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Feeding strategy of the jundiá *Rhamdia quelen* (Siluriformes, Heptapteridae) in costal lagoons of southern Brazil

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ABSTRACT. Feeding strategy and mouth morphology of 'jundiá' in costal lagoons of south of Rio Grande do Sul were studied. Gut contend of 189 individuals were collected from 2002 to 2004 and analysed according Amundsen. Fishes and crustaceans were the feeding items more frequent in the diet. Mollusk, insects and plants had low FO%. Season variation in diet showed lower variety of feeding items during summer and higher in winter. The diet vary according to site were irrigation channels showed low FO% for all items. The 'jundiá' showed generalist feeding strategy, generally preying on fish and crustaceous. On the description of its feeding apparatus the importance on the capture prey was observed.

Key words: swamp, diet, mouth morphology, Taim.

RESUMO. Estratégia alimentar do jundiá *Rhamdia quelen* (Siluriformes, Heptapteridae) nas lagoas costeiras do sul do Brasil. Neste trabalho, foi analisada a estratégia alimentar e a morfologia da boca do jundiá que ocorre nas lagoas costeiras do sul do Rio Grande do Sul. Foram coletados 189 indivíduos entre os anos de 2002 e 2004 e o conteúdo estomacal foi analisado de acordo com Amundsen. Os itens alimentares mais frequentes na dieta foram peixes e crustáceos. Outros itens como moluscos, insetos e plantas apresentaram baixa FO%. Na análise por estações do ano, observou-se menor diversidade de itens alimentares no verão e maior no inverno. A dieta variou de acordo com o local de coleta e nos canais de irrigação todos os itens apresentaram baixa FO%. O jundiá apresentou estratégia alimentar generalista, com tendência a predar peixes e crustáceos. Na descrição morfológica, foi observada a importância das estruturas bucais na captura do alimento.

Palavras-chave: banhado, dieta, morfologia, Taim.

Introduction

It is crucial to study the feeding habits of a species in order to understand its ecology and its role in the trophic structure (BASILE-MARTINS et al., 1986). Ecological studies of the freshwater fishes inhabiting the Patos Lagoon' drainage basin is scarce, probably as a resulted of the complex systematic that characterized these Neotropical fishes (TAGLIANI, 1994).

Remarkable seasonal changes can take place in fish diets and according to area. These are primarily related to shifts in food resource composition and availability, which are associated to reproductive pulses and physicochemical changes in aquatic ecosystems (ARAÚJO et al., 2005). This way individual that some species could show temporal and spatial differences in diet (ARAÚJO et al., 2005; SILVA et al., 2007). The mouth shape, size and position, and teeth anatomy had relation with feeding habit (WOOTTON, 1990).

The 'jundiá', *Rhamdia quelen*, is a freshwater catfish of wide geographical distribution from central México to Buenos Aires, Argentina (SILFVERGRIP, 1996). It is highly abundant in the coastal lakes of the southern most part of Brazil, and is largely consumed by local human populations. Up to our knowledge, published information regarding this group is restricted to systematic description, notes on distribution (EIGENMANN; FISHER, 1917; GOSLINE, 1945; RINGUELET et al., 1967; SILFVERGRIP, 1996) and no information about its feeding are reported to south of Brazil. In order to increase our current knowledge of jundiá's biology, the present study characterizes aspects of its mouth morphology, and describes its diet and feeding strategy. Seasonal changes in the diet and the environment will be discussed.

Material and methods

Fish samples were obtained in the Mirim, Mangueira, Nicola, Jacaré and Flores coastal lakes and in the São Gonçalo Channel during field trips conducted by the Taim Hydrological System site of the Brazilian

Long Term Ecological Research program, and for an caught for artisian fisherman (PELD) (Figure 1).

