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Feeding dynamics of *Cichla kelberi* Kullander & Ferreira, 2006 introduced into an artificial lake in southeastern Brazil

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The objective of this study was to characterize the seasonally of the diet of *Cichla kelberi* in an artificial lake in Leme-SP, determining the food items and their relation to the sex and gonadal maturity of the fish sampled. The diet of *C. kelberi* presents a dynamic in three different periods: winter months were characterized by low feeding activity and a high concentration of undetermined fish; increase in feeding activity occurred in the spring, with *Tilapia* sp. being the dominant food item; and a high rate of cannibalism was observed in the summer and early fall. The plasticity in the composition of the diet was marked by quantity of prey available during the different periods of the year, and the reproductive period.

O objetivo desse estudo foi caracterizar sazonalmente a dieta de *Cichla kelberi* em um lago artificial em Leme-SP, determinando os itens alimentares e as relações com os sexos e com a maturação gonadal dos exemplares amostrados. A dieta de *C. kelberi* apresenta uma dinâmica em três diferentes períodos: os meses de inverno foram caracterizados por baixa atividade alimentar e alta concentração de peixes indeterminados, durante a primavera ocorreu um aumento na atividade alimentar, sendo *Tilapia* sp. o item alimentar dominante e durante o verão e início do outono foi evidenciada alta taxa de canibalismo. A plasticidade na composição da dieta foi marcada pela quantidade de presas disponíveis durante os períodos do ano e pelo período reprodutivo.

Key words: Seasonality, Cannibalism, Predation, Competition.

Introduction

The introduction of exotic species has resulted in consequences for the receiving environment that are often unknown or subjugated. For piscivore species, some of the main effects include the decline and extinction of natural populations, predation and reduction in the size of the introduced species, genetic degradation of these species, dispersion of parasites and disease, or a combination of these factors (Zaret & Paine, 1973; Fernandes *et al*., 2003).

Species of the genus *Cichla* (peacock bass) are among the most conspicuous and widely distributed predators in South American watersheds (Winemiller, 2001). These fishes are the main resources for food and sport fishing in various regions of the continent (Kullander & Ferreira, 2006). Their popularity has been the intentional introduction of *Cichla* species in diverse tropical and sub-tropical freshwater regions in the world, at times leading to the decrease of populations of native fish species (Winemiller, 2001). Peacock bass were introduced into regions such as Florida, Hawaii, Panama, Puerto Rico, and in Brazil, in the southeast (Hoeinghaus *et al*., 2003), midwest (Resende *et al*., 2008), northeast (Fontenele & Peixoto, 1979), and south (Kullander & Ferreira, 2006). Natural to the Araguaia and Tocantins River basins, *C. kelberi* was before identified as *C. monoculus* (Kullander & Ferreira, 2006), being found in many reservoirs in southeastern Brazil.

In addition to its strong attraction for sport fishing and as a food resource, *Cichla* species are used to control the population density of other exotic species such as *Tilapia* sp. and *Oreochromis* sp. (Winemiller, 2001) because of their voracity, prolificacy, and capacity to adapt to different lentic environments (Zaret, 1980).

Knowledge regarding fish diet is best acquired through the study of large areas. However, studies of a given locality carried out over a period of a year enable comparisons with data obtained in other regions. This information can contribute to subsequent studies and interpretations of the diet of *C. kelberi* in modified anthropic environments, and the possible consequences

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that this species can cause these environments. The objective of this study was to characterize the seasonality of the diet of *C. kelberi* in an artificial lake in southeastern Brazil, determining the feeding and their relations with the gonadal maturity of the fish sampled.

