Alterations in the *Pterodoras granulosus* (Valenciennes, 1833) (Osteichthyes, Doradidae) diet due to the abundance variation of a bivalve invader species in the Itaipu Reservoir, Brazil

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ABSTRACT. Variations in the diet of *Pterodoras granulosus* (Osteichthyes, Doradidae) were evaluated from 1994 to 1998 taking into account two events that affected the abundance of an introduced bivalve *Corbicula fluminae*: (i) the abundance explosion of the bivalve in the reservoir, started in 1994 and (ii) the slaughter of the bivalve population due to fluctuations in water level, started in July 1996. Stomach contents were analyzed and results were shown considering the methods of frequency of occurrence and volumetric, combined in an alimentary index (AI). In 1994, 1995 and 1996 *C. fluminae* was the most consumed item, constituting about 90% of the diet. A decrease of this item intake (39%) was verified in 1997, with an increase of the vascular plants intake (26%). The diet of *P. granulosus* changed drastically in 1998, when it became based on algae (49%) and vascular plants (45). These results indicate the important role played by water level fluctuations in reservoirs, on the food availability for *P. granulosus*.

Key words: diet, *Pterodoras granulosus*, bivalve, Itaipu Reservoir.

RESUMO. Alterações na dieta de *Pterodoras granulosus* (Valenciennes, 1833) (Osteichthyes, Doradidae) devido a variação na abundância de uma espécie invasora de bivalve no reservatório de Itaipu, Brasil. Foram avaliadas as alterações na dieta de *Pterodoras granulosus* (Osteichthyes, Doradidae), no reservatório de Itaipu, no período de 1994 a 1998, associadas às alterações na abundância de um bivalve invasor, *Corbicula fluminea*, considerando-se dois eventos: (i) a explosão de *C. fluminea* no reservatório a partir de 1994, e (ii) a mortandade desse bivalvia em função das flutuações do nível de água a partir de julho/96. Os conteúdos estomacais, foram analisados pelos métodos de ocorrência e volumétrico, combinados no Índice Alimentar. A análise mostrou que *C. fluminea* foi o principal alimento nos anos de 94/95/96, representando aproximadamente 90% da dieta. Em 1997, houve uma queda no consumo de *C. fluminea* (39% da dieta), concomitante a um incremento no consumo de vegetal (26%), enquanto no ano de 98 a dieta foi composta basicamente por algas filamentosas (49%) e vegetal superior (45). Estes resultados evidenciam a importância da flutuação do nível da água em reservatórios sobre a disponibilidade alimentar de *P. granulosus*.

Palavras-chave: dieta, *Pterodoras granulosus*, Bivalvia, reservatório de Itaipu.

Introduction

Reservoirs are restrictive environments for many riverine fish species, mainly due to the alterations that they cause in the water dynamics. Species found in low densities in the river may, however, find favorable conditions in the reservoir and proliferate, while others, not finding adequate conditions, may have be drastically reduced or even eliminated (Agostinho, 1992). High feeding (Paiva, 1983; Petts, 1984) and reproductive plasticities (Welcomme, 1979; Agostinho *et al.*, 1999) are among the strategies presented by fish species with high potential for colonization in this type of environment.

Sudden alterations in the food resources availability in reservoirs result from (i) the land areas flooding in a given moment, (ii) the high biological production in the subsequent period and (iii) the production decrease after the trophic depletion that

results from the flooded organic material mineralization (Agostinho *et al.*, 1999). Further changes in the resources availability are expected in hydroelectric reservoirs, on account of environmental alterations resulting from level fluctuations imposed by the dam operation.

Pterodoras granulosus (armado), rare in the experimental fishery in the Itaipu Reservoir area before the damming (Itaipu Binacional, 1979), began to occur in this reservoir and in the lotic stretches of its tributaries soon after its formation (Benedito-Cecílio *et al.,* 1997). Since then, this species importance in the commercial fishery was intensified (Okada, 1990). From 1987 to 1998 it was the second most important species (Okada, 2001). With its distribution restricted to the stretch below Sete Quedas waterfall, before the Itaipu Reservoir (Zawadzki *et al.*, 1996), it eventually reached the upper stretches of the Paraná River, with this natural barrier flooding .

Di*et al*terations of *P. granulosus,* imposed by the biomass flooding and up surging period were registered by Hahn *et al.* (1992), who classified it as euriphagous with a tendency to herbivorous behavior.