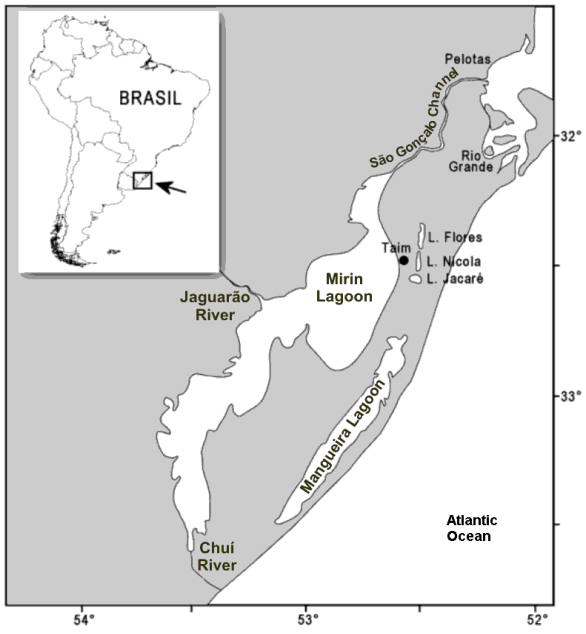

Figure 1. Map of costal lagoons of South Rio Grande do Sul, Brazil.

Fishes were collected from November 2002 to October 2004 using gillnet, purse seine and hook and line, preserved in 10% formalin and later identified, processed and stored in 70% alcohol at the Ichthyology Laboratory of the Fundação Universidade Federal de Rio Grande (FURG).

For each individual, we recorded the following measurements to the 0,01 mm, using calipers: Total length (TL), standard length (SL), head length, snout length, mouth width, head width, inter-orbital distance and eye's diameter. Individuals were weighed (g), and stomachs were dissected for analysis. Each food item in the stomach was identified to the lowest possible taxonomic level, counted and weighed using an electronic scale (with precision of 0.01 g). In order to analyze stomach contents we used the frequency of occurrence in percentage (FO%) and the weight of each feeding item (HYSLOP, 1980). Feeding strategy was determined by the graphical analysis proposed by Amundsen et al. (1996). This method allows the calculation of the 'prey-specific abundance of prey', which take in account only those predators in which the actual prey occurs ($P_i = (\sum S_i / \sum S_{ti})$ x 100; where P_i is the prey-specific abundance of prey i, S_i is the stomach content (volume, weight or number) comprised of prey i, and S_{ti} is the total stomach content in only those predators with prey i in their stomach).

The interpretation of the Amundsen's diagram can be obtained by examining the distribution of points along the diagonals and axes of the graph. The diagonal from the lower left to the upper right corner provides a measure of prey importance, with dominant prey at the top, and rare or unimportant prey at the lower end. The vertical axis represents the feeding strategy of the predator in terms of specialization or generalization. Predators have specialized on prey positioned in the upper part of the graph, whereas preys positioned in the lower part have been eaten only occasionally (generalization). Prey points located at the upper left of the diagram would be indicative of specialization by individual predators, and those in the upper right would represent specialization of the predator population.

Individuals with stomach content were pooled by season as follow: summer 2002 (November and December), autumn 2003 (March and April), winter 2003 (June, July and August), autumn 2004 (March, April and May), winter 2004 (June, July and August) and spring 2004 (September and October). The lack of information on January and February was because fishing was prohibited in the lakes during this period.

Results

Total of 189 individuals was analyzed, ranging from 117 and 469 mm in total length (TL), after pooling them in size classes of 10 mm (Figure 2). Some of these specimens were preserved at the Ichthyology Collection of the Oceanography Department at FURG.

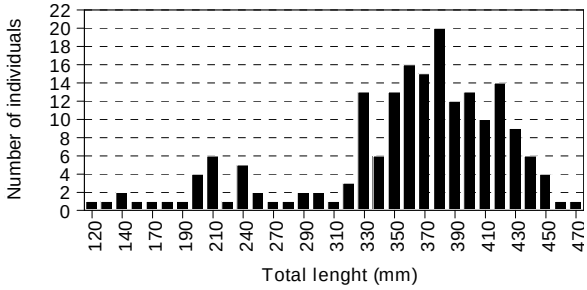

Figure 2. Distribution of fishes for size (mm).

Larger individuals (> 410 TL mm) were caught by hook and line, whereas individuals ranging from 330 to 430 TL mm were captured by gillnet with mesh size of 45 mm. Individuals of these sizes classes were the most abundant in the samples. Individuals ranging from 120 and 330 TL mm were captured in lower numbers using several fishing gears such as hook and line, purse seine, gillnet (15, 20, 30 and 35 mm of mesh sizes).

Morphology

Morphometric measurements focused in the head, where are situated the morphological structures related with feeding (MOYLE; CECH, 2004; WOOTTON, 1990). Individuals had large heads measuring 23.1 to 34.6% of the standard length (SL), a dorsum-ventral axis marked flattened, head wider (15.9 to 23.1% of SL) and snout (9.2 to 14.3% of SL), eyes situated in a dorsum-lateral position with an interorbital distance measuring 5.9 to 10.8% of SL (Table 1).

