Foraging behavior among fishermen from the Negro and Piracicaba Rivers, Brazil: implications for management

A. Begossi¹,⁴, R. A. M. Silvano² & R. M. Ramos³
¹Museu de História Natural, I.B., Unicamp, Brazil
²Depto. de Ecologia, UFRGS, RGS, Brazil
³PROCAM, USP, S.P., Brazil

Abstract

Foraging theory in ecology has been useful for the analysis of patterns relating to the cost and benefit of looking for, harvesting and obtaining food, including the costs of searching for and manipulating food (or prey). Within foraging theory, Optimal Foraging Models have also been applied to the foraging behavior of fishermen. Such models are important tools for understanding the decision processes taken by fishermen, such as: how many patches (or fishing spots, grounds or sites) to exploit, how long to stay in a patch, the costs and benefits of visiting distant patches, which fish should be caught, and which fish should be sold or consumed. The criteria by which fishermen make decisions concerning the use of the river space and the use of the available fish diversity are important reference parameters for river management. We give two examples of the application of Optimal Foraging Models to the behavior of fishermen by studying two riverine communities in Brazil. The first, located in the Amazon, on the Negro River, in the city of Barcelos, and the second, located in southeastern Brazil, São Paulo State, on the Piracicaba River, including two fishing communities: Santa Maria and Tanquã. Methods included sampling fish landings at known landing points, in local markets or at fishermen’s houses. In the Amazon (Negro River), in Barcelos, we collected data from 79 fishing trips, at the main landing point, the fish market, in August 2001. On the Piracicaba River, data on fishing trips and fish landings covered 256 fishing trips, collected at fishermen’s homes, from October 1994 to September 1995. The Optimal Foraging Models employed are Central Place Foraging Models, considering the travel time to the fishing spot (cost) and the quantity of fish caught (benefit). Such analyses show that the movement of fishermen to distant places is related to the fish-market value of target fish. Decision making processes underlying fishermen’s movements are important to be taken into account for fishery management.

Keywords: Amazon, artisanal fisheries, management, human ecology, optimal foraging.
1 Introduction

Modeling in behavioral ecology has been an important factor for understanding the cost and benefits of decisions regarding reproduction, food procurement, food acquisition and food choices. In particular, as pointed out by Lendrem [1], Optimal Foraging Models tackle questions about how behaviors are performed given a maximization of some optimality criterion [1]. Theory and examples of the use of Optimal Foraging Theory are available in Stephens and Krebs [2]. According to Pyke [3] Optimal Foraging Theory predicts that an individual will always be trying to maximize his net energy gain while foraging. The application of Optimal Foraging Theory to understand human decisions and behaviors is given by Bettinger [4] and Smith [5], among others. Optimal Foraging Models have been applied in the analysis of resource exploitation behavior of distinct human populations, such as indigenous hunters from Neotropical forests, as shown through a set of examples by Setz [6], to small farmers, by Laferrière [7] and to artisanal fishermen by McCay [8], Begossi [9] and Begossi and Richerson [10].

Central Place Optimal Foraging Model, developed by Orians and Pearson [11], is a particular Optimal Foraging Model in which the forager will try to maximize his net-energy intake while traveling to resource patches, exploiting them, and returning home (the central place). To achieve such maximization, the forager should bring more food (in quantity or quality) when exploiting distant places, which implies in a greater traveling time. This model is suitable to analyze fishermen’ behavior by taking fishing spots (grounds or sites) as resource patches, travel time as the round trip from home to the fishing ground, which means the cost of food acquisition, and the quantity of fish caught as the benefit obtained or the energy intake. This approach has been applied in studies of Brazilian marine small-scale fisheries by Begossi [9] and Begossi and Richerson [10]. These studies considered that, when exploiting more distant fishing grounds, fishermen should catch more fish or employ a greater fishing effort, in order to compensate for an increase in the travel time from home. This prediction is confirmed only if there is a positive relationship between travel time and weight of fish caught, for example.

Tropical artisanal fisheries furnish a considerable amount of animal protein to people living in developing countries, and in Brazil, contributing with more than half of fish catches in the country, as given in Begossi [12] for marine areas and in Petrere [13] for rivers. Artisanal fishing is usually less impacting on fish communities than large commercial and industrial fisheries, which employ a great fishing effort, but these fisheries have been threatened by the urbanization and environmental degradation, especially in the Brazilian South, as described by Silvano [15]. Therefore, an understanding of the decision processes of fishermen is a necessity in order to understand fishing tactics and strategies, and in order to have subsidies for management. The main objective of this study is to understand fisher’s behavior on the Negro and Piracicaba Rivers in the light of Central Place Foraging.
2 Study sites and methods

2.1 The Negro River: the fishery at Barcelos, Amazonas

The city of Barcelos is located on the banks of the Negro River, in the Amazon (Fig. 1), and its municipality includes a population of about twenty-four thousand inhabitants, fishing being the main male activity of the urban inhabitants (about eight thousand), as shown by the study by Silva and Begossi [16]. In spite of being a locality where fishing for ornamental fish occurs, such as for cardinal (*Paracheirodon axelrodi*) and acará-disco (*Symphisodon* spp.) [16], this study deals with fishing for food fishes.

