Selection of netted prey by piranhas, *Serrasalmus spilopleura* and *S. marginatus* (Pisces, Serrasalmidae)

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ABSTRACT. The frequency of attacks by piranhas on specimens of netted fish was analyzed from monthly catches in gill nets set out for 24 hours and checked every 8 hours, from June 1987 through May 1988, in lakes, channels, and rivers of the upper Paraná river floodplain, Brazil. Captured fish were identified and marks of attack by piranhas on their fins and flesh were recorded. The probability of detection of netted fishes, their body structure, and behavioral aspects were the factors determining the selective piranhas attacks. There was no significant relationship between the frequency of predator attacks and the relative abundance of the prey. Community composition was the main factor determining the attack frequency, which differed according to environment.

Key words: *Serrasalmus spilopleura*, *Serrasalmus marginatus*, Serrasalmidae, piranha, prey selection, predation.

RESUMO. Seleção de presas emalhadas em redes de espera por piranhas, *Serrasalmus spilopleura* e *S. marginatus* (Pisces, Serrasalmidae). A freqüência de ataque de piranhas aos peixes emalhados foi analisada a partir de capturas mensais utilizando redes de espera, expostas durante 24 horas, com despescas a cada 8 horas, no período de junho de 1987 a maio de 1988, em lagoas, canais e rios da planície de inundação do alto Paraná, Brasil. Os peixes capturados foram identificados e as marcas de ataque de piranhas às nadadeiras e ao corpo registradas. A probabilidade de detecção das espécies emalhadas, a estrutura corpórea e aspectos comportamentais foram os fatores determinantes do ataque seletivo das piranhas. A relação da freqüência de ataque com a abundância relativa de presas por predador não foi significativa. A composição da comunidade foi o fator determinante da freqüência de ataque diferenciada entre os ambientes.

Palavras-chave: *Serrasalmus spilopleura*, *Serrasalmus marginatus*, Serrasalmidae, piranha; seleção de presa, predação.

Piranhas, neotropical fishes belonging to the family Serrasalmidae, are mutilating predators whose diet includes whole fish and fragments of fish flesh, fins, and scales, as well as fruits and seeds (Goulding, 1980; Nico and Taphorn, 1988; Winemiller, 1989; Sazima and Machado, 1990; Almeida *et al*., 1998). Piranhas prefer fins during their juvenile and subadult stages, and gradually change to flesh or whole fish as they grow (Machado-Allison and Garcia, 1986; Nico and Taphorn, 1988; Almeida *et al*., 1998).

Certain aspects of piranha attacks have been treated in the literature, namely, strategies of prey selection and capture (Markl, 1972; Sazima and Machado, 1990; Winemiller and Kelso-Winemiller, 1993), intensity of attacks on fins (Northcote *et al*., 1986, 1987; Winemiller and Kelso-Winemiller, 1993), avoidance strategies by prey (Sazima and Machado, 1990; Winemiller, 1990) and the influence of abiotic factors on the intensity of attacks (Agostinho *et al*., 1997).

Frequency of attacks by piranhas on specimens of netted fish is analyzed to answer the following questions: i) Do the piranhas select their prey among the netted fishes? ii) Is there a relationship between attack frequency and prey abundance?

Material and methods

Study site. Collections were made monthly from June 1987 through May 1988, on the floodplain of the upper Paraná river (22°40' - 22°50 'S; 53°10' - 53°40 'W) (Figure 1). Sampling floodplain includes numerous temporary and permanent lakes. Collections were carried out in ten stations, grouped in three types of environments: lakes (Fechada, Guaraná, Patos, and Pousada das Garças), channels

and arms of the river (Corutuba Channel, Baía I and Baía II), and rivers (Paraná, Ipoitã, and Ivinheima).

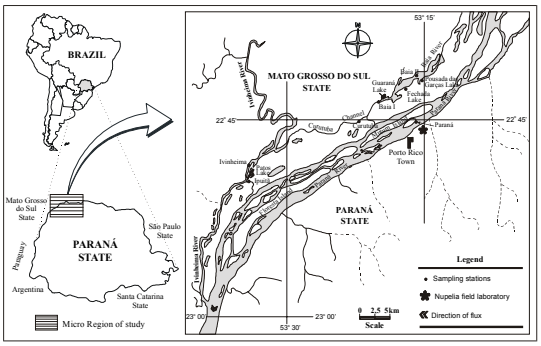

Figure 1. Sites sampling stations on the upper Paraná river floodplain

Sampling. Gillnets were 1.7m high and 20.0 m long with mesh sizes of 3, 4, 5, 6, 8, 10, 12, 14, and 16 cm (between opposite knots). Nets were set out once a month at each station, for 24- hour periods and checked at 07:30, 18:30, and 22:00 hours.

