncertainty regarding the outcome of fisheries management (Fulton et al., 2011). Although fisheries management could provide long-term economic benefits to fishers through the recovery of fish stocks, fishers usually behave in ways to maximize short-term gains and may not be willing to, or simply cannot, postpone economic benefits (Cinner and Aswani, 2007; Begossi et al., 2011; Kawata, 2012). Therefore, fisheries management should be sensitive to fishers' immediate economic and social needs, and by knowing the factors that most affect fishers' income it is possible to better evaluate the impact, effectiveness and acceptance by fishers of current and planned management measures (Johnston et al., 2012).

Inland fisheries in the Brazilian Amazon are mostly small-scale (Bayley and Petrere, 1989) and are usually performed with small canoes exploring a wide variety of species and habitats, using multiple types of gear and landing catches sparsely in several small ports (Cerdeira et al., 2000; Hallwass et al., 2011). These characteristics, combined with logistical restrictions, make difficult the monitoring and enforcement of management rules. Although we lack long-term fisheries statistics for most of the Amazonian regions, there is evidence that fishing effort has increased and that some preferred commercial fish species have decreased in abundance and size; also, some fishes have been caught at sizes smaller than the first maturity (Petrere et al., 2004; Castello et al., 2011), which indicates the need for fisheries management. In addition to overfishing, hydroelectric dams in large Amazonian rivers may also decrease fish production and threaten fish stocks, causing local extinction of commercial fish species (Hallwass et al., 2013). The fisheries management rules in the Brazilian Amazon tend to be imposed top-down from the government. These rules, such as a closed season with individual quotas, a prohibition of specific fishing gear and a minimum size for some fish species, are too general and usually disregard the heterogeneity and particularities of the all the considered fishing communities (Castello et al., 2013). Some recent initiatives of participatory management (co-management) adopted locally devised management rules and have better considered fishers' concerns (Almeida et al., 2009; Castello et al., 2009; Lopes et al., 2011). Nevertheless, most of the current fisheries management rules imposed from the government in the Brazilian Amazon have not been based on fishers' behavior, and the efficacy of these regulations has not been sufficiently monitored. Although there is limited evidence that lakes closed to fishing (with fishers' consent) and fishing quotas of highly valued fish species have increased the abundance of commercial fishes (Almeida et al., 2009; Castello et al., 2009), some management measures, such as gear restrictions or closed seasons, have not been evaluated. Thus few studies exist that explicitly link fisheries management measures, fishing rewards and fishers' behavior in the Brazilian Amazon, as management measures have usually been evaluated on the basis of the status of fish stocks (Petrere et al., 2004).

We analyzed the relative effect of fishers' behavior (effort and fishing gear used) and environmental variables (season and habitat) on immediate rewards (biomass of fish caught) of small-scale fishers in the Lower Tocantins River, Brazilian Amazon. Based on these results, we provide practical suggestions to managers about fishers' potential compliance using scenarios based on combinations of management measures.

2. Methods

2.1. Study area

The Tocantins River is a clear water river located on the eastern portion of the Brazilian Amazon Basin. In 1984, the construction of the Tucuruí dam and the Hydroelectric Power Plant flooded an area of 2830 km^2, possibly effecting the livelihood of people living downstream from the dam (Ribeiro et al., 1995; Hallwass et al., 2013).

We studied small-scale fishers from five rural fishing villages (Açaizal, Calados, Ituquara, Joana Peres and Umarizal) in the Lower Tocantins River (municipality of Baião, Pará State), approximately 100 km downstream from the Tucuruí dam (Fig. 1). These villages are spread through an area encompassing different habitats (lakes, tributaries, main river channel and flooded forest), and some fishers there are also dedicated to small-scale agriculture. We chose these villages because they are the main fishing villages in the area (see Hallwass et al., 2011 for more information).

2.2. Sampling of fish landings

We sampled 572 fish landings from all canoes that arrived during the day (7:30 to 18:00, approximately) for 11 days in the flooded season (December 2006, $n = 50$ landings), 26 days in the high-water season (March 2007 and February 2008, $n = 260$), 14 days in the receding-water (June 2007, $n = 125$), and 16 days during the low-water season (August and September 2007, $n = 137$), for two to five consecutive days in each village and season (total of 67 sampling days). For each fish landing, we recorded the biomass (kg) of each fish species caught. Fish were identified by their local

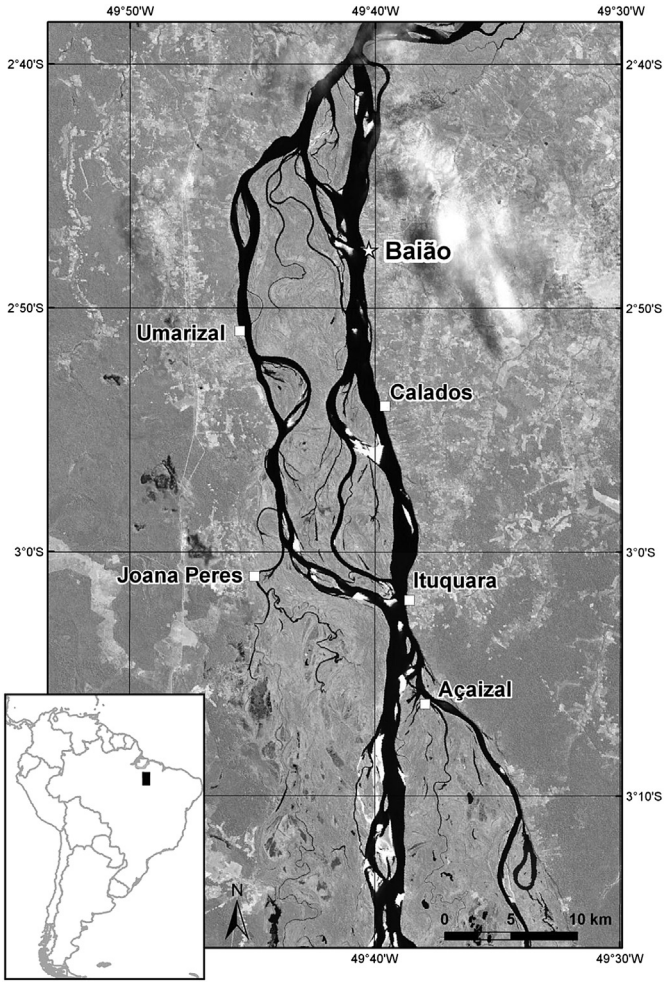

Fig. 1. Map showing the location of the five studied fishing villages (Açaizal, Calados, Ituquara, Joana Peres and Umarizal) and Baião city in the Lower Tocantins River, Brazilian Amazon.