![Figure 1: Research sites: Negro and Piracicaba Rivers, Brazil.](image1)

![Figure 2: Fishing using the zagaia in the Negro River, Amazon, Brazil.](image2)
In Barcelos, local commercialization of food fish occurs at landing points, especially in the fish market. One of the main techniques used in the local fishery is the zagaia, a harpoon-type trident used to fish at night. Fishermen are usually well-trained in this technique, used in the flooded forests (igapó) with the help of flash lights (Fig. 2). The main fish caught through the zagaia are species of cará (Cichlidae), tucunaré (Cichla spp.), traíra (Hoplias malabaricus) and pacu (species of Myleus and Metynnis), Silva and Begossi [16]. The landing point used for the samples of fishing trips is the Municipal Market of Barcelos, where the fishing activity was approached during 9 days between August 14-25, using standard questionnaires in which the traveling time, total time fishing and weight of fish caught were recorded. The fish were weighed per catch per trip, and not per species. Motor canoes were the main kind of boats used by the 27 fishermen that had their trips sampled in Barcelos.

2.2 The Piracicaba River: the fisheries of Tanquã and Santa Maria da Serra

The Piracicaba River Basin is located in São Paulo State, southeastern Brazil (Fig. 1). This river was impounded at its downstream portion in 1962 as a result of the construction of Barra Bonita reservoir that also embraces the Tietê River. Two small fishing villages with active fishermen are located along the reservoir banks, at the portion corresponding to the Piracicaba River: Ponte de Santa Maria da Serra and Tanquã. Fishermen from these villages use gillnets and motor-powered boats, store fish in freezers, and sell their catch to buyers, who distribute the fish among nearby cities. The main fish caught, according to Silvano and Begossi [17] are corimbatá (Prochilodus lineatus), corvina (Plagioscion squamosissimus), mandi (Pimelodus spp.) and cascudo (mainly Liposarcus aff. anisitsi). Fish landings were sampled at the two fishing villages, six days per month, between October 1994 and September 1995, recording the quantity of fishes caught (in Kg) per species, travel time to fishing grounds (in minutes) and quantity of gillnets employed (in m²). Fishermen reported the last two measures. We grouped the fish landings from the two localities for analysis. During some fishing trips, fishermen used 30-mm, stretched-mesh gillnets in order to capture lambaris (four small fish species of Characidae): Astyanax bimaculatus, A. schubarti, Moenkhausia intermedia and Triportheus signatus, as observed by Silvano [15]. Fishing trips with paddled canoes (13% of the total) were not considered in the analysis, as the travel time was not comparable with the motor-powered boats.

For the localities studied on the Negro River and on the Piracicaba River, we considered the travel time as a measure of cost and the mass of fish caught as the reward. Fishing effort is time spent fishing in the Negro River, and quantity of nets employed in the Piracicaba River [15]. We made simple linear regression analysis to verify the influence of the travel time on the quantity of fish caught. Logarithm (Ln) transformations were performed in cases of non-normality of the data and in order to avoid heteroscedasticity.
3 Results

The Central Place Optimal Foraging Model predicts that fishermen exploiting more distant places should catch more fish in order to compensate for the costs of a longer trip to fishing grounds.

3.1 Negro River, Barcelos

We obtained data from 79 fishing trips, 73 of which were performed using the zagaia. For this reason, we used the data from the zagaia trips for the calculations concerning the Optimal Foraging Model, and a few incomplete data were excluded. Approximately 2,184 Kg were obtained, especially including species of tucunaré (710 kg), cará (622 Kg), traíra (208 Kg), and pacu (157 Kg). The regression line is as follows, considering returns (Kg), and travel time (Hour).

a) $\ln Kg = 2.97 - 0.01 \ln Tt$, df = 64, $r^2 = 0.02$, $p > 0.90$ (n.s.).

The non-significant result shown may signify that travel time is not a significant parameter to evaluate fishermen’s decisions concerning their tactics (choice of spots to fish) or strategies (return in Kg). Another question thus intrigued us: when fishermen go farther, to distant spots, do they fish for a longer time? The regression line, as follows, considers then fishing time (Tf, dependent variable), and travel time (Tt, independent variable). Time is a percent of the fraction of the day.

b) $Tf = 0.42 - 0.33Tt$, df = 64, $r^2 = 0.23$, $p < 0.001$ [Fig. 3].