Table 1. Morphometric data for 119 individuals of *Rhamdia aff quelen*; percentages expressed as standard length and head length; SD = standard deviation; CV = coefficient of variation.

	Min	Max	Mean	SD	CV
TL (mm)	171	469	356		
SL (mm)	135	389	294		
	Standard length				
Head length	23.1	34.6	27.8	1.4	5.0
Head width	15.9	23.1	19.8	1.6	8.1
Snout length	9.2	14.3	11.2	0.7	6.1
Mouth width	9.6	19.1	13.8	1.2	8.8
Eye diameter	2.8	4.7	3.4	0.4	10.9
Interorbital distance	5.9	12.8	10.3	0.8	7.5
	Head length				
Head width	58.2	81.9	71.5	4.8	6.7
Snout length	33.0	45.1	40.5	1.7	4.3
Mouth width	41.4	69.8	49.8	2.7	5.5
Eye diameter	10.0	17.2	12.4	1.4	11.6
Interorbital distance	21.5	41.3	37.1	2.4	6.4

The mouth was composed of a uniform and wide plate, being delimited by the buccal opening and the first gill arch. Lips were fleshy and not protractile, being the superior larger than the inferior. Some tooth had bright color and were wrapped into tin skin, whereas other smaller tooth were conical with brown extremities (Figure 3a). Pharyngeal tooth were comprised by two pairs; the superior had a rounded and convex shape, whereas the inferior had a triangular one (Figure 3b).

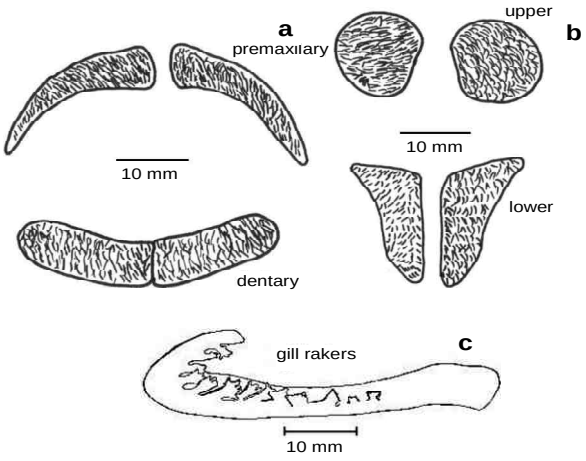

Figure 3. Feeding structures of mouth; (a) premaxillary and dentary; (b) pharyngeal tooth; (c) rakers in the first gill arch.

Rakers in the first gill arch were short and lobular ranging in number from 9 to 14 elements, which suggest adaptation to capture larger preys (Table 1; Figure 3c).

Stomach content analysis

Total of 189 individuals was analyzed, from which 40 (21.1%) had empty stomachs. Feeding items more frequent in diet were fish and crustaceans respectively. Other items in the diet were mollusks, insects, plants and organic matter, which had lower frequency.

The freshwater catfish *Parapimelodus nigribarbis* (Boulenger, 1889) was the most common (FO% = 23.5) prey among the fishes consumed by the 'jundiá', followed by *Hoplias malabaricus* (Bloch, 1794), *Loricariichthys anus* (Valenciennes, 1836), *Platanichthys platana* (Regan, 1917), *Odontesthes* spp. and specimens of the family Characidae that showed FO% < 0.7. The item 'fishes' remaining composed of scales and eggs of fishes, including fishes well digested and not identifiable, had a FO% of 26.1. Among the food group 'crustaceans', it was found mainly shrimps and isopods, followed by anomuran, amphipods and ostracods. The shrimp *Palaemonetes argentinus* (Nobili, 1901) had FO% = 35.6 and the isopod *Telotha henselii* (Von Martens, 1869) showed FO% = 19.5.

