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Commercial fishing in the Brazilian Amazon: regional differentiation in fleet characteristics and efficiency

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Abstract Regional differentiation in fleet characteristics and economic efficiency, as well as the total elasticity of scale in the commercial fishing fleets of the Brazilian Amazon were analysed. Data were collected in 893 interviews with boat operators in four major ports on the River Amazon. Boats operating from the largest cities (Belém and Manaus) are mostly operated by hired skippers and non-permanent crews, while boats from smaller cities (Santarém and Tefé) are mostly owner-operated and use permanent crews. In the lower Amazon, a large proportion of fishermen (89% in Santarém and 53% in Belém) are based in rural areas, while in the upper Amazon commercial fishermen are predominantly urban-based. A production function analysis identified boat length, gear type used (gill net/purse seine), number of fishermen employed, quantities of fuel and ice used, and education level of the skipper as significant factors determining the catch. The analysis provided no evidence of regional differences in stock levels. The use of purse seines was associated with significantly higher catches (by 32%), all other factors being equal. Purse seines are banned in the lower Amazon (Santarem and Belem), and this results in overall lower levels of technical efficiency in this region. No significant total scale effect on efficiency was detected. These results are discussed with respect to the institutional sustainability of current fisheries co-management initiatives.

KEYWORDS: catch prediction, co-management, commercial fishery, production analysis, translog model.

Introduction

Amazonian fisheries are exploited both commercially and for subsistence. Commercial fishing is carried out predominantly by mobile and often urban-based professional fishermen, while subsistence fishing is carried out locally by rural people resident in the floodplain areas. Both commercial and subsistence fishing exploits stocks in the main river channel as well as in floodplain lakes, many of which are accessible to large commercial boats in the flood season (Almeida, McGrath & Ruffino 2001). The commercial fishing fleets in the Amazon expanded rapidly in the 1970s and 1980s, fuelled by increasing demand for fish from urban populations and the rise of an export-oriented processing industry. The resulting pressure on fisheries resources has led to widespread attempts by rural communities to restrict commercial fishing in local floodplain lakes (McGrath, DeCastro, Futemma, Amaral & Calabria 1993; DeCastro 1999). However, there was no legal basis for such community management initiatives, and frequent conflicts ensued with commercial interests insisting on their right of free access to all navigable waters. This situation has changed fundamentally with the new Brazilian federal fisheries law enacted in 1998. Fishing regulations devised by local communities may now be legally recognized and enforced by the government, provided that they do not explicitly discriminate against outsiders or conflict with governmental regulations on closed seasons, gear restrictions or protected species. Effectively the new law creates a co-management system where local communities and the government share responsibility for fisheries management and

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enforcement (Sen & Nielsen 1996). It does not, however, give communities property rights in the fisheries resources.

Regulations stipulated in co-management agreements are legally binding for mobile commercial fishing operators, and are enforced by local environmental agents working in association with the Federal Environment Agency. The regulations commonly put severe restrictions on commercial fishing in floodplain lakes through boat size and gear restrictions as well as total catch limits (Almeida, Lorenzen & McGrath 2002). Despite this, commercial fishermen have remained largely outside the management process, with no formal representation in the agreements and little power to influence regulations (except where rural-based commercial fishermen participate in their capacity as local residents). The further proliferation of co-management agreements will have major implications for the commercial fishing sector, and its ability to respond to and engage with the co-management process will be important to the institutional sustainability of co-management as well as the future of the sector.

While the federal fisheries law applies to the whole of the Brazilian Amazon, regional differences are apparent in the institutional sustainability of agreements as exemplified by the levels of conflict associated with them in the upper and the lower Amazon. In the upper Amazon region of Tefé, co-management agreements do not involve consultation with those engaged in commercial fishing even informally, and are subject to intense conflict and frequent transgressions (Queiroz 1999). In the lower Amazon region of Santarém on the other hand, the fishermen's unions have become informally involved in the co-management process, and conflict and transgression are rare (DeCastro 1999).