The low fluctuation of the reservoir level in 1992 facilitated the installation of a population of bivalve mollusks in subsequent years, especially the invader *Corbicula fluminae*. Thus, a populational explosion of this species was observed on the entire expanse of the reservoir (Okada, 2001).

The success of this species as an invader of the Paraná basin lower parts is well-known (Cataldo and Boltovskoy, 1999), presumably having been introduced in Argentina in the Rio da Plata estuary during the 60s and 70s (Ituarte, 1981). This bivalve's occurrence has been registered in the Paraná-Paraguay river system, including northern Argentina, Uruguay, Paraguay and southern Brazil (Cataldo and Boltovskoy, 1999). On the Paraná River Delta, this species may, occasionally, reach a density higher than 10,000 shells/m^2 (Boltovskoy *et al.*, 1995).

Considering that *P. granulosus* is omnivore and that it consumed native bivalves in the Itaipu Reservoir from 1983 to 1989, even though in low percentages (Hahn *et al.*, 1992), this study aims to verify this species diet variations from 1994 to 1998, taking into account two events that affected this bivalve abundance: (i) the explosion of *Corbicula fluminae* in the reservoir, started in 1994, and (ii) the slaughter of this bivalve due to fluctuations in the water level, started in July, 1996.

Material and methods

Studied area

The Itaipu Reservoir, closed in October 1982, located on the Brazil-Paraguay border, presents a flooded area of 1,350 km^2 and extends for about 151 km, between the parallels 24º05' and 25º33'S and the meridians 54º00' and 54º37'W. Its mean depth is 22m, reaching 170m in areas near the dam. The water mean residence time is 40 days, while in the main channel it is only 29 days (UEM-Nupélia/Itaipu Binacional, 1999). In relation to its limnological, ichthyofaunistic and fishing characteristics, the Itaipu Reservoir presents a strong longitudinal gradient, making it possible to recognize three distinct zones: fluvial, transition and lacustrine (Okada, 1999) (Figure 1).

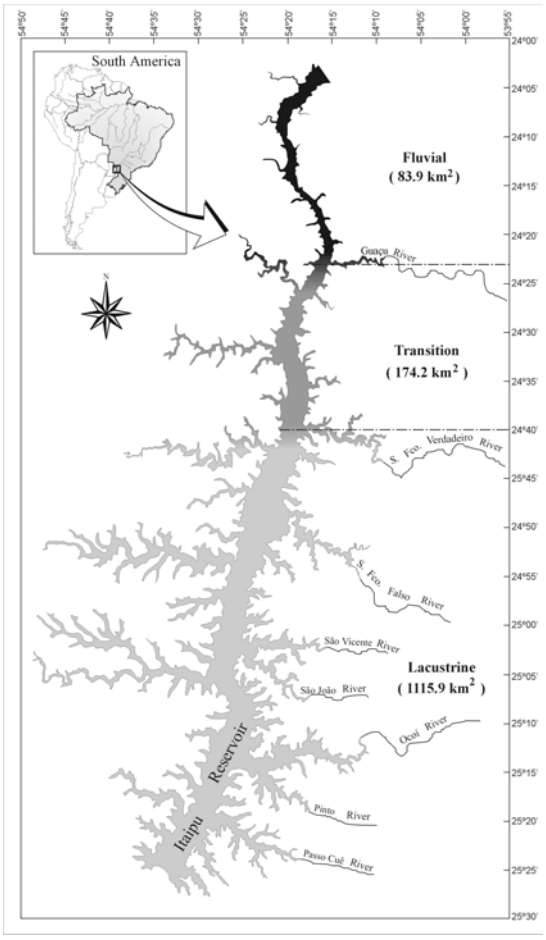

Figure 1. Collection sites

The characterization of these longitudinal strata is given by Thorton (1990), mentioned by Agostinho *et al.* (1999) in reservoirs of the Paraná River basin and delimited by Okada (1999) and

Pagioro (1999) in the Itaipu Reservoir. The *fluvial zone* is located near the mouth of the reservoir, where the body of water is generally narrow and shallow, with reduced light penetration, high turbidity, low primary production, nutrients high concentration and a large amount of sediment. Transport is the dominant process in this region, as a result of its proximity to the river. The transition zone has an intermediary position between the mouth of the river in the reservoir and the dam, presents a high light availability and a high sedimentation rate and is, generically speaking, the most productive zone. The *lacustrine zone* is near the dam, relatively extensive and deep, with a reduced sedimentation rate and low productivity, often due to its great depths.