Material and Methods

The lake is located in a tropical area (22º 13'S 47º 18' W) in the municipality of Leme-SP. The climate is typical of this region, with average annual temperature of 21ºC and average annual precipitation of 1,400 mm. The region has two typical seasonal periods: one warm and rainy beginning in October and ending in April, and the other cold and dry, extending from May to September (Souza *et al*., 2008). The lake was built approximately fifty years ago and occupies an area of 360,000 m^2 with a depth ranging from 1 to 9 m. Twenty years ago, species of *Cichla* were introduced into the lake, *C. piquiti* and *C. kelberi* Kullander & Ferreira, 2006, of which only the latter are currently found in the lake. These introductions were carried out with the objective of controlling the populations of other exotic species, *Tilapia rendalli* Linnaeus, 1757 and *Oreochromis niloticus* Boulenger, 1912.

The collections were made monthly, totaling 14 samples (November and December, 2005, and from April, 2006 to March, 2007). Each collection period lasted eight hours, with three fishermen using baitcasting (Gomiero, 2010). This type of fishing is effective for catching peacock bass in a wide variety of environments (Taphorn & Duque, 1996; Jepsen *et al*., 1999; Gomiero *et al*., 2009). This method proved very effective in evaluating the biology of *Cichla*, including the assessment of diet, because it is a predator species and opportunistic (Gomiero & Braga, 2004a, b). These fish are adapted to living in clear water, as they are guided mainly by vision, moving during the day, which makes it difficult to catch them using gill nets (Braga & Gomiero, 1997; Winemiller, 2001; Gomiero & Braga, 2003a; Gomiero, 2010).

The individuals were conserved in ice for analyses at the Ichthyology Laboratory at São Paulo State University in Rio Claro, SP. Measurements taken for each individual included: total length (mm), total mass (grams), sex, mass of gut contents and mass of the gonads (Braga, 1990).

The guts were conserved in alcohol (70%) and later weighed, and the preys found were identified to the lowest taxonomic level possible.

To analyze feeding activity during one year (monthly), the Repletion Index (RI) was adopted, which consists of the relative mass of the gut contents and total mass of the fish (Hyslop, 1980). The seasonal variation in feeding activity was compared using Kruskal-Wallis analysis (5%) and BioStat 5.0 software (Ayres, 2007).

The preys found in the guts were analyzed using the following indices:

- Frequency of Occurrence (Fi): relative percentage of number of guts containing a given taxonomical group of prey compared to the total number of guts containing food in a given month (Hyslop, 1980; Bowen, 1983).

- Numerical Frequency (FN): relative percentage of a given taxonomical group of prey compared to the total number of prey observed in a month (Hyslop, 1980; Bowen, 1983).

The seasonal variation in the composition of the diet (Fi and Ni) was compared monthly using Spearman's rank correlation (5%) (Fritz, 1974). This method was adopted because the data did not reveal normal distribution.

Analyses of the diet were complemented with the gonadosomatic index (GSI), determined monthly, using the ratio of gonad mass to total fish mass multiplied by 100 (Vazzoler, 1996). GSIs were calculated separately for males and females. Reproduction has a strong influence on cannibalism, as observed in several studies with *Cichla* in places where the species was introduced (Godinho *et al*., 1994; Duraez *et al*., 2000; Santos *et al*., 2001; Gomiero & Braga, 2004a, b; Fugi *et al*., 2008).

Results

During the data collection period, 491 individuals of *C. kelberi* were captured and analyzed (271 immature and 220 adults). Considering the adults, it was possible to identify 115 females and 105 males. Individuals with gut contents were found in all samplings (Fig. 1), with the exception of the collection carried out in August.

Comparisons of feeding activity showed significant differences ($p < 0.05$), with the lowest RI values observed during the cold months and the highest values in the warm months (Fig. 2).

The diet of *C. kelberi* consisted mainly of fish, represented by seven food items: *Tilapia* sp., *C. kelberi*, *Geophagus brasiliensis*, *Hoplosternum littorale*, Insecta, Ophidia and unidentified fish.

Analyses of Frequency of Occurrence (Fi) showed that three food item categories were more representative. The unidentified fish was observed in all the months, with a high percentage from May to October. *Tilapia* sp. was predominant from September to December, and in December, consumption of small individuals of *C. kelberi* was observed, reaching the highest values in February, March, and April.