The purpose of this study is to analyse regional differentiation in the Amazon commercial fishing fleet, with particular reference to characteristics that may have a bearing on the sector's capacity to adapt to and engage with the co-management agreements. Although fishing has been extensively studied in individual regions of the Amazon (Petrere 1978a, 1978b; Isaac, Milstein & Ruffino 1996; Batista 1998; Almeida *et al.* 2001) there has been no systematic study of regional differentiation.

The study has two main parts. First, differentiation in basic characteristics of boats and skippers is analysed. Secondly, a production function is estimated and used to evaluate regional differences in efficiency and the total elasticity of scale in the sector. Results are discussed with respect to the institutional sustainability of co-management agreements and their possible effects on the efficiency of commercial fishing.

Materials and methods

Study area

Field studies were conducted in the main ports of four regions: Belém in the Estuary, Santarém in the Lower Amazon, Manaus in the Central Amazon and Tefé in the Middle Solimões (Fig. 1). Belém is a city with over 1 million inhabitants and is located in the Amazon estuary, formed by the rivers Amazon and Tocantins. Santarém is located on the River Amazon, 600 km upstream from Belém. Santarém is a city of 150 000 inhabitants and it is considered the main commercial centre of the Lower Amazon. Manaus is a city with over 1 million inhabitants, located on the Rio Negro, a few kilometres upriver from the confluence of the rivers Negro and Solimões (where the River Amazon originates). Finally, Tefé is a relatively small town with about 70 000 inhabitants, located on the River Solimões about 600 km upstream from Manaus. Estimated volumes landed are 20 000 t in Belém, 30 000 t in Manaus, 4000 t in Santarém, 2000 t in Tefé (Barthem, Guerra & Valderrama 1995; Isaac *et al.* 1996; Batista 1998; Barthem 1999; Almeida *et al.* 2001).

The fishing areas associated with these ports are largely, but not fully isolated. A small proportion of the catch is obtained from overlapping areas, and boats may also occasionally land catches in ports other than their home port.

Data collection

Interviews were conducted at the main landing sites for each port daily during the peak hours of fish landing (in the morning in Belem and Santarem, at night in Manaus and both morning and afternoon in Tefé). There was one collector in each port so the boats were interviewed as they arrived to sell the fish. Interviews essentially followed the same model in all ports and included questions on the characteristics of the fishing vessel, number of fishermen and canoes, ice use and fuel consumption, trip itinerary and duration of the voyage, catch size and composition, and the final sale price of fish. Skippers were also asked about the number of trips undertaken in the past month, and this information was used to scale up the catch, ice use and fuel consumption data to monthly totals. Interviews also included questions on the life history of the skippers (birth place, age, level of education, involvement in activities other than fishing) and fishing

