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Stomach Content Analysis of *Deuterodon* Species (Eigenmann, 1907), A "Lambari" Genus from the Atlantic Forest

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ABSTRACT

The stomach contents of nine Deuterodon species were analyzed. Diet was determined analyzing 73 stomachs and items were identified and had their abundance estimated according to a semi-quantitative scale. Frequency of occurrence, percent composition and a similarity analysis of diets for each species were examined. The stomach analysis revealed that 80% of the food items are autochthonous. All the species were considered typically omnivorous. Aquatic insects, mainly Chironomidae larvae, and vegetal debris were the most important food consumed by the studied fishes.

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INTRODUCTION

The Atlantic Forest, one of the richest and most threatened ecosystems of the planet (Myers *et al*., 2000), contains many endemic fish species (Menezes, 1996). Streams in the Atlantic Forest harbor a rich freshwater fish fauna, with an intimate association with the riparian vegetation, considered important for food, shelter and reproduction (Menezes *et al*., 1990). Fish feeding studies constitute important surveys, as they are a way of knowing how the energy flows inside a system where the fish species lives, and they permit one to evaluate how a species maintains, grows and reproduces in the system (Zavala-Camin, 1996). Once more, fish feeding studies permit one to interpret what type of trophic relationships an aquatic system sustains and the ecological role played by them (Hahn *et al*., 1997).

The Characiformes constitutes the second most diverse order of Neotropical freshwater fishes, being a group of fishes with a great variety of forms and reproductive behaviors (Vazzoler and Menezes, 1992). Among the families of Characiformes, a highlight for family Characidae, with nearly 1100 species valids, representing approximately 58% of all living Characiformes species (Oliveira *et al*., 2011).

The old subfamily Tetragonopterinae is considered the most successful Characidae taxon, having invaded essentially all biotopes in the Neotropics (Géry, 1977; Nelson, 1994; Lowe-McConnell, 1999). Lima *et al*. (2003) reorganized many small "tetra fish" as *incertae sedis* in Characidae. Mirande (2010) includes *Deuterodo*n species and most small characids, cited anteriorly by Lima *et al*. (2003) as incertae sedis, within the subfamily Tetragonopterinae (clade 224).

The genus *Deuterodon* Eigenmann, 1907 is composed by seven valid species (Lucena and Lucena, 2002). In additional, three nominal species called *incertae sedis* in Characidae (*D. parahybae* Eigenmann, 1908; *D. pedri* Eigenmann, 1908 and, *D. potaroensis* Eigenmann, 1909). *Deuterodon* is a very important genus, perhaps been the ecological equivalent of *Astyanax* genus in most coastal drainages of Southeast and South of Brazil. *Deuterodon* present a large distribution in the Atlantic Forest; all yours species are distributed across the coastal streams, mainly in South and Southeastern Brazil, from Rio Grande do Sul to Minas Gerais States, except by *Deuterodon potaroensis* inhabit Potaro River (Nicaragua).

However, there are few studies of its feeding habitats. Aranha *et al*. (1998); Vitule and Aranha

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(2002); Barreto and Aranha (2006); Vitule *et al*. (2008) reported information about habitat and diet for D. langei. Mazzoni & Rezende (2003) reported feeding habits of *Deuterodon* sp. from the Ubatiba River. Sabino and Castro (1990) reported food habits of *D. iguape* from the Atlantic Forest, southern Brazil, and Fogaça *et al*. (2003), food habits in a study of the fishes of south Brazil. These studies found that *Deuterodon* species have been shown to be omnivorous by Sabino and Castro (1990); Mazzoni and Rezende (2003); Vitule and Aranha (2002) and, Vitule *et al*. (2008); omnivorous/herbivorous by Aranha *et al*. (1998) and, Barreto and Aranha (2006) or insectivorous, with a predominance of aquatic insects in its diet by Fogaça *et al*. (2003).

The aim of this paper is to describe and compare the diet of all described species in the genus *Deuterodon*, except *D. potaroensis*, through the analysis of stomach contents.

MATERIALS AND METHODS

The specimens of *Deuterodon* species analyzed collected from Rio Grande do Sul into Minas Gerais Atlantic costal drainages (Table 1). This species are from LBP, LIRP and MCP (Institutional abbreviations follows Sabaj Pérez, 2010), which the collections were sampled in different areas (Table 1). The fishes were catched using a bag seine net. In the laboratory the specimens were measured the standard length of each individual. The stomachs were taken off and dissected to identify the alimentary items. Invertebrates were identified to the lowest possible taxonomic category. The following identification keys were used: Costa *et al*. (2006); Fernández and Domínguez (2001) and Rafael *et al*. (2012).