The numerical frequency (Ni) was found to be similar to the frequency of occurrence, although the number of each food item observed was different. The percentage was higher for *Tilapia* sp. and for *C. kelberi* because many food items from the same taxonomic group were found in the same gut (Fig. 4), shows that when the species feeds a particular item, it feeds in bulk.

The Fi and FN were analyzed according to the Spearman correlation, showing that significant similarities ($p < 0.05$) occurred in the diet of *C. kelberi* in the months of three distinct periods: May, June, July, and September (winter and beginning of spring) with the predominance of indeterminate items; October, November, and December (end of spring and summer) with higher frequencies of *Tilapia* sp.; and February, March, and April (end of summer and beginning of fall) with a high index of cannibalism (Figs. 3 and 4).

Parallel to the diet, maturity stage and GSI were analyzed to verify their association with feeding activity and food items consumed during one year. The largest GSI values were found

in October, January, and April for males and in the months from September to January for females (Fig. 5). During these months were observed higher rates in feeding activity with the predominance of *Tilapia* sp. before the reproductive period and a high rate of cannibalism after.

Discussion

The monthly difference in number of individuals of *C. kelberi* collected may be the result of differences typical of the seasons of the year. Among the biotic factors, the principle ones were variations in temperature and rainfall, as well as variations in the duration of daylight. Added to these are biotic factors such as reproductive period and availability of food.

The genus *Cichla* is considered common in South American rivers and lakes with clear and dark water (Hoeinghaus *et al*., 2003) in Amazon basin, and is never found in turbid waters (Winemiller, 2001). In the Volta Grande Reservoir, Gomiero & Braga (2003a) observed higher capture rates for *Cichla* species between 9:00am and 3:00pm in seasons with higher temperatures (spring and summer) and on brighter days. This is evidence that the genus *Cichla* is more active under conditions of more light, remaining active longer on days with longer periods of clarity. These findings are in agreement with characteristics of other cichlids with diurnal behavior and marine ancestry (Keenleyside, 1991).

Various factors explain the large number of individuals caught between December and March. The high number caught at the beginning of this period in comparison to the previous period is due to increases in temperature and feeding activity, beginning of the reproductive period (Gomiero *et al*., 2009) and a large number of immature individuals caught after the first spawning period occurred in November-December. A similar situation was reported by Souza *et al*. (2008), who observed an increase in reproductive activity during the period of higher temperatures.

Some fish may reduce feeding activity in lower temperatures due to reduced metabolism and slower digestion, causing a loss of appetite (Zavala-Camin, 1996); inversely, an increase in temperature has the tendency to increase the rate of ingestion due to more accelerated digestion (Jobling, 1993). In the colder months, the majority of guts presented small quantities of food, with the opposite occurring in the hotter months. Feeding rates are influenced by characteristics such as season of the year due to differences in water temperatures and the duration of periods of light and dark, which determine the increase or decrease in availability of food (Zavala-Camin, 1996). Because they are piscivorous, the feeding activity of *Cichla* is related to the abundance of food (Winemiller, 2001; Luz-Agostinho *et al*., 2008). In various reservoirs in southeastern Brazil, high values of the condition factor of the in the hotter months are related

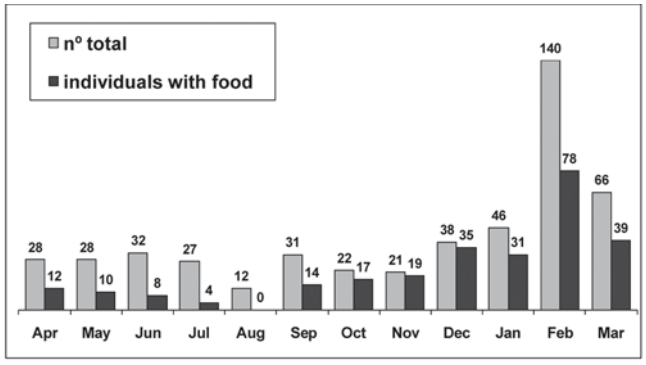

Fig. 1. Number of individuals caught during the collection period.