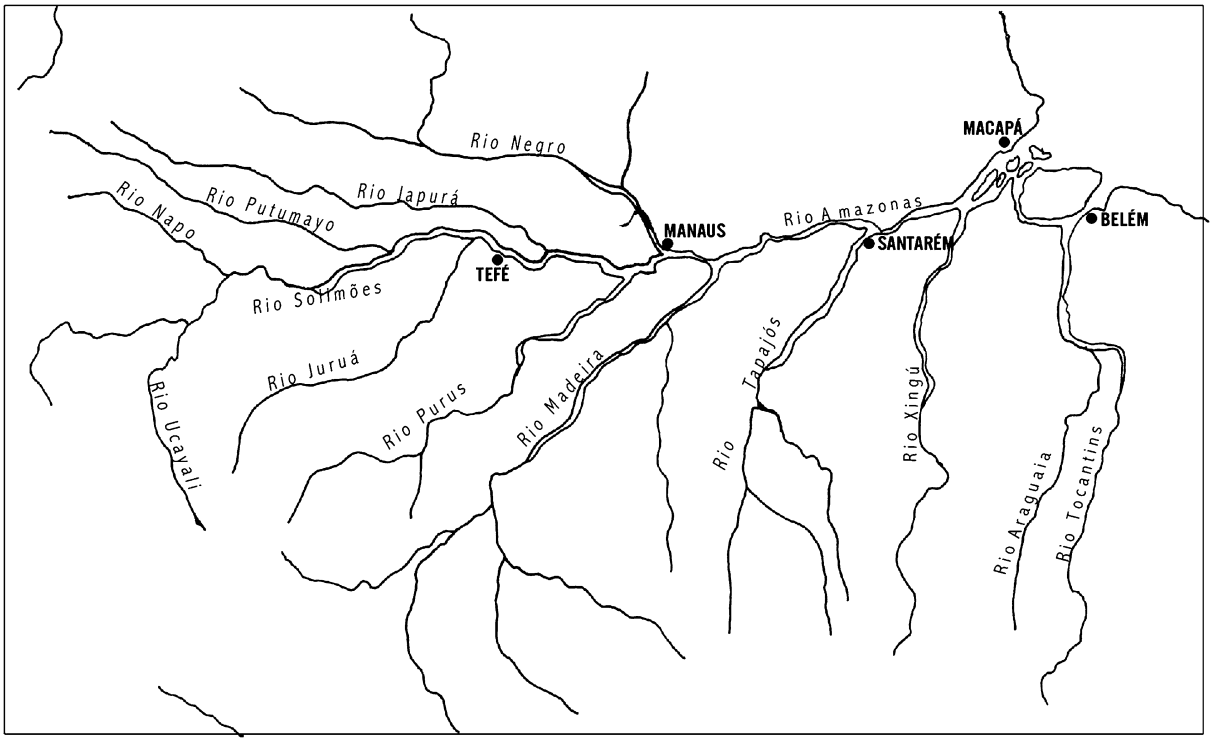

Figure 1. Main fishing ports in the Brazilian Amazon.

activities (where and when fishing activities occurred, conflicts with other fishermen, bank loans). Data collection covered two full years (1998 and 1999) in Belém, 1 year in Manaus (June 1999–June 2000), 1 month each in January and June 1998 in Santarém, and October 1998 to January 1999 and May to July 1999 in Tefé.

Description of fleet characteristics

Multiple comparisons of mean values with confidence limits were used to describe regional differentiation in fleet and skipper characteristics. A correlation matrix was used to explore relationships between variables.

Regional and scale effects on efficiency

Exploratory analyses were carried out to test for seasonality in input–output relationships in the fleets for which at least one full year of data were available (Belém and Manaus). No significant seasonal effects were detected and therefore all data were pooled by port regardless of season.

Production functions show the relationships between inputs and outputs given the current state of technology. In fisheries, output is the harvest and inputs are the fish stock, capital (boat and gear), labour (quantity and quality), and consumables such as fuel and ice. In the present study, the inputs were quantified as follows. The fish stock could not be measured directly, hence dummy variables for fishing ports were introduced to account for possible regional differences in stock abundance. Capital inputs were described by several different measures of boat size (length, ice storage capacity, and engine power), and the type of gear used (gill nets or purse seine). Labour inputs were measured as the number of fishermen employed on the boat, and skipper characteristics (age, years of schooling, and dummy variables for owner-operator or hired skipper and for affiliation with the fisher's union). Fuel and ice inputs were measured directly.

A Cobb–Douglas production function was estimated to determine output elasticities for the different inputs, and test for regional differentiation in stock levels (Bairam 1994):

$$\ln c = \ln \alpha_0 + \sum \alpha_i \ln x_i + \sum \beta_j D_j$$

where c is the catch, x_i are the factors of production, α_i are the output elasticities of these factors, D_j are dummy variables and β_j are the corresponding coefficients. The total scale elasticity ϵ is the sum of the output elasticities, and the variance of ϵ is the sum of

the variances of the factor elasticities. The production function was estimated by stepwise multiple regression.

Results

Regional differentiation in fleet and skipper characteristics

Physical boat characteristics are summarised in Table 1. In contrast to the other ports, the Tefé-based fleet comprised both covered boats with inboard engines and smaller, open canoes with outboard engines, which are listed separately. The Manaus-based fleet has the largest boats in terms of length, motor power and in particular ice storage capacity, while the overall boat sizes in the other fleets are similar. Fishing was carried out almost exclusively with gill nets and purse seines. Purse seines are banned in the lower Amazon state of Para (ports of Belém and Santarém), but are frequently used in the upper Amazon.

