THE APPLICATION OF ECOLOGICAL THEORY

TO HUMAN BEHAVIOR:

NICHE, DIVERSITY AND OPTIMAL FORAGING

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ABSTRACT

General ecological models have been useful to analyze the behavior and use of natural resources by human populations. The niche concept, described as the range of conditions in which a population lives, is useful to understand the degree of resource use by human communities. Seasonal changes in the consumption of natural resources may be detected using niche theory. Diversity indices, such as the Simpson index, are a tool to evaluate the intensity of resource use, in temporal and spatial terms. Optimal foraging theory deals with the search and choice of food. It is useful to analyze the choice of animals consumed by people including the cost (search and handling times) and benefit (calories, money) of a decision. Central place foraging is a special case of optimal foraging and may be applied to the behavior of hunters and fishers. This study is based on research carried out in Brazilian fishing communities, called *caicaras,* located in Atlantic Forest areas. Research includes diversity of animals and plants used and fishing strategies, especially related to the time spent in fishing grounds or patches.

INTRODUCTION

General ecological concepts have been applied to human populations since the beginning of this century, when, for example, in the social sciences the "Chicago school" used concepts of competition and succession in urban populations (Begossi, 1993). After the fifties, cultural ecology, an area with an anthropological basis, has used concepts from evolutionary ecology, such as adaptation (Alland, 1975; Alland and McCay, 1973), niche (Hardesty, 1977), and optimal foraging models (Hames and Vickers, 1982; Hawkes et. al. 1987; Keegan, 1986; Winterhalder and Smith, 1981).

The concept of niche, applied by Hardesty (1975; 1977) for human subsistence, is based on the variety of resources used by a human population. In the eighties, niche studies in human ecology were apparently "out of fashion". The demand for research on conservation brings back studies of niche, because it is a valuable tool to analyze the level or intensity of resource use by a population. For example, the niche concept may be employed to evaluate the use of animals and plants by a native population in a conservation unit.

Diversity indices are a too! for measuring resources used by populations and for estimating niche breadth. These indices take into account the number of species (richness index) or also include the relative abundance of species, such as the Simpson and Shannon-Wiener indices (Magurran, 1988).

Optimal foraging theory has its application to human ecology especially in the eighties. Before this time, optimal foraging was largely applied in ecology to analyze the costs and benefits of food obtention and choice by animals. As some other ecological models, it has its roots in microeconomical models (Rapport and Turner, 1977) and it is used to analyze food choice and strategies of hunting and fishing in human populations. Optimal foraging models are part of a field called "human behavioral ecology" (Smith, 1992).

The purpose of this study is to show the application of some ecological concepts to human populations, focusing on communities called *caicaras,* living close to the Atlantic Forest in Brazil, and to show the relevance of those concepts for management and conservation.

STUDY SITES

The areas studied are located close to remnants of the Atlantic Forest, in southeast Brazil (Figure 1). They are Búzios Island, with about 44 families, the community of Gamboa, Itacuruçá Island, Sepetiba Bay, with 26 families, and the community of Puruba Beach, Ubatuba district, with 14 families.

Living close to the coast, the communities of *caigaras* depend on fishing and some agriculture (manioc, among others) for subsistence. *Caicaras* are the native or traditional populations of the southern Brazilian coast, which descend from Portuguese and Indians. Historical, anthropological, and economical aspects of the *caicaras* are found in Diegues (1983) and Mussolini (1980). Atlantic Forest remnants are becoming Biosphere Reserves (MAB-UNESCO)(Lino, 1992). Some areas in Figure 1 are conservation units (State Park of Serra do Mar - *Parque Estadual da Serra do Mar),* such as Búzios Island, or are located in their limits, such as Puruba Beach.

Fishing by *caicaras* is performed with hook and lines or with nets, in paddled or motorized canoes. Important marine animals at Búzios Island are bluefish *(Pomatomus saltatrix),* halfbeak *(Hemiramphus balao)* and squid *(Loligo sanpaulensis);* at Sepetiba Bay, mullets *(Mugil curema* and *M.*

platanus), weakfish (species of *Cynoscion,* among others *),* sand drum (*Micropogonias furnien)* and kingfish *(Menticirrhus americanus),* besides shrimp *(Penaeus schmitti)* (Begossi, 1992a; Begossi and Richerson, 1991); at Puruba Beach, snook *(Centropomus parallelus),* mullets, kingfish and different species of catfish. Fishing at Puruba occurs close to the mouth of the rivers Quiririm and Puruba.