The isopod *T. henselii* have been recorded in the Taim area as an external parasite in fishes (BUCKUP; BOND-BUCKUP, 1999). According to these authors, adult individuals of this isopod occur in gills, tegument or mouth of catfishes and armored catfishes, whereas young individuals are active free swimmers. Only one adult individual was found in the stomach content of the 'jundiá', which seem to suggest that they prey upon mainly on juvenile forms. Other crustacean preys occurring in lower FO% were the anomuran *Aegla* sp. (5.4) and the ostracod *Clamidoteca* sp. (0.7). Insects were represented mainly by Ephemeroptera (FO% = 11.4) and Coleoptera (FO% = 6.7), followed by lesser frequent items such as Trichoptera, Odonata, Diptera and Plecoptera. Otherwise, mollusks were comprised of gastropods *Heleobia* sp., *Pomacea* sp. and *Drepanotrema* sp. and bivalves *Corbicula* sp. and *Neocorbicula* sp. The mollusk with higher frequency was *Heleobia* sp. (FO% = 12.8). The 'jundiá' caught a wide spectrum of prey (Table 2).

Table 2. Principal items found in diet of *Rhamdia aff. quelen*; (G%)= weight percentage; (FO) = frequency of occurrence.

	Feeding items	FO	G%	FO	G%
Mollusks		22.15	4,38		
	Heliobia sp.			12.75	0.2
	Drepanotrema sp.			2.68	0.04
	Pomacea sp.			6.04	3.29
	Bivalvia			0.67	0
	Neocorbicula sp.			4.7	0.35
	Corbicula sp.			5.37	0.51
Crustaceans		43.62	10,65		
	Palemonetes argentinus			35.57	8.2
	Aegla sp.			5.37	1.77
	Thelotha helsenii			19.46	0.17
	Amphipoda			2.01	0.01
	Clamidotheca sp.			0.67	0.51
Insects		17.45	3,09		
	Insect not identifiable			0.67	0
	Efemeroptera			11.41	2.64
	Coleoptera			6.71	0.01
	Odonata			1.34	0.2
	Tricoptera			0.67	0
	Diptera			2.68	0.19
	Plecoptera			0.67	0
	Acarina			0.67	0
	Araneida			0.67	0
Fishes		59.73	77,73		
	Platanichthys platana			0.67	3.12
	Hoplias malabaricus			1.34	0.46
	Parapimelodus nigribarbis			23.49	35.03
	Odontesthes sp.			0.67	0.95
	Loricariichthys anus			1.34	3.81
	Synbranchus marmoratus			0.67	0.01
	Characidae			1.34	0.15
	Astyanax fasciatus			0.67	0.34
	Astyanax bimaculatus			0.67	1.34
	Oligosarcus jenynsii			0.67	15.06
	Scales			10.7	0.78
	Rests			26.17	15.71
	Eggs			2.01	1.01
Plants		12.75	0.19	12.75	0.19
	Organic matter	21.48	3.95	22.15	3.95

The diet of 'jundiá' was comprised mainly of fishes and crustaceans that showed FO% of 61.0 and 43.0, respectively. Others items such as mollusks, insects, arachnids, organic matter and plants were considered complementary items in the diet (Figure 4).

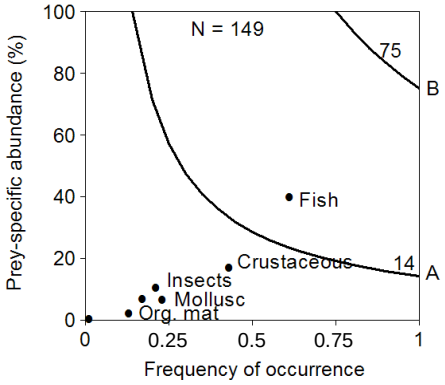

Figure 4. Feeding strategy in weight, analysed for all periods; Pi-G% = specific abundance of prey in weight; FO = frequence of occurrence. The isolines represent the different values of prey abundance: A = isolines hypotetical of dominance 100 S^{-1}, where S = total number of prey found in contents; B = isolines of the 75%.

Feeding analysis by seasons

There was low variation in the 'jundiá's' diet among seasons and fish preys seemed to be the predominant feeding items across the study (Figure 5). Summer 2002 had the lowest variety in feeding items, which could be related with the lower number of individuals sampled in this period (Figure 5a). The item 'fishes' showed higher frequency (FO% = 65.0), followed by insects and crustaceans (both with 29.0).