Skippers from the four fleets showed a number of common characteristics (Table 2). In all cases, the majority is dependent on fishing as their main source of income, and with the exception of Belém, the majority have always worked in the sector. Additionally, the level of affiliation with the Fisherman's Union is high in all fleets. In spite of these similarities, there was a clear regional difference between skippers and crew. Some general trends are evident between small and large cities. Boats based in smaller cities (Santarém, Tefé) tend to be operated by the owner and use permanent crew while the reverse is true for larger cities (Belém, Manaus). Operators from smaller towns also show the highest levels of affiliation to the Fishermen's Union. The majority of fishermen in the lower Amazon (53% in Belém and 89% in Santarém) are based in rural areas, while the fishermen in the upper Amazon/Solimões are predominantly urban-based. Fishing is the main source of income for the majority of operators in all ports, but a far higher proportion (40%) of skippers in the Santarém region have other sources of income than elsewhere (< 20%). Labour mobility in the fisheries sector is highest in Belém, where boats tend to be operated by young, professional skippers who depend on fishing for their income but have had other previous occupations, and non-permanent crews. Manaus has the highest proportion of skippers who have always worked as fishermen, but only a minority use permanent crew.

The correlation matrix (Table 3) shows the overall relationships between the various boat and skipper characteristics and catch. Overall, boat characteristics (ice storage capacity, boat length and engine power) are highly correlated with each other, with the number of fishers employed, and with the resulting catch. As a rule, the larger a boat, the more fishermen will be taken on a trip, and the higher the catch landed. Social

Table 1. Key boat characteristics. Mean values with 95% confidence intervals. Mean values followed by the same superscript letters are not significantly different

Port	Belém	Santarém	Manaus	Tefé (boats)	Tefé (canoes)
Length (m)	10.0 (9.5, 10.5)^{a}	12.1 (11.4, 12.8)^{b}	14.4 (14.0, 14.8)^{c}	11.8 (11.2, 12.4)^{b}	7.9 (7.7, 8.0)^{d}
Ice storage capacity(t)	4.8 (4.4, 5.2)^{a}	4.3 (2.5, 6.1)^{b}	11.1 (9.8, 12.4)^{c}	3.6 (2.7, 4.4)^{b}	0.5 (0.4, 0.6)^{d}
Engine power (hp)	30 (27, 33)^{a}	26 (21, 30)^{a}	36 (33, 40)^{b}	23 (18, 28)^{a}	8.1 (7.3, 8.8)^{d}
Number of fishermen	5.2 (4.9, 5.5)^{a}	8.6 (7.2, 10.0)^{b}	8.2 (7.8, 8.6)^{b}	5.7 (5.0 6.4)^{a}	3.1 (2.7, 3.4)^{c}
Proportion using purse seines (%)	0^{a}	0^{a}	49 (44, 54)^{b}	36 (22,50)^{c}	11 (4, 19)^{d}
Catch (tones per month)	2.8 (2.6, 3.1)^{a}	5.1 (3.1, 7.1)^{bd}	7.1 (5.8, 8.5)^{b}	3.8 (2.1, 5.5)^{ad}	1.6 (1.2, 1.9)^{c}

Table 2. Socio-economic characteristics of fishing boat operators landing in major ports of the Brazilian Amazon basin. Mean values with 95% confidence intervals. Mean values followed by the same superscript letters are not significantly different

	Belém	Santarém	Manaus	Tefé
Operator is owner (%)	33 (29, 37)^{a}	60 (41, 79)^{b}	34 (29, 39)^{a}	78 (70, 86)^{b}
Affiliated to Colonia (%)	68 (63, 73)^{a}	86 (78, 94)^{b}	52 (46, 58)^{c}	77 (69, 85)^{ab}
Uses permanent crew (%)	37 (32, 42)^{a}	90 (82, 98)^{b}	39 (34, 44)^{a}	94 (83, 100)^{b}
Fishing only source of income (%)	96 (94, 98)^{a}	60 (49, 71)^{b}	86 (82, 90)^{c}	82 (75, 89)^{bc}
Fishermen based in rural area (%)	53 (48, 58)^{a}	89 (79, 99)^{b}	39 (34, 44)^{c}	25 (17, 33)^{d}
Age (years)	37 (36, 38)^{a}	40 (37, 42)^{a}	40 (38, 41)^{a}	39 (37, 41)^{a}
School education (years)	3.1 (2.9, 3.3)^{a}	3.0 (2.6, 3.4)^{ab}	3.2 (2.9, 3.5)^{a}	2.4 (2.0, 2.8)^{b}
Always worked as fisherman (%)	32 (28, 36)^{a}	51 (40, 62)^{b}	78 (74, 82)^{c}	57 (48, 66)^{b}