All specimens caught were identified, and the marks left by piranha attacks on their fins and bodies were recorded. Identification of species was based on classification by Eschmeyer (1990) and Britski *et al.* (1999). Infrequent attacks by other predators such as otters and turtles were also recorded; however, piranhas make precise incisions, while other predators macerate the tissues over a more extensive area. An attack on the body consisted of any bite which either took pieces of muscle, or extracted simultaneously muscles and fins.

Data analysis. Attack frequency, expressed as the percentage of fish attacked in relation to the total catch, was analyzed by taxon and type of environment. Paired attack frequencies by type of environment were compared by χ^2 test (Zar, 1974).

Attack frequency was grouped into three categories: 1) ≥ 30%: intense attack; 2) 10-30%: less intense attack; and 3) < 10%: incipient attack.

The correlation between attack frequency and relative prey abundance, expressed by the ratio between the number of fishes and the number of piranhas caught per month and environment, was evaluated. Pearson's correlation coefficient with its respective degrees of significance was calculated and tested (Zar, 1974). Significant differences imply in $p < 0.05$.

Results

During the sampling period, 825 specimens of *Serrasalmus spilopleura* and 752 specimens of *Serrasalmus marginatus* were caught. Since it was not possible to differentiate which of the two species had attacked the netted fish, attack frequency was calculated for the two species together.

Specimens belonging to the families Apteronotidae, Rhamphichthyidae, Erythrinidae, Cynodontidae, Sternopygidae, Ageneiosidae, and Auchenipteridae, all with catch frequencies less than 5%, were intensely attacked. Fishes of the families Soleidae, Callichthyidae, Serrasalmidae, and Loricariidae, together accounting for more than 42% of catch, underwent only incipient attacks (Figure 2, Table 1).

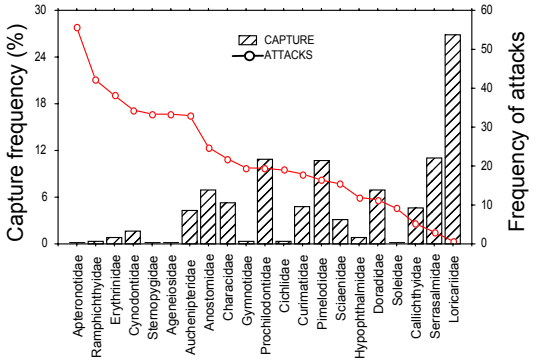

Figure 2. Capture frequency and frequency of piranha attacks for different families of fish

Table 1. List of families and number of individuals captured in gill nets and attacked by piranhas

Family	Covering*	Caught (n)	Attacked (n)	Attacks (%)	Attacks on body parts (%)	
					Fins	Body
Apteronotidae	Naked body	18	10	55.56	00.00	100.00
Sternopygidae	Naked body	6	2	33.33	00.00	100.00
Gymnotidae	Naked body	41	8	19.51	12.50	87.50
Auchenipteridae	Naked body	631	208	32.96	19.23	80.77
Rhamphichthyidae	Naked body	38	16	42.11	25.00	75.00
Pimelodidae	Naked body	1556	255	16.40	28.92	71.08
Hypophthalmidae	Naked body	117	14	11.97	33.33	66.67
Ageneiosidae	Naked body	15	5	33.33	40.00	60.00
Characidae	Scales	759	166	21.87	40.36	59.64
Cynodontidae	Scales	244	84	34.43	42.35	57.65
Doradidae	Naked body	1013	115	11.35	51.97	48.03
Loricariidae	Plates	3905	27	0.69	53.57	46.43
Sciaenidae	Scales	460	71	15.44	57.75	42.25
Callichthyidae	Plates	673	35	5.20	62.86	37.14
Serrasalmidae	Scales	1597	49	3.07	67.35	32.65
Erythrinidae	Scales	118	45	38.14	68.18	31.82
Curimatidae	Scales	696	125	17.96	74.07	25.93
Anostomidae	Scales	1004	249	24.80	77.51	22.49
Cichlidae	Scales	58	11	18.97	81.82	18.18
Prochilodontidae	Scales	1575	306	19.43	89.22	10.78
Soleidae	Scales	11	1	9.09	100.00	00.00

* Predominant type of body covering

The frequency of attack on the body was intense in fish with bodies that are either naked or covered

with tiny scales. In fish with heavy scales or plates covering the body, the incidence of attacks on the fins was higher than on the body (Table 1).

The lack of correlation between the frequency of attacks and the relative abundance of the prey per predator ($r=0.38$, d.f. = 34, $p>0.05$) indicates that the difference in frequency of attacks between environments is not related to the relative abundance of prey per predator. The frequency of piranha attacks on netted fish was lower in lakes (8.47%) than in channels (16.47%) and rivers (18.42%) (χ^2 test, $p<0.05$). The catch frequency per family varied according to environment. There was a predominance of fish in lakes belonging to families that suffered less intense and incipient attacks (Figure 3).