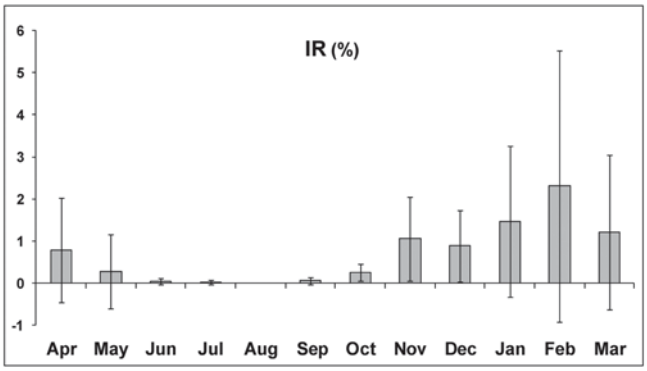

Fig. 2. Means and standard deviations of the Repletion Indices (RI) of *Cichla kelberi* during the collection period.

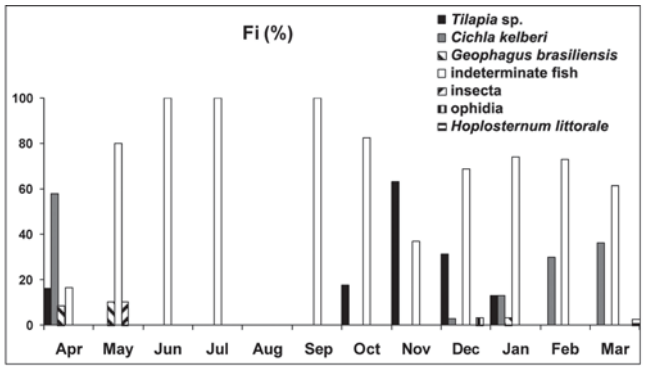

Fig. 3. Frequency of Occurrence (Fi) of the food items of *Cichla kelberi* during the collection period.

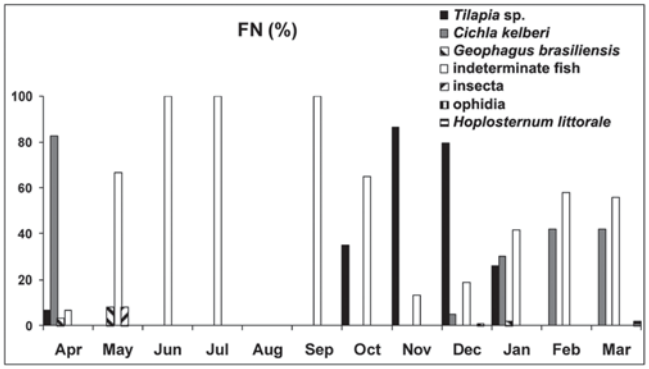

Fig. 4. Numeric Frequency (FN) of the food items of *Cichla kelberi* during the collection period.

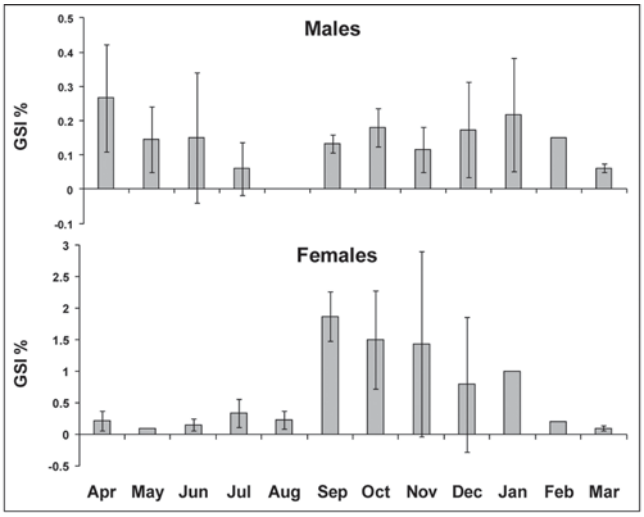

Fig. 5. Means and standard deviations of the Gonadosomatic Indices (GSI) of *Cichla kelberi* during the collection period.

to the increase in feeding activity and greater development of the gonads. (Gomiero & Braga 2003b; Gomiero *et al*., 2008; Souza *et al*., 2008).