Data collection and analysis

The data used in this study refer to the project "Fishing yield statistics in the Itaipu Reservoir" carried out by Nupélia-Universidade Estadual de Maringá in partnership with Itaipu Binacional. Samplings were taken from 22 fishery areas, distributed in the three zones above described of the reservoir (fluvial, transition and lacustrine). The data from 1994 to 1996 were monthly obtained from the professional fishery catches. They were obtained in quarterly experimental collections from 1997 to 1998.

All specimens were measured, weighed and their stomachs removed and fixed in 4% formalin. The food items from the stomach contents were identified and their volumes obtained by displacement in a graduated test tube. The occurrence and volumetric methods (Hyslop, 1980), were combined in the Alimentary Index (AI) (Kawakami and Vazzoler, 1980).

Variations in diet were evaluated at each reservoir zone (fluvial, transition and lacustrine) and through the year. Differences were tested using a non-parametric test (Spearman ranking)(Siegel, 1975).

The mean daily levels of the quotas from 1992 to 1998 (furnished by Itaipu Binacional) were used to verify variability in reservoir level fluctuations.

Results

The analysis of 646 *P. granulosus* stomachs showed that this species' diet is composed of mollusks (mainly *Corbicula fluminae*), vascular plants (aquatic and terrestrial), algae (mainly filamentous), detritus/sediment and others (insects, other invertebrates and fish remains) (Table 1). The standard length of the examined fishes varied from 5.5 to 55.8 cm and no difference was found among the lengths.

In 1994, 1995 and 1996 *C. fluminae* was the most important item, constituting about 90% of the diet. A fall in the consumption of this resource (39%) was verified in 1997. It was followed by vascular plants (26%, mainly aquatic), algae (18%, mainly *Spyrogira*) and detritus/sediment (15%). This species diet changed drastically in 1998, becoming basically composed of plants: algae (49%) (mainly *Spyrogira*) and vascular plants (44%) (aquatic and terrestrial), while *C. fluminae* represented less than 1% of the diet (Table 1).

Table 1. Food resources (AI%) used by *Pterodoras granulosus* in different collection years (⋆ values <0.001)

Items	94 n = 40 AI (%)	95 n = 247 AI (%)	96 n = 212 AI (%)	97 n = 89 AI (%)	98 n = 58 AI (%)
BIVALVIA	87.72	93.61	94.81	39.24	0.40
C. fluminae	87.602	93.592	94.770	36.974	0.274
Gastropoda	0.122	0.018	0.039	2.816	0.127
ALGAE	1.03	1.23	1.16	17.97	49.04
Spyrogira				17.468	49.202
Rhodophyta				0.020	
Chlorophyceae	0.959	1.151	0.315	0.268	
Cianophyceae				⋆	
Bacillariophyceae				0.048	⋆
Unidentified	0.069	0.076	0.839	0.163	1.149
VASCULAR PLANTS	6.20	2.74	2.20	26.41	44.73
Aquatic	5.934	2.272	1.957	20.770	28.658
Terrestrial	0.645	0.470	0.245	5.637	16.067
DETRITUS/SEDIMENT	4.29	2.33	1.83	15.29	5.51
Sediment	0.343	0.302	0.006	0.518	⋆
Detritus	3.946	2.073	1.824	14.776	5.504
OTHERS	0.76	0.09	0.00	1.09	0.33
Insecta					
Chironomidae	⋆	⋆	0.001	0.001	0.115
Coleoptera	0.010	0.007	⋆	⋆	0.002
Ephemeroptera			⋆		⋆
Hemiptera				⋆	
Homoptera	⋆				
Hymenoptera	⋆			0.002	0.001
Lepidoptera					⋆
Odonata	0.014	⋆	⋆	0.004	
Trichoptera			⋆	0.040	⋆
Insect remains	0.353	0.038	⋆	0.197	0.038
Other invertebrates	0.0008		⋆	0.037	0.006
Fish				0.259	

The Spearman Correlation, used in the comparison of the *P. granulosus* diet for the five years of the study showed that, among the analyzed pairs of years, only in 1998 the diet differed significantly from the other years (Table 2).