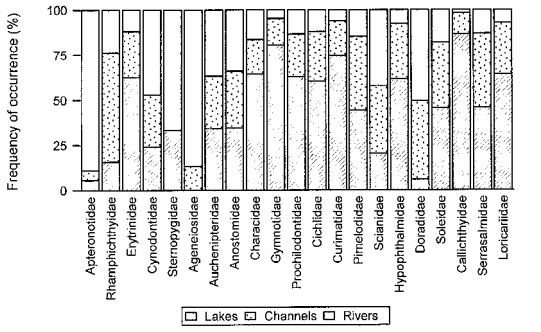

Figure 3. Frequency of occurrence of the families of fish per type of environment sampled

Discussion

High frequency of attacks on individuals of a given species may indicate either greater vulnerability of prey or preference of the predator (Winemiller and Kelso-Winemiller, 1993). In this study the first possibility is discarded because the prey are equally vulnerable.

The fact that the species most attacked in nets were not those that were caught with much frequency, indicates that *Serrasalmus* preys selectively on some species. Prey selection by piranhas on fish fins has also been recorded under natural conditions (Northcote *et al*., 1987; Winemiller and Kelso-Winemiller, 1993).

After detecting the prey, the predators select them according to the net gain yielded by the prey (Pitcher and Hart, 1982; Gerking, 1994). The fact that there was neither any possibility of escape by the netted prey nor any selection by size, since the piranhas bit off pieces, indicated that, after detected, the netted prey was selected as a function of the energy yield to the predator.

The manner in which fish were stuck to the nets allowed both ends to perform movements in attempts to escape. Species with elongate bodies have longer ends free for movement and, consequently, a higher probability of being detected by the piranhas, since serrasalmids are attracted by prey in difficulty (Goulding, 1980; Sazima and Machado, 1990).

Fishes of families that suffered intense attacks had elongated bodies, and some had electric organs and/or survived longer in the nets than members of other families caught. Representatives of the intensely attacked families Erythrinidae and Auchenipteridae survive longer than those of families Sciaenidae and Hypophthalmidae which, although with elongated bodies, were attacked less frequently. It was due to that fact that they died quickly after netted.

The emission of an electric field and the elongated body of the gymnotoids may have contributed to their detection by the predators. Although they do not possess electric organs, same large teleosts may perceive the electric fields created by gymnotoids (Kramer, 1990). In the Venezuelan llanos, the gymnotoids were the second most attacked group by piranhas (Winemiller and Kelso-Winemiller, 1993). Owing to its efficiency to catch large piscivores, *Gymnotus carapo* is the bait preferentially used by sports and professional fishermen in the upper Paraná river.

Cichlids were the group most frequently attacked by piranhas reported in other studies (Northcote *et al*., 1987; Winemiller and Kelso-Winemiller, 1993). However in our study the frequency of attacks on the netted cichlids was less intense. Out of the four species caught, three (*Crenicichla lepidota, C. haroldoi,* and *Cichlasoma paranaense*) suffered only incipient or no attacks. This may be due to the presence of spots on the posterior region of the body, which mimic eyes and confuse predators (Winemiller, 1990). *Satonoperca pappaterra*, which lacks such a spot, was intensely attacked.

The incipient attacks on the fins and the body in the family Serrasalmidae, represented mainly by the genus *Serrasalmus* (90% of the catch in the family), may be related to the recognitian of other piranhas by sight, mainly because of their characteristic oval shape. Piranhas attack objects only if they are not oval (Markl, 1972).

Greater frequency of attacks was observed on the fins of species which have their bodies covered by large resistant scales and bony plates. This indicates that body covering determines the part of the body

that is preferentially attacked. Incipient attacks on the Callichthyidae and Loricariidae were due to the presence of plates covering the body, and to the rigidity of the fin rays, which probably limits the attacks mainly by young piranhas.

Catch frequency per family varied according to environment. In the lakes there was a predominance of fish belonging to families with less intense and incipient attacks. This suggest that the frequency of attack per environment is a function of ichthyofauna composition of the rather than a function of relative abundance of prey per predator.

Our study suggests that piranhas (*S. spilopleura* and *S. marginatus*) select the netted fish. The selection of their preys may be related with probability of detection of netted fish, body structure of the prey and behavior of these predators. Attack frequency is not related with relative abundance of prey but with ichthyofauna composition. However, prey selection by piranhas may be influenced by other factors. Nico and Moralés (1994) emphasized that food quality may influence prey selection. We suggest more detailed studies in order to identify how the chemical composition and palatability of prey affect their selection by piranhas.

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