PROCEDURES

Field work was performed at Búzios Island in 1986-87, at Gamboa, Itacuruçá Island (Sepetiba Bay) in 1989-90 and at Puruba, Ubatuba district in 1991-93.

General data (literacy, food preferences) were gathered in interviews, and data on diet included a random sample of 12 families at Búzios and 12 available families at Puruba Beach. The animal food consumed was systematically recorded in 5 days per month at Búzios (12 months) and in 10 days per month at Puruba (6 months).

Data on fishing trips were gathered at landing points, and included time spent on fishing, travel time, gear and catch per species, among others. A total of 906 trips were sampled at Búzios and 784 trips (line fishing) were used for the model of central place foraging. At Puruba Beach 197 trips were recorded (112 of line fishing). Data gathered at Gamboa (Sepetiba Bay), in order to analyze in detail the time of permanence in a patches, included participation in fishing trips (total of 22 trips), recording the time spent fishing in each patch and the catch per patch (Begossi, 1992a).

NICHE THEORY AND DIVERSITY INDICES

The concept of niche used in ecology is called the "Hypervolume model", defined as a n-dimensional space and representing all variables related to the life of an organism (Pianka, 1983).

Measures of diversity, such as the Simpson index (Levins, 1968), are used to measure what is called niche width or niche breadth. For example, the plants used by a population may be one dimension of its niche. In Table 1, different dimensions of the niche of *caigara* communities are shown, such as animals consumed and plants used for medicine. These represent the major natural resources used by these populations.

A total of 100 plants are used at Gamboa (Figueiredo *et al.,* 1993), and at Búzios Island 61 plants are used for food and 32 in house and canoe construction, besides the medicinal plants. The diversity of plant uses by the *caigaras* is very high, even compared to Amazonian communities (Begossi *et al.,* 1993). Comparisons among different *caicara* communities show that the diversity of plant use decreases as communities are located far from the shore and in smaller islands, following predictions of Island biogeography theory (Figueiredo *et al.* 1993). In Table 1, the Simpson index for Puruba Beach, a coastal community, is higher than for Búzios Island (located 24 Km off the coast) and Gamboa (0.8 Km off the coast). The lower diversity (richness) of medicinal plants is found at Búzios Island, in spite of its relative isolation. Comparisons using the Shannon-Wiener index are in Fígueiredo *et al.* (1993).

The niche breadth of animal food of families of Búzios Island varies seasonally and among families. Following predictions of ecological theory, Begossi and Richerson (1993) observed narrow niches for some high income families, because families concentrate in preferred food.

The index for animal food consumption is higher for Búzios Island than for the coastal community of Puruba (Table 1). *Caigaras* from Puruba have more access to beef and to other sources of meat than inhabitants of Búzios. This may contribute for narrow niches at Puruba, as observed in urban centers (Matavele et al., in press). The smaller sample taken at Puruba (6 months) may also contribute for a lower diversity, because the availability of the different fish species is highly seasonal.

Mullets, followed by snook, is the main fish consumed at Puruba Beach (Table 2). Fresh cattle meat and chicken represent 35% of the animal food. Fish is very important in the diet of the *caigaras,* representing 68% at Búzios Island and 52% at Puruba Beach. Seasonal differences in fish catches influence the kind of animal food: *paratí* (mullet) was the major food in April and May, months in which it was caught. Diversity indices are low in May, when mullet was part of many meals. In May, the two Simpson indices taken (average per month and per family and of all families per month) are low, indicating a low variability among families whereas in June, this variability increases, as the total index is higher.

Compared to other human populations (Hardesty, 1975), we observe a high diversity of animal food consumption in these communities, typical of unpredictable environments, such as a marine environments, in which prey is highly mobile. The consumption of local animal food is also high at Puruba Beach, in spite of its proximity to Ubatuba, a city of about 40,000 inhabitants.

Food choice includes food avoidances or prohibitions. Food taboos were observed at Búzios Island, such as prohibitions of lizard, ray and bonito (Begossi, 1992b), of puffer fish, rays and mullets at Sepetiba Bay, and of rays and catfishes at Puruba. Food taboos are a luxury and communities with abundant animal protein may show food taboos. In these communities, many taboos are diet restrictions during illnesses (Begossi, 1992b).