Table 3. Correlation matrix of boat characteristics and catch (log transformed). Significant correlations ($P < 0.01$) in bold

	Catch (t)	Fishermen *n*	Ice storage (t)	Boat length (m)	Engine power (hp)	Owner-operated	Age (years)	Education (years)	Colonia membership	Gear	Ice	Fuel
Catch (t)	1.00	**0.56**	**0.53**	**0.46**	**0.47**	**−0.17**	0.03	0.06	0.00	**0.27**	**0.58**	**0.57**
Fishermen		1.00	**0.61**	**0.74**	**0.63**	**−0.24**	**0.09**	−0.04	−0.03	**0.32**	**0.55**	**0.65**
Ice storage (t)			1.00	**0.66**	**0.64**	**−0.20**	**0.16**	0.00	−0.04	**0.30**	**0.67**	**0.64**
Boat length (m)				1.00	**0.64**	**−0.19**	**0.16**	−0.03	−0.05	**0.43**	**0.54**	**0.64**
Engine power (hp)					1.00	**−0.24**	**0.11**	0.04	0.02	**0.20**	**0.58**	**0.70**
Owner-operated						1.00	**0.29**	−0.03	**0.23**	−0.04	**−0.24**	**−0.26**
Age (years)							1.00	**−0.26**	**0.32**	0.05	**0.10**	**0.13**
Education (years)								1.00	0.00	0.00	−0.02	−0.06
Colonia membership									1.00	**−0.10**	0.03	−0.01
Gear										1.00	**0.23**	**0.21**
Ice											1.00	**0.66**
Fuel												1.00

Table 4. Production function parameters estimated for the Amazon commercial fleet

Economic production function Coefficients	Parameter (SE)
Capital equipment	
Boat length	−0.51 (0.17)
Boat ice capacity	NS
Boat engine power	NS
Labour	
Number of fishermen	0.53 (0.09)
Age of skipper	NS
Education level of skipper	0.10 (0.05)
Skipper affiliation	NS
Consumables	
Fuel	0.20 (0.05)
Ice	0.35 (0.04)
Total elasticity ϵ	0.67 (0.20)
Dummy variables	
Santarem stock level	NS
Manaus stock level	NS
Tefé stock level	NS
Gear type	0.28 (0.09)
r^2	0.43

characteristics are less strongly correlated with each other or with physical trip characteristics, but some patterns are evident: larger boats are more likely to be skippered by a person other than the owner, use non-permanent crew and be urban-based than smaller boats.

Regional and scale effects on efficiency

Of the various input measures considered, only boat length, gear type, number of fishermen, education level of the skipper and fuel and ice quantities were retained in the final multiple regression model (Table 4). Multicollinearity of the input variables (see Table 3) implies that the role of individual inputs cannot be clearly established, and the negative elasticity estimated for boats size must therefore be interpreted with caution. Total scale elasticity was estimated as 0.67, not significantly different from the one given a standard error of 0.20. None of the regional coefficients were significant, hence there is no evidence for regional differentiation in stock levels. Boats using purse seines achieve significantly ($P < 0.050$) higher catches (by 32%) for the same level of other inputs than those using gill nets.