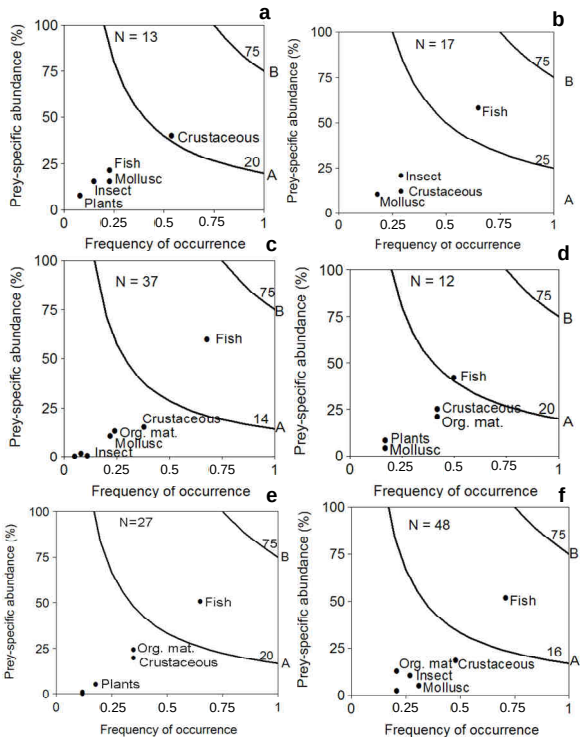

Figure 5. Feeding strategy in weight, analysed by season of the year; Pi-G% = specific abundance of prey in weight; FO = frequence of occurrence. The isolines represent the different values of prey abundance: A = isolines hypotetical of dominance 100 S^{-1}, where S = total number of prey found in contents; B = isolines of the 75%. (a) summer 2002; (b) autumn 2003; (c) autumn 2004; (d) winter 2003; (e) winter 2004; (f) spring 2004.

Fishes and crustaceans were dominant preys in jundiá's diet (Figures 5b and c) during autumn, although the importance of each one changed between years. In 2003, crustaceans were the most frequent feeding item, followed by fishes and mollusks (Figure 5b). In contrast, in 2004, fishes were the dominant preys followed by crustaceans and organic matter (Figure 5c). Insects appeared only in the autumn of 2003.

Fishes were the dominant items during winter of 2003 and 2004, showing higher frequency values when compared to other seasons (71.0 in 2003 and

68.0 in 2004) (Figures 5b and d). Finally, during the spring of 2004, the 'jundiá' had higher preference for fishes (FO% = 65.0), followed by crustaceans and organic matter (FO% = 35.0) (Figure 5f).

Gender comparison revealed no differences in diet and feeding strategy. Therefore, we did not report these results here. The number of empty stomachs also was similar between genders (female = 22.0% and male = 22.8%).

There were differences in diet along site collections (Figure 6). We analyzed a total of 134 individuals (31 with empty stomachs) from the Mirim Lake, and fishes and crustaceans showed the highest FO% values in this site (67.0 and 45.0, respectively) (Figure 6a). In others lakes (Nicola, Jacaré, Flores and Mangueira) within the Taim wetland, we analyzed 38 individuals (7 with empty stomachs). The dominant feeding items were also fishes (FO% = 52.0) and crustaceans (FO% = 45.0) in these sites (Figure 6b). Finally, we studied the diet of 16 individuals (2 with empty stomachs) from the irrigation channels connected to the São Gonçalo Channel, near the municipality of Santa Isabel.

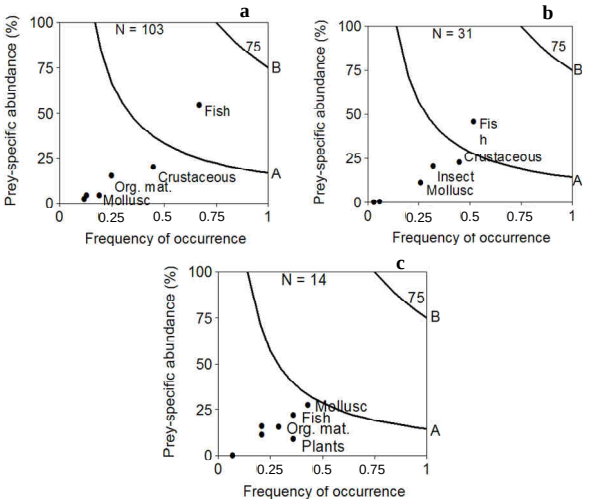

Figure 6. Feeding strategy in weight, analysed by site; Pi-G% = specific abundance of prey in weight; FO = frequence of occurrence. The isolines represent the different values of prey abundance: A = isolines hypotetical of dominance 100/S, where S = total number of prey found in contents; B = isolines of the 75%. (a) Mirim lagoon; (b) Taim swamps; (c) São Gonçalo Channel.