OPTIMAL FORAGING THEORY

Starting with the classical studies of MacArthur and Pianka (1966), Emlen (1966), and Schoener (1971), optimal foraging theory became a tool to predict and analyze strategies of resource exploitation. Optimal foraging models depend on decision assumptions (forager's choices), currency assumptions (choice evaluations) and constraint assumptions (limits of choices and trade-offs)(Stephens and Krebs, 1986:5). A detailed analysis of food choices at Búzios Island, including currencies (or food value) is found in Begossi and Richerson (1992). Reviews on human ecological studies may be found in Smith (1983) and Setz (1989) (for indigenous communities).

The model of central place foraging is a special case of optimal foraging, including the distance to foraging patches. According to Pyke (1984), the model of central place foraging includes movements when searching for food, relationship of diet and distance of foraging place, and association between distance and patch choice and time of permanence in a patch.

Table 3 shows the application of central place foraging for fishing strategies of the *caigaras.* Fishing grounds represent patches and distance is estimated by travel time. The mode! of central place foraging show that travel time has low influence in catches and also on the time spent fishing in a patch, in the case of fishers from Búzios Island. Different from fish catches, travel time has a reasonable influence in the time spent in a patch for shrimp fishing at Gamboa. Searching for fish at Gamboa includes movements along many patches (average of 6), whereas searching for shrimp includes in average 2 patches (Begossi, 1992a). The influence of the distance of patches in the time spent fishing is weak for Búzios Island and negative (r= -0.57) at Puruba Beach. For fishing in Table 3, especially at Gamboa, catches increase as more time is spent in patches.

The unpredictability of marine resources at Búzios Island, relatively far from the coast, may be higher than for Gamboa or for the coastal community of Puruba. Marine animals may be more available for artisanal fishers in bays rather than in moving schools as at Búzios. The features of a less mobile prey, such as the shrimp of Gamboa, contribute to the results in Table 3.

Fishers need some environmental clues in order to evaluate the "quality of a patch", or the productivity of a fishing ground. For artisanal fishers, the evaluation of fishing grounds depends on the mobility of the prey, because in distant fishing grounds (Búzios Island) or in fish catches (Puruba), the evaluation of the patches by fishers are apparently harder than for shrimp fishing in a bay (Gamboa). It would be important to compare results of encircling net fishing at Puruba with the results of Gamboa. In spite of the influence that the time spent in a patch has on the shrimp fishing at Gamboa, Begossi (1992a) showed that fishers tend to leave the patches later than predicted by the optimal foraging model. Fishers depend on "rules of thumb", usually related to their last try in a patch, or in a trip, which are the basis for their evaluation of resources.

CONCLUSIONS

Diversity indices and niche breadth are useful tools to analyze and quantify the intensity of use of resources by a human community. They also show with detail seasonal changes and intra-community variability, besides permitting comparisons among communities.

Optimal foraging theory is useful to understand fishermen's behavior in terms of tactics and decisions. The apparently optimal behavior of shrimp fishers from Gamboa may be due to a lower mobility of the prey. The unpredictability of hook and line fishing at Búzios Island may explain the low regression coefficients found.

The Atlantic Rain Forest is one of the top conservation areas and the *caigaras* are a native people with detailed knowledge on the resources of the forest as well as on their uses. There are many conflicts between the subsistence of the *caigaras* and the State Park legislation in areas were this study was undertaken. A way to solve those conflicts would be the creation of Extractive Reserves in order to allow the *caigaras* to continue to live in the forest coast and participate in its management (Begossi, 1994). The knowledge on the intensity of use of resources would be fundamental to organize these reserves and to have new insights in terms of extraction and manufacture (handicrafts) of forest resources. The knowledge of the strategies used by the *caigaras* to fish is also a basic condition to manage the riverine or marine resources.

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Table 1. Two dimensions of the niche of the *caiçaras*: animal food consumed and plants used. The average Simpson index is taken based on indices per family and per month; the index in parenthesis is the Simpson index of all families per month. Data on animal food consumed include 12 families in each community (12 months at Búzios and 6 months at Puruba).

LOCAL	ANIMAL FOOD CONSUMED		NUMBER OF MEALS	MEDICINAL PLANTS		NUMBER OF INTERVIEWS
	Richness	Simpson		Richness	Simpson	
Búzios I * Island	65	4.25 (8.47)	1,241	46	20.94	28
Gamboa (Itacuruçá Island)	__	___	____	72	20.82	58**
Puruba Beach	43	3.86 (5.76)	1,311	66	28.97	22***

Sources: * Begossi and Richerson (1993); ** Figueiredo et al. (1993);
*** Rossato et. al (in press).