Seven food items were observed in the diet of *C. kelberi*. Unspecified fish, *i.e*. with a high degree of digestion, appeared throughout the year and were the exclusive items during the winter. The items *C. kelberi* and *Tilapia* sp. were the most represented, albeit in different periods. Other items such as *Geophagus brasiliensis*, Insecta, Ophidia, and *Hoplosternum littorale* were considered occasional, as they were found in few guts during the year. In species of *Cichla*, the high percentage of guts with low contents may be associated with the limited availability of food and the reduction in the predator's metabolism, resulting in low consumption of the prey (Santos *et al*., 2001).

Various studies have shown differences in the diet in different regions. In non-modified environments, species of *Cichla* show great diversity of food items, with predominance of species of Characiformes and Siluriformes (Goulding, 1980; Novoa, 1996; Williams *et al*., 1998; Jepsen, 1999; Winemiller, 2001; Novaes *et al*., 2004; Resende *et al*., 2008). On the other hand, in modified environments, the diversity of food items is low, with high frequency of cichlids and a high incidence of cannibalism (Godinho *et al*., 1994; Duraez *et al*., 2000; Santos *et al*., 2001; Gomiero & Braga, 2004a, b; Fugi *et al*., 2008). The cichlids present various characteristics that enable them to exploit lentic environments, such as a developed swim bladder and fins associated with specialized musculature ideal for controlling precise movements and remaining in the water in column (Zaret, 1980). During the formation of the Serra da Mesa Reservoir, Novaes *et al*. (2004) observed that the species of characidae were more abundant in the diet of *C. monoculus* during the filling phase, and cichlids were more abundant during the operational phase (full reservoir). This is a strong indication that species of *Cichla* exploit resources available in the environment, demonstrating opportunistic behavior.

Lowe-McConnell (1999) comment with the great majority of tropical fish do not have specialized diets or specific feeding restrictions, and show variability according to the availability of food. And the diets of fish can also be affected by spatial and seasonal changes which, in turn, affect food availability (Abelha *et al*., 2001). In the lake in Leme, high consumption of two food items was observed in distinct periods. High consumption of *Tilapia* sp. occurred in the months from October to January as a consequence of the initiation of the specie's reproductive period at the end of the winter (personal observation), which resulted in the availability of a high number of small individuals in the period that followed, spring and early summer. The initiation of the reproductive period of *C. kelberi* was also observed during this period, as reflected in the high values of gonadosomatic relations of the females. The high number of juvenile tilapia was an important food source during the reproductive period of *C. kelberi*.

Cannibalism was observed in December, January, and February as a consequence of the first spawning, which took place in the spring (Gomiero *et al*., 2009a) and the scarcity of alternative food items. Cannibalism increased even more in March and April due to the second spawning, which occurred in the summer (Gomiero *et al*., 2009a). These facts are concomitant with the reduction of availability of small individuals of *Tilapia* sp.

Interactions between different age classes or stages in a single animal population are very common (Hasting & Constantino, 1991). In piscivore fish, cannibalism is common and is a strong mechanism for controlling population density (Nikolsky, 1963; Wooton, 1990). Cannibalism occurs in response to the influences of specific conditions of a local population, and the frequency and intensity may vary substantially within the same population and among interactions with other species (Fox, 1975). In large reservoirs, a pattern similar to that observed in the lake in Leme was found, with cannibalism in the spring and summer, and consumption of other preferred items in the other periods of the year (Santos *et al*., 2001). In modified environments, cannibalism was considered a principal feeding behavior of the species *Cichla*, mainly during the reproductive period (Gomiero & Braga, 2004a; Fugi *et al*., 2008), while low rates of cannibalism occur in natural environments due to the high availability of prey (Winemiller, 2001). Zaret (1977) suggests three conditions that prevent cannibalism for the species *Cichla* in natural environments: territoriality of a given group of fish; juveniles that live in the same area are offspring of a single couple; and abundance of prey. Although these arguments show territoriality and nest defense, the lake in Leme does not have enough prey diversity, unlike natural environments. In addition, when the juveniles become independent, they seek refuge in aquatic vegetation (Zaret, 1977, 1980; Gomiero & Braga, 2004b). In Leme, there is no aquatic vegetation, which exposes an abundance of juvenile *C. kelberi* to predation. Santos *et al*. (2001) suggest that cannibalism may be the result of overpopulation and small quantity of prey available.