In these artificial channels, mollusks were the most frequent (FO% = 43.0) item in the diet, followed by fishes (36.0) and plants (36.0). In contrast with individuals inhabiting the lakes, 'jundiá' from the irrigation channels had a generalist feeding strategy with preys showing lower FO% (Figure 6c).

Discussion

According to Wootton (1990), shape, position and size of the mouth, shape and number of gill rakers and shape of the pharyngeal tooth are morphological traits related to feeding. Fishes preying upon larger particles usually have short and fewer gill rakers, as we observed in this specie. The 'jundiá' exhibited a wide mouth positioned subinferiorly, with fleshy lips. Within the buccal cavity, the species was equipped with well-developed plates of teeth distributed in the premaxillary and dentary. These adaptations of buccal apparatus has function of select preys of the bottom. Similar morphology adaptations were noted in *Iheringichthys labrosus* (ABES et al., 2001) that select organisms of meso and macro benthos.

Fish and crustacean comprised the mainly diet of 'jundiá' during all season exhibiting a preference for this items. The most important fish prey was *Parapimelodus nigribarbis* it is a small demersal fish that lives in school occurring exclusively in Patos and Mirim basin and some rivers in north of Rio Grande do Sul (BEMVENUTI; MORESCO, 2005).

The crustaceans and mollusk found in the diet of 'jundiá 'were also found in the diet of the silverside *Odontesthes humensis* de Buen, 1953 (RODRIGUES; BEMVENUTI, 2001), that inhabits similar lakes. They seemed to be preferential food items for fishes feeding in the bottom.

In the stomach content no pieces of *Pomacea*'s shells were found, only its operculum and mantle. This seems to reveal the ability of the 'jundiá' in crushing the shell with its pharyngeal tooth, sorting apart its fragments in order to ingest only the gastropod's body. The marine catfish *Genidens barbus* (Lacépede, 1803) also had this ability to manipulate mollusk preys (REIS, 1986).

Seasonal change in diet of 'jundiá' acted for the fact that in tropical streams, the abundance of benthic invertebrates varied among streams, habits, and season (ANGERMEIER; KARR, 1983; FLECKER; FEIFAREK, 1994). The relative abundance of drifting taxa and benthic invertebrates also showed variation among seasons in a temperature stream (ANGERMEIER, 1982). This way the dominance of insects in the diet during the warmer months probably is related with their reproduction in this period. At this time, Ephemeroptera hatched in profusion usually just after dawn and, most of them, will fall down to the water surface, and then will become easy preys for fishes (MORESCO; BEMVENUTI, 2005). Deus e Petrere-Junior (2003) studying the feeding strategy

of *R. quelen* in Itinguçu river, Brazil described a generalist strategy during the summer and reducing the variety of items in winter tending to specialization. However in this work the food items was separated for small group, (shrimp, crab etc.) if we group the items in bigger group, (crustaceous, fish, plant etc.), we could conclude that *R. quelen* in this work showed a tendency to predate crustacean in both season.

In our study based on the Amundsen's method, the *Rhamdia quelen* is a generalist feeding strategy. Feeding items more frequent in their diet were fishes and crustaceans, respectively. Catfishes of the family Ariidae also showed similar preference (KOBELKOWSKY; CASTILHO-RIVERA, 1995). In contrast different result was showed for Gomiero et al. (2007), studying *R. quelen* that inhabit rivers in Atlantic Forest in southeast of Brazil. In this place the 'jundia' showed a preference for feeding insects and plants. Arcifa e Meschiatti (1993), studying *Rhamdia.* ssp. in Brazilian reservoir found insects and fishes were the major components of diet. Furthermore, Gomes et al. (2000) described *R. quelen* with an omnivore.

We conclude that the 'jundiá' (*R. quelen*) that inhabit costal lakes is a omnivore fed on wide variety of items, displaying a generalist feeding strategy with a tendency towards piscivory. Within its feeding spectrum, the species seemed to feed upon preys more abundant in the environment, which could explain why insects, arachnids, mollusks and plants occurred in various amounts across seasons and site collections. These preys represent occasional feeding items and its occurrence in the diet would depend of its availability in the environment. It was possible to deduce that the species catches its food throughout the water column, though more intensely at the bottom.

Acknowledgments

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