Discussion

Regional differentiation in fleet characteristics

Overall the commercial fisheries sector throughout the Brazilian Amazon is characterized by a high degree of professionalism. In all regional fleets, the majority of operators are dependent on fishing as their main source of income. With the exception of the Belém fleet, the majority of boat operators have always worked in the sector. However, apart from these common characteristics the study identified substantial regional differentiation in the characteristics of skippers and crew. Boats landing in smaller cities tend to be operated by the owner and use permanent crew while the reverse is true for larger cities. Overall, this suggests a high degree of specialization and relatively low mobility of operators in the sector as a whole. Hence, any changes in management are unlikely to lead to rapid entry into or exit from the sector. Labour mobility in the fisheries sector is highest in Belém, where boats tend to be operated by non-permanent crews under the command

of relatively young skippers who, although presently dependent on fishing for their income, have had previous occupations outside the sector.

The majority of fishermen in the lower Amazon are based in rural areas, while those in the upper Amazon/Solimões are predominantly urban-based. Consequently benefits from the commercial exploitation of fisheries resources accrue in rural areas of the lower Amazon, but are effectively transferred to urban areas in the upper Amazon/Solimões.

Levels of affiliation with the Fishermen's Union are generally high, and highest in the fleets landing in smaller towns. This suggests that the fishermen's unions can effectively represent the majority of commercial fishermen throughout the Brazilian Amazon.

Regional and scale effects on efficiency

The production function analysis indicates that there are no regional effects on efficiency that could indicate differences in stock levels. This suggests that stock levels are similar in different regions of the Amazon basin, and that observed differences in fleet characteristics are unlikely to reflect adaptations to differences in resource availability. While there is no regional effect linked to stock levels, an indirect regional effect is introduced by the legislation banning the use of purse seines in the lower Amazon state of Para, which includes the ports of Santarem and Belem. Given that the use of purse seines results in 32% higher catches for the same level of other inputs, boats operating in the lower Amazon effectively do so at lower levels of efficiency that those operating in the middle and upper Amazon.

No significant scale effects on efficiency were detected. This may be expected given that the technology used is essentially modular: the main fishing boats serve to store and transport the catch, while active fishing is carried out from canoes. Larger fishing boats carry more fishermen and canoes, but otherwise use the same technology as smaller boats. Alternatively, larger boats tend to operate over larger areas and may be better placed to respond to spatio-temporal variation in resource availability. Overall, the current results indicate that there is no efficiency advantage to larger boats, but this conclusion must be interpreted with caution as the standard error of the elasticity estimate is large.

Implications for co-management

Many of the fleet characteristics and their regional differentiation reported above have implications for the ability of the commercial fishermen to respond to and engage with the co-management agreements. Overall the fishing sector is characterised by very low labour mobility and a high level of dependence on fishing as the sole or dominant source of income. This suggests that most commercial fishermen will remain in the sector although their activities will be increasingly restricted by the proliferation of co-management agreements. Constructive engagement of commercial fishermen in the co-management process is therefore important for minimizing negative impacts on livelihood that could exacerbate conflicts and threaten the institutional sustainability of co-management. The high level of affiliation of commercial fishermen with their fishermen's unions suggests that these institutions would be well-placed to represent them in the co-management process.

As many co-management agreements restrict the size of boats allowed to operate on floodplain lakes, a possible response would be for commercial operators to switch towards smaller boats. Constant elasticity suggests that such a change would be neutral with respect to the economic efficiency of fishing.

As mentioned in the introduction, there appear to be regional differences in the level of conflicts associated with agreements and therefore their institutional sustainability. Given the lack of regional differentiation in resource availability, the higher levels of conflict observed in the upper Amazon cannot be explained by higher resource scarcity. However, substantial differentiation in certain fleet characteristics may, at least in part, explain the different levels of conflict. Conditions in the lower Amazon region of Santarém are in many ways the most favourable for the institutional sustainability of co-management systems. The majority of commercial fishermen are rural-based, i.e. part of communities that may instigate co-management agreements or have already performed so. By virtue of their residency, they have a say in local agreements and may reap benefits from increases in local resource abundance that may partially compensate for access restrictions elsewhere. Moreover, in the Santarém region they have a high level of affiliation with the Fishermen's Union, which is informally involved in many local agreements. A comparatively high proportion of operators have sources of income other than fishing and may therefore be more able and willing to change their fishing effort and practices than the more strongly fisheries-dependent operators elsewhere.

