Benefits of Community Fisheries Management to Individual Households in the Floodplains of the Amazon River in Brazil

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We study the incentives by fisher households in the floodplains of the Amazon river ("*várzeas*") surrounding the city of Santarém, Brazil, to comply with fisheries community management efforts. Fishing accords are community level agreements that have emerged in the region as a response to increased fishing activity and fisheries depletion since the 1980s. The main question we seek to answer is what effect fishing accords implementation efforts happening at the level of the household on those same households in terms of time savings, which would be a signal to continue participating in such fisheries management arrangements. Through a factor demand approach that has time as the main fishing production factor in a system of simultaneous factor demand equations, we use data collected with fisher households at different moments of the flooding regime of the Amazon river to find that fishing accords enforcement effort generate positive time savings to individual households.

The *várzeas* of the Amazon river stretch throughout an area of 180,360 km^2 that is influenced by nutrient-rich waters. Its environment is constantly changing as a reflection of the "flood pulse", through which water levels are continuously fluctuating, following a yearly pattern as waters rise and advance into surrounding land out of the main river channel, recede, and then rise again (Bayley and Petrere, 1989; Bayley, 1995). The flood pulse is felt not only by the *várzea* ecosystem but also by its inhabitants, whose lives follow a multi resource use strategy composed of a series of economic activities shadowing the different flooding stages throughout the year. Fishing, however, has stood out as a main income generating activity and takes advantage of a highly productive diversity of fishing environments, in a mosaic composed by river streams and lakes of various sizes.

A common pool resource, fisheries in the *várzeas* of Santarém have suffered the impacts of urbanization and population growth in the Amazon region, with an increase in the volume of outside and illegal commercial fisher boats. With property rights virtually nonexistent, households were forced to self-organize into communities and develop and enforce fishing accords to protect their fisheries. The federal government finally started to invest in legally defining property rights in the *várzea*, which accounted for the use of its resources, in the 2000s. However, enforcing these rights has been left to the communities. This way, the process of enforcing fishing accords varies across the *várzea*, depending on a junction of ecologic, socio-economic factors.

The literature studying fishing accords in the *várzea* of Santarém has been largely directed to the social arrangements that compose the community management of fisheries, seeking explanation for what makes them function or not (for example, see Castro & McGrath, 2003; McGrath et al., 2008). The measure of success is mostly related to resource health, measured in terms of catch per unit effort, such as presented in Almeida el at. (2002). McGrath et al. (2007) are the first ones to mention how fishing accords may change household fishing strategies depending on the costs and benefits the accords may represent, and they emphasize the need to look at households individually in fishing accords enforcement.

Our study herein presented is the first that we are aware of that seeks to examine individual enforcement and fishing strategies, and to estimate the welfare impact of fishing accords on individual households. We use an extensive 2015 data set based on socio-economic surveys, designed following standards in the economics literature, collected in 26 communities of more than 650 households randomly sampled through population-stratified methods in the

várzea during two points of the flood cycle, for a total of more than 1200 observations. We also use biomass data collected during the same period for a sub-group of the communities where the socio-economic surveys where undertaken, and which we use as proxy for fisheries health.

We consider time savings as the primary source of benefits in studying how fishing accords enforcement undertaken at the level of the household (this has been used before in the fuelwood literature, e.g., Kohlin and Amacher 2005). We estimate an econometric model based on cost minimization problem whereby a household, given its optimal catch, must choose the amount of labor time it allocates to fishing and to the enforcement of fishing accords in the face of a fishery that may or may not be protected by community action. This leads to a three stage least square estimation (3SLS, Zellner and Theil, 1962), in a system of factor demand equations that allow measurement of statistically significant drivers of labor time allocation to fishing activities, effort allocated to enforcing community fishing accords, and fuel use. The model accounts for unobserved variables, simultaneity of decisions, and inherent heterogeneity of households and endogeneity. The estimated model is used in a predictive sense to compute the average benefits accrued from fishing accords upon the same households that enforce them across communities in the sample. The mechanisms linking fishing accords enforcement effort and fishing labor demand is a higher quality resource stock in protected fishing sites. Time savings generated by the enforcement of fishing accords represent a measure of the net benefits of community cooperation to protect resources as an alternative to more conventional forms of intervention such as government-imposed restrictions.

The factor demand analysis reveals that statistically important drivers to labor demand and fuel include the level of dedication of a household and its history in implementing fishing accords, the *várzea* landscape, the flood pulse, distance to the main regional market, and biomass. The results also show that heterogeneity and endogeneity exist in the data and are controlled for in the econometric model. The time savings results based on the econometric model are revealing. Based on a six month period covered by the sampling, time savings generated to the average household in the sample is 39 eight-hour-long days, ranging from 10 to 96 eight-hour-days depending on the community. In aggregate terms, we find 25,082 eight-hour-days of fishing labor saved for the whole of the 23 communities in the second semester of 2015 (or 49 eight-hour-days per family).

The findings of our research represent a fundamental and underlying incentive to engage in proper enforcement of fishing accords, and they show the impact of a well-organized and well prepared community actions in the face of common pool resource pressures. Better fishing opportunities make households better off and protect forests and other natural resources in the *várzea* through less time redirected from poor fishing to land resource use.

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