Table 2. Animal food consumed by 12 families of Puruba Beach, in monthly samples of 10 days (6 months) in 1993. The Simpson index is averaged per family and per month (average) and the total index of all families per month is also shown (total). Local name (Portuguese) is in parenthesis. Only food consumed in more than 10 meals is shown.

FOOD		NUMBER OF MEALS						
		MONTH						TOTAL
		Feb	Mar	Apr	May	Jun	Jul	
FISH								
Mullet (paratí)	*Mugil curema*	9	36	82	109	68	55	359
Snook (robalo)	*Centropomus parallelus*	15	12	14	5	31	9	86
Mullet (tainha)	*Mugil* sp.	5	0	10	2	16	28	61
Catfish(bagre)	*Genidens genidens, Rhamdia* sp., *Pimelodella* sp.	11	6	0	0	9	0	26
Sand drum (corvina	*Conodon nobilis Micropogonias furnieri*	5	10	5	0	2	3	25
mojarra (carapeba)	*Diapterus olisthostomus*	0	9	0	1	4	4	18
round scad (carapau)	(nc)	9	0	2	4	0	0	15
mojarra (carapicú))	*Eucinostomus melanopterus Eugerres brasilianus*	0	6	0	0	4	3	13
black margate (sargo)	*Anisotremus surinamensis*	1	0	10	0	0	0	11
OTHER								
Beef		65	42	43	29	32	58	269
Chicken		31	39	34	26	19	25	174
Egg chicken		30	26	2	11	26	21	116
Sausage		6	4	0	1	6	9	26
Jerky		5	1	3	2	0	2	13
NONE*		21	24	18	28	23	16	130
MEALS		218	210	217	208	234	224	1,311
AVERAGE SIMPSON		4.37	5.02	3.36	2.32	3.82	4.26	3.86**
TOTAL SIMPSON		6.88	7.84	4.42	2.80	6.32	6.33	5.76**

*= absence of animal protein; ** average.
nc= not collected (at Búzios Island is *Decapterus punctatus* - Carangidae). For information on fish species of Búzios and Sepetiba, see Begossi and Figueiredo (1994).

Table 3. Fishing strategies of the *caiçaras* and predictions of optimal foraging theory. Central place foraging including the time of permanence in a patch is used . Tt= travel time, Tp= time of permanence in a patch, Kg= weight of fish catch. Data from Búzios and Puruba include hook and line fishing. Fishing at Gamboa is performed with encircling nets. Time is in minutes.

PREDICTIONS (Central place foraging)	RESULT	LOCAL
catches increase, as travel time increases	Kg= 1.66 + 6.02 Tt, r^2= 0.08, p < 0.001, df= 783.	Búzios Island*
	not significant (p > 0.3)	Puruba Beach
more time is spent in patches, as travel time increases.	Tp= 1.45 + 1.09 Tt r^2 =0.09, p < 0.001 df= 783	Búzios Island*
(SHRIMP)	Tp= -49.3 + 1.53Tt, r^2=0.22, p < 0.05, df= 21	Gamboa** Itacuruçá Island
(FISH)	not significant (p > 0.1)	
	Tp= -0.0008 - 0.24Tt, r^2=0.32, p < 0.001, df= 110	Puruba*** Beach
catches increase, as time spent in patches increase	Kg= -0.56 + 2.20Tp, r^2= 0.14, p < 0.001, df= 783	Búzios Island
(SHRIMP)	Kg= -0.20 + 0.02Tp r^2= 0.38, p < 0.001 df= 22	Gamboa,** Itacuruçá Island
(FISH)	Kg= 0.04 + 0.18Tp r^2= 0.26, p <0.001, df= 46	
	Kg= 021 + 0.75Tp r^2= 0.13, p < 0.001, df= 111	Puruba Beach

Sources: * Begossi (in press); ** Begossi (1992a).
*** Autocorrelation and heterocedasticity were detected in the data, which were corrected through the first difference method and log transformations (Gujarati, 1978: 240). It is expected to find autocorrelation in data from fish catches, because fishers tend to return to a patch after a successful trip.

FIGURE LEGEND

Figure 1. Map of the study sites, including Búzios Island, Itacuruçá Island (1) , where Gamboa is located (Sepetiba Bay) and Puruba (2), at Ubatuba district.