Conversely, commercial fishing in the upper Amazon has remained the preserve of urban-based dwellers who stand to gain little from co-management agreements

that serve primarily to restrict their access to floodplain lakes. Hence opposition to the agreements and transgression by commercial fishing may continue to threaten the institutional sustainability of co-management in the upper Amazon (Queiroz 1999; Oliveira & Cunha 2000). However, both sides may stand to gain from constructive engagement. The dominant contribution of urban fishermen to commercial landings also implies a low level of rural participation in fishing as an income-generating activity. Consequently, rural fishermen may not realise the full economic benefits from increased control over fisheries resources. Inclusion of commercial fishermen in management agreements, possibly with some form of access and profit sharing between them and local communities, may generate benefits to both groups. The fishermen's unions could play a key role in the further development of co-management agreements, but this would require a more flexible and less confrontational approach on the sides of both local communities and the unions.

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References

Almeida O., Lorenzen K. & McGrath D. (2002) Impact of co-management agreements on the exploitation and productivity of floodplain lake fisheries in the Lower Amazon. In: *Proceedings of the 9th Biennial Conference of the International Association for the Study of Common Property*, 12 pp. [http://www.iascp2002.org/Abstracts/almeidao080502.doc]

Almeida O., McGrath D.G. & Ruffino M.L. (2001) The commercial fisheries of the lower Amazon: an economic analysis. *Fisheries Management and Ecology* **8,** 253–269.

Bairam E. (1994) *Homogeneous and Nonhomogeneous Production Functions*. Aldershot: Avebury, 146 pp.

Barthem R. (1999) A pesca Comercial no médio Solimões e sua interação com a Estação Ecológica do Mamirauá. In: H. Queiroz & W.G.R. Crampton (eds) *Estratégias Para Manejo de Recursos Pesqueiros Em Mamirauá. Brasilia: Sociedade Civl Mamiraua/Cnpq*, pp. 72–107. (In Portuguese)

Barthem R.B., Guerra H. & Valderrama M. (1995) *Diagnóstico de los Recursos Hidrológicos de la Amazonia*. Lima: FAO/TCA, 162 pp.

Batista V. (1998) *Distribuição, Dinâmica da Frota e dos Recursos Pesqueiros da Amazônia Central*. PhD Thesis. Amazônia: Universidade do Amazonas & INPA, 291 pp. (In Portuguese)

DeCastro F. (1999) Fishing Accords: the political ecology of fishing intensification in the Amazon. PhD Thesis, IN, USA: University of Indiana, 206 pp.

Isaac V.J., Milstein A. & Ruffino M.L. (1996) A pesca artesanal no Baixo Amazonas: análise multivariada da captura por espécie. *Acta Amazonica* **26,** 185–208. (In Portuguese)

McGrath D.G., Castro F., Futemma C., Amaral B.D. & Calabria J. (1993) Fisheries and evolution of resource management on the Lower Amazon floodplain. *Human Ecology* **21,** 167–195.

Oliveira A. & Cunha L. (2000) Community management of the floodplain lakes of the meddle Solimões River, Amazonas State, Brazil: a model of preservation in transformation. In: *Proceedings of the 8th Biennial Conference of the International Association for the Study of Common Property (IASCP)*, 20 pp. [in http://129.79.82.27/IASCP00/program.aspandcd]

Petrere M. Jr (1978a) Pesca e esforço de pesca no estado do Amazonas I. Esforço e captura por unidade de esforço. *Acta Amazonica* **8,** 439–454.

Petrere M. Jr (1978b) Pesca e esforço de pesca no estado do Amazonas II. Locais e aparelhos de captura e estatística de desembarque. *Acta Amazonica* **8** (Suplemento 2)**,** 54 pp. (In Portuguese)

Queiroz H. (1999) A pesca, as pescarias e os pescadore de Mamirauá. In: H. Queiroz & W.G.R. Crampton (eds) *Estratégias Para Manejo de Recursos Pesqueiros Em Mamirauá. Brasilia: Sociedade Civl Mamiraua/Cnpq*, pp. 37–71. (In Portuguese)

Sen S. & Nielsen J.R. (1996) Fisheries co-management: a comparative analysis. *Marine Policy* **5,** 405–418.