Table 2. The Spearman Correlation among the pairs of years studied. (Values of *P* in italics and *R* in bold)

	94	95	96	97	98
94		*0.0004*	*0.0068*	*0.0004*	*0.6445*
95	0.9642		*0.0136*	*0.0068*	*0.5887*
96	0.8928	0.8571		*0.0004*	*0.3833*
97	0.9642	0.8928	0.9642		*0.5345*
98	0.2142	0.2500	0.3928	0.2857	

The variation general tendencies registered in the two upper zones of the reservoir were similar to those described earlier, except for the relevance presented by the algae in the transition zone in the last year (1998, 38%) (Figure 2).

In the lacustrine zone, however, vascular plants predominated in the diet during the first two years (1994-95), being followed by mollusks (1996-97) and algae/detritus/sediment (1998).

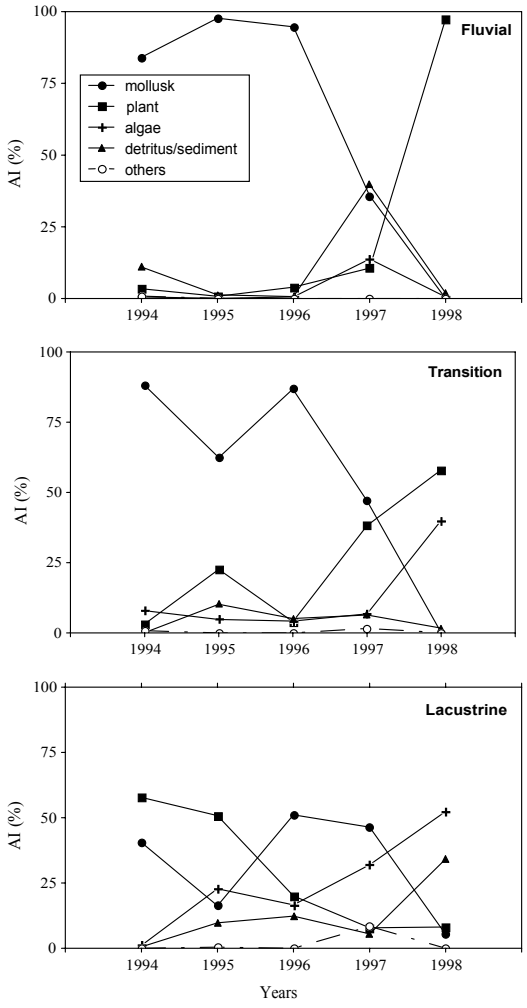

Figure 2. Variations in the *P. granulosus* diet during the years studied in the three zones of Itaipu Reservoir

Figure 3 shows the average daily levels of the water quotas of the Itaipu Reservoir from 1992 to 1998. These results reveal that during the first two years the variation range was restricted to 60cm, when a mollusk explosion occurred, especially from the introduced *C. fluminae*. Water level fluctuations increased reaching 1.5m during the period from Jul. 1996 to Dec. 1998, when high mollusk mortality was observed. *P. granulosus* experienced a relevant di*et al*teration in these years: in 1998 it virtually stopped ingesting *C. fluminae* and algae and plants. became more than 90% of its diet.

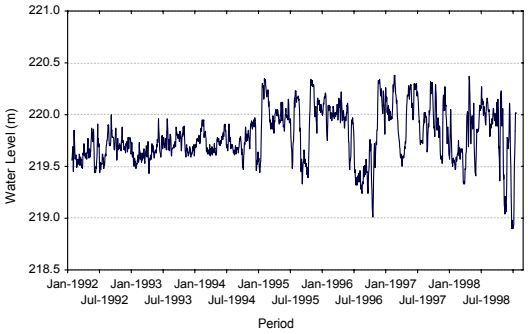

Figure 3. Daily water level values of the Itaipu Reservoir from 1992 to 1998

Discussion

The opportunism of many fish species in the available food capture and in the lack of preference has been the object of broad discussions in the literature (Nikolsky, 1963; Keast, 1977; Gerking, 1994). Thus, with the shortage of a given preferred resource, resulting from environmental conditions, most fish can temporarily resort to a more available resource.