Figure 3: Graphic results of the regression for time spent fishing (costs) as the dependent variable, and distance of the fishing sites or travel time (n=66).
3.2 Piracicaba River, Tanquã and Santa Maria

A total of 256 fishing trips were recorded: 31 for lambari, 145 of corimbatá and 49 of other fishes. Next, we show the regression lines considering all the catch, and the target species corimbatá and lambari (travel time is in minutes):

\[\text{c) } \ln K_g = 3.15 + 0.01 \ln T_t, \quad df=223, \quad r^2=0.03, \quad p<0.01\]

\[\text{d) } \ln K_g \text{ corimbatá } = 1.65 + 0.01 \ln T_t, \quad df=143, \quad r^2=0.03, \quad p < 0.05\]

\[\text{e) } \ln K_g \text{ lambari } = 11.12 + 0.49 \ln T_t, \quad df=29, \quad r^2=0.22, \quad p<0.01 \ [\text{Fig. 4}]\]

Figure 4: Graphic results of the regression for lambari fishing in the Piracicaba River, considering benefits (Kg) as the dependent variable, and costs (distance to fishing sites or travel time) (n=31).

4 Discussion

The Central Place Optimal Foraging Model helps us in the understanding of the fishing decisions as long as we use the results within the context of fishing and to evaluate the selection of variables of the model. On the Negro River, travel time does not seem to be a key factor in terms of the decision of fishermen. Other factors seem to play a role and we should think about such variables for further modeling and understanding. Fishermen use the zagaia at specific spots, usually close to trees in the flooded forest. Perhaps travel time is not important here because: a) spots are available around their area, and there is no huge difference in travel time to reach them. This may not be the case, as the minimum travel time observed is 1.2 hours (0.05 day fraction) and the maximum 13.4 hours (0.56 day fraction), which means that fishermen indeed used some spots that are far away from their home b) fish are available throughout the area, since you can go to any spot you know to get the fish, but perhaps returns are related to target species and not to the whole set of fish caught. In that case, it would be
worthwhile to use the model just for target species, such as tucunaré, for example. For the Negro River, we do not have data available on the weight of the fish, separated per species, and, therefore, we cannot go a step farther for that case. It is interesting to observe that travel time influenced negatively on the time spent fishing: as long as they go farther, they stay less time fishing [b], contrarily to predictions of the Central Place Optimal Foraging Model. A possible explanation to such pattern would be that Rio Negro fishermen might have a total limited amount of time (including time to reach and to stay in fishing spots) to devote to fishing. Therefore, if they spend more time traveling they should save fishing time. Then, Negro River fishermen would probably be time minimizers instead of catch maximizers. This behavior may be associated to the necessity of conciliating fishing with other activities, or even to ice limitation (to preserve fish) which increases the risk of fish spoiling. In addition, for a better understanding of decision processes on the Negro River, a long data set analysis would be interesting along with local observation of the behavior of fishermen while fishing.

On the Piracicaba River, fishermen tend to capture more fish when they exploit distant places. Such an increase in fish rewards cannot be attributed only (or mainly) to a greater fishing effort, as the quantity of nets employed (fishing effort) is not correlated to travel time, as observed by Silvano [18]. The influence of travel time on the fish caught in the Piracicaba River case may be influenced mainly by two factors: the degree of fishermen’s knowledge of fish behavior and the degree of external influences on fishing activities.