In the present study, it was observed that the dietary dynamic of *C. kelberi* is characterized by three different periods: low feeding activity and high concentration of undetermined fish during the winter months; increased feeding activity in the spring, with *Tilapia* sp. being the dominant food item; and a high rate of cannibalism during the summer and early fall.

The plasticity in the composition of the diet was influenced by possible seasonal variations, the type and quantity of prey available during the periods of the year, and the reproductive period.

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Appendix 1. Statistical comparison (Spearman rank correlations) of Fi of the *Cichla kelberi* between months. The significant correlations coefficients are highlighted in bold ($p < 0.05$).

	Apr	May Winter	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
May	0.1240	1.0000			-	-	-	-	-	-	-
Jun	0.4237	0.6831	1.0000		-	-	-	-	-	-	-
Jul	0.4237	0.6831	**1.0000**	1.0000	-	-	-	-	-	-	-
Aug	-	-	-	-	1.0000	-	-	-	-	-	-
Sep	0.4237	0.6831	**1.0000**	**1.0000**	-	1.0000		-	-	-	-
Oct	0.5084	0.3726	0.7637	0.7637	-	0.7637	1.0000	-	-	-	-
Nov	0.4622	0.1490	0.5091	0.5091	-	0.5091	**0.9444**	1.0000	-	-	-
Dec	0.6408	0.0626	0.6417	0.6416	-	0.6417	**0.8401**	**0.7974**	1.0000	-	-
Jan	**0.9320**	0.3131	0.6417	0.6417	-	0.6417	0.7701	0.7001	0.7745	1.0000	-
Feb	0.7637	0.3726	0.7637	0.7637	-	0.7637	0.5000	0.2777	0.6301	**0.7974**	1.0000
Mar	0.5939	0.1978	0.6756	0.6756	-	0.6756	0.3686	0.1474	0.4232	0.5677	**0.8846**

Appendix 2. Statistical comparison (Spearman rank correlations) of FN of the *Cichla kelberi* between months. The significant correlations coefficients are highlighted in bold ($p < 0.05$).

	Apr	May Winter	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
May	0.0313	1.0000			-	-	-	-	-	-	-
Jun	0.3208	0.6831	1.0000		-	-	-	-	-	-	-
Jul	0.3208	0.6831	**1.0000**	1.0000	-	-	-	-	-	-	-
Aug	-	-	-	-	1.0000	-	-	-	-	-	-
Sep	0.3208	0.6831	**1.0000**	**1.0000**	-	1.0000		-	-	-	-
Oct	0.4900	0.3726	0.7637	0.7637	-	0.7637	1.0000	-	-	-	-
Nov	0.4900	0.1490	0.5091	0.5091	-	0.5091	**0.9444**	1.0000	-	-	-
Dec	0.71.84	0.1240	0.4236	0.4237	-	0.4236	**0.7858**	**0.8320**	1.0000	-	-
Jan	**0.9320**	0.3100	0.6354	0.6354	-	0.6354	0.6933	0.6009	0.7307	1.0000	-
Feb	0.7001	0.3726	0.7637	0.7637	-	0.7637	0.5000	0.2777	0.5084	**0.8320**	1.0000
Mar	0.5058	0.1978	0.6756	0.6756	-	0.6756	0.3686	0.1474	0.3066	0.6338	**0.8846**