Lowe-McConnell (1999) reports that most tropical fish show a considerable plasticity in their diet. Predators can change their preferred prey while they grow or change biotope, depending on the prey availability (subject to seasonal factors) or on a succession of factors and their interactions in a given year. Thus, despite the existence of fish with marked trophic specializations in tropical environments, most exhibit great feeding flexibility (Agostinho *et al.*, 1995; Araujo-Lima *et al.*, 1995). For Gerking (1994), dietary flexibility is an adaptive character, in as much as individuals live under mutable environmental conditions, and the conservative use of a given resource whose availability is variable may affect its growth or fitness.

Pterodoras granulosus is recognizedly a species that presents a wide food spectrum, being considered an omnivore (Hahn *et al.*, 1992; Montalto *et al.*, 1999). Its opportunistic character may be seen in the first three years of colonization of the Itaipu Reservoir, where, in the first year, it consumed essentially vascular plants (mainly terrestrial), while in the second year it incorporated relevant quantities of

benthic invertebrates, which began to constitute the base of its diet in the third year (Hahn *et al.*, 1992). Alterations in the fish-consumed food items proportion are expected and to some degree predictable at the start of reservoirs formation , even among other species with a more reduced food spectrum. Thus, during the first years of reservoir formation, alterations in food availability result from: (i) incorporation of terrestrial items due to reservoir filling and (ii) high productivity, especially of invertebrates, characteristic of this phase (O'Brien, 1990). However, when the high production phase passes (end of the upsurge period), the proportion of food resources tends to change again and new changes are expected in the composition of the fish diet.

Abrupt changes in food availability after the period of high productivity are dependent on dam operational procedures, especially those that involve marked variation on water levels. These food availability variations, which lead to relevant changes in the diet composition, contrary to what is observed in natural environments, are acyclic. Although without a systematic evaluation of the available food resources alterations, the d*iet al*terations of the "armado" in the Itaipu Reservoir since its formation seem to corroborate this tendency. Thus, after a diet based essentially on terrestrial plants, made available by the flooding soon after the formation of the reservoir, it began to feed on benthic invertebrates when the benthic communities installed themselves, as described by Hahn *et al.* (1992).

Low variability in the reservoir level in subsequent years allowed, from 1994 on, the massive proliferation of an introduced bivalve mollusk, *Corbicula fluminae* (Okada, 1999), which was included as the main food of the "armado" (90%) from 1994-96. Occupying the shallow marginal areas of the reservoir, the stock of this bivalve was drastically affected by variations in the reservoir level from 1996, especially by the level depletion during the second half of that year and in subsequent years. Mollusk slaughters in reservoirs marginal areas were reported by Fisher and LaVoy (1972), who demonstrated that water level fluctuations in a Connecticut River reservoir (USA), with littoral region exposition, were responsible for a decrease of benthic fauna density in periodically exposed areas, compared to those that are always flooded. These authors verified that the mollusks were among the organisms that presented high density decrease in environments subjected to sudden level variation. The reduction in this food resource availability was reflected in the "armado" diet, which began to be mainly of vascular plants, now of aquatic origin, and filamentous algae. The high consumption of filamentous algae, represented essentially by *Spyrogira* in the transition and lacustrine regions, is possibly associated with a reduction in the aquatic macrophytes biomass, also due to water level variation, concomitant with the abundance increase of this algae.

Change tendencies in the *P. granulosus* diet were more evident in the fluvial and transition zones than in the reservoir more internal areas (lacustrine zone). The reasons for this difference in responses may be partially explained by the high occurrence of submerged aquatic macrophytes in the arms of the reservoir lacustrine region (Souza, 2000) and by its conspicuous gradient, where the upper areas present more turbid waters and high mollusk densities, in opposition to the high water transparency in the more internal areas. (Okada, 1999). Thus, the consumption of plants (mainly aquatic) in the lacustrine zone in 1994 and 1995 was greater than that of *C. fluminae*, which suggests that the species consumed food that, in addition to being abundant, is a regular part of its diet.

The mollusk consumption by *P. granulosus* (including *C. fluminae*) is reported by Montalto *et al.* (1999) for natural environments in the basin lower stretches. In this study, the authors also highlight the presence of another invader bivalve (*Limnoperna fortunei*) in the *P. granulosus* diet and considered it to be the most ingested food. Knowing that this invader proliferation has a highly negative impact on the turbines operation, the control imposed by *P. granulosus* may represent a promising possibility for its biological control.

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