Perhaps Piracicaba fishermen are fishing at distant places, aiming to catch either corimbatá or lambari. The corimbatá are migratory and the lambari a sedentary characin species, as shown by Agostinho et al [19]. Both lambari and corimbatá have economic value for fishermen. Gillnets are a passive gear, remaining overnight at fixed chosen fishing grounds. Fishermen presumably can catch more fish if they know to a certain degree where the fish stay or will pass in the river. As Observed by Silvano [18] and Silvano and Begossi [20], Piracicaba fishermen have knowledge of fish habitats and migratory behavior, and this knowledge is well-developed for both schooling fishes with seasonal migrations, such as the corimbatá, and sedentary fish, like the lambari. The influence of travel time on the lambari caught (Fig. 3) in the Piracicaba River is probably due to fishermen knowledge about possible habitat preferences of lambaris, which might be more abundant in more distant fishing grounds [18]. A close relationship between fishing strategies and corimbatá seasonal migrations was observed at Grande River, also in southeastern Brazil, by Castro and Begossi [21] and at the Pantanal wetlands by Ferraz de Lima [22]. At the Negro River, in the Brazilian Amazon, the complex migratory behavior of the prochilodontids jaraquis, *Semaprochilodus* spp. regulates both the timing and kind of fishing, according to Ribeiro and Petrere [23]. At the Piracicaba River, the influence of travel time (22%) on the quantity of lambari caught may reflect an ability of fishermen to find this sedentary fish. This ability could be associated to the degree of specialization of this fishery, as the lambari are the fishermen’s sole fish target when using 30-mm mesh gillnets. The kind of fishing
gear employed (gillnets) and the lambari’s sedentary habits may favor its location by Piracicaba fishermen. As pointed out by Durrenberger and Pálsson [24], in the Icelandic marine cod fishery, the knowledge of fishes’ spatial and temporal distributions is a key factor in determining good catches. In this context, fishermen using gillnets may acquire more precise information about fish location and movements than long-line fishermen. Among marine fishermen from southeastern Brazil, a positive relationship between catches and travel distance was observed only for the shrimp fishery at Gamboa Bay, not occurring among island fishermen who exploit schooling fish. This result can be related to the reduced mobility of shrimp compared to fish, making shrimp easier to find, as suggested by Nehrer and Begossi [25]. A similar situation occurs in the Icelandic marine cod fishery [24], in which fishermen visit distant fishing grounds aiming to increase their catches, but the fishermen’s decision processes depended on many other variables that were not addressed by the statistical procedures of the study.

A multitude of other factors influencing Piracicaba and Negro fishermen can be related to the difficulties of finding fish in unpredictable environments, to the influence of market pressures on foraging activities, and to the environmental changes occurring seasonally in the river, which in the Piracicaba River includes anthropogenic alterations. At the Barra Bonita reservoir, there is some indirect evidence that water pollution, deforestation and impoundment have been changing the composition of the fish community, and, hence, of the fish landings, during the past eleven years [16]. Begossi [9, 14], using the Optimal Foraging Theory predictions, did not observe a relationship between travel time and quantity of fish caught at Búzios Island, which could be due to difficulties in locating fish and to the climatic constraints of the maritime environment. At Sepetiba Bay, artisanal fishermen tend to exploit fishing grounds for a longer time than expected by the Optimal Foraging Model. This deviation may be related to the competition with large foreign fishing vessels, which harvest the same fishing spots [9]. Additional evidence is provided by Nehrer and Begossi [25] using Central Place Foraging in the artisanal fishery of Copacabana Beach, Rio de Janeiro, in which traveling time had a 22% influence on the fish catches of the locally called ‘noble fish’, which are target species with good market prices. McCay [8] observed that diverse external political and economical factors influenced the strategies of New Jersey marine fishermen. In the case of artisanal fishermen, market pressures seem to be relevant.

Not uncommonly, hunting and fishing behaviors of indigenous people from Neotropical forests follow Optimal Foraging predictions, as shown by Bettinger [4], Smith [5] and Setz [6]. This perhaps reflects a greater knowledge of the organisms exploited, when visible and less mobile preys (non-migratory) are caught. In rivers and seas, preys are hidden, invisible, and mostly highly migratory. The animals hunted can be tracked in the forest, and fish stocks may be more easily assessed in small rivers. Furthermore, many indigenous populations exploit natural resources mostly for subsistence, while the artisanal fishermen from Negro River, Piracicaba River, and those from the Brazilian
coast are influenced by market values, as a result of fish sales and purchase of manufactured goods.

5 Conclusions

Our analysis of the costs and benefits of the decisions of Negro and Piracicaba fishermen on fishing tactics and strategies, especially on the use of the aquatic space, by using Optimal Foraging predictions, bring information that can be useful for fishery managers. Fishermen possibly do not choose among fishing spots according only to the distance from home, but they may also consider the probabilities of a good catch. Governmental environmental managers may decide to prohibit fishing in some portions of the river or of the reservoir environment, at least during some months, for fish stocks to recover and to reproduce. In choosing where to close the fishery, managers, associated with local fishermen, should consider not only the distance of fishing spots from fishing villages, but also the importance of those grounds for fishermen, since remote grounds can be more rewarding than the nearby ones, especially if they contain species targeted by fishermen. Our results apply to Piracicaba lambari fishermen, but may be not the case of Rio Negro fishermen, who did not catch more fish in distant fishing spots.

Acknowledgements

This research was conducted through Grants Fapesp 97/04446-9 and 98/16160-5 and CNPq productivity scholarships.

References


Begossi, A. Artisanal fisheries in the SE Brazilian coast: using fisher information towards local management, Sustainable tourism (Section 6), F. D. Pineda & C. A. Brebbia (Eds.), The WIT Press: Southampton, pp 239-245, 2004.