The methods used for diet analysis were frequency of occurrence (Hynes, 1950; Hyslop, 1980) and the percent composition (Hynes, 1950; Dufech *et al*., 2003). Nevertheless, for graphical representation (Figure 2), the data was grouped in ten categories: allochthonous insects; autochthonous insects, including aquatic insects in the adult or larval phases of development, respectively; arachnids which includes aquatic mites; annelids (Oligochaeta); superior plant material; filamentous algae and detritus.

The placement of species in feeding guilds was determined by successively separating groups of species with stomach contents composed of more than 50% of a single food item, and leaving at the end those omnivorous species with no marked dominance of a given food category.

The feeding similarity between the Plecoptera genera was determined by cluster analysis, using the UPGMA method and Jaccard index (NTSYS 2.1, Rohlf, 2000). The dendrogram distortion was evaluated by the cophenetic correlation coefficient (Romesburg, 1984). That coefficient was obtained correlating the original similarity matrix with the matrix obtained from the dendrogram; r $\geq$ 0.8 is considered a good value (Rohlf, 2000).

Results:

Nine *Deuterodon* species were included in present study. Seventy three stomachs were able to examine the contents and determine the diets (Table 2). The stomach contents were composed of 40 food items (Table 2). In relation to the origin of the alimentary items, most of them were autochthonous (32 items, 80.0%). Among the autochthonous ones, the most representative was aquatic immature insects. Chironomidae and Baetidae larvae were the main aquatic immature insects consumed. Superior plant materials were the most important allochthonous food item. *Deuterodon iguape* consumed mostly filamentous algae. *D. rosae* consumed mostly superior plant material followed by aquatic insects. While the other species consumed mostly benthic aquatic insects, especially immature stages of Diptera (Chironomidae) followed by superior plant material and detritus (Figure 1). The categories referring to allochthonous insects and superior plant material were predominant in diet of *Deuterodon* species.

Table 1: Voucher specimens of *Deuterodon* species analyzed, localities and drainages collected.

			Locality	Drainage
D. iguape	LIRP 1016	23º 21’35.96”S 44º 50’48,75”W	Ubatuba, SP, Brazil	Rio da Fazenda, Bacia Costeira do Atlântico Leste
	LIRP 1049	23º 21’35.96”S 44º 50’48,75”W	Ubatuba, SP, Brazil	Rio da Fazenda, Bacia Costeira do Atlântico Leste
D. langei	LIRP 505	25º 29’10.57”S 48º 49’48.63”W	Morretes, PR, Brazil	Rio Marumbi, Bacia do rio Nhundiaquara
	LIRP 6392	25º 25’57.25”S 48º 48’05.76”w	Morretes, PR, Brazil	Riacho Carí, Bacia Costeira do Atlântico Leste
	MCP 13965	25º 56’00.67”S 48º 54’53.32”W	Pedra Branca, PR, Brazil	Rio São João, Bacia do rio Guaratuba
D. longirostris	LIRP 7766	27º 43’18.00”S 48º 53’36.00”W	Águas Mornas, SC, Brazil	Rio Cubatão, Bacia do rio Cubatão
	MCP 16581	27º 45’00”S 48º 56’00”W	Aguas Mornas, SC, Brazil	Rio Teresópolis, Bacia do rio Cubatão
D. parahybae	LBP 7706	S 23º35’43” W 45º34’00”	Paraíbuna, SP, Brazil	Rio dos Prazeres, Bacia do Paraíbuna
	MCP 13964	20º14’00”S 41º30’00”W		Rio São João II, Bacia do rio Itapemirim
D. pedri	LIRP 7540	19º 13’53.90”S 42º	Ferros, MG, Brazil	Rio Santo Antônio, Bacia do rio

Australian Journal of Basic and Applied Sciences, 9(5) March 2015, Pages: 192-198

		58’34.02”W		Santo Antônio
D. rosae	LBP 2049	25º 41’30’S 48º 34’25”W.	Paranaguá, PR, Brazil	Rio Colônia, Bacia do Atlântico Leste
	MCP 12209	26º 26’06.11”S 49º 11’53.39”W	Corupá, SC, Brazil	Arroio afluente do rio Itapocú, Bacia do rio Itapocú
D. singularis	LIRP 6391	28º 19’50.16”S 49º 01’08.22”W	Gravatal, SC, Brazil	Córrego afl. do rio Capivari, Bacia do Atlântico Leste
	MCP 28768	28º 03’35.06”S 48º40’18.53”W	Garopaba, SC, Brazil	Arroio afluente da Lagoa Garopaba, Bacia do rio Garopaba
D. stigmaturus	LIRP 6390	29º 39’42.0”S 50º12’37.0”W	Maquiné, RS, Brazil	Arroio Água Parada, Bacia do rio Maquiné
	MCP 14683	29°31'00.0"S 50°05'60.0"W	Terra de Areia, RS, Brazil	Rio Mitmann, Bacia do Atlântico Leste
D. supparis	LIRP 7523	27°39'21.0"S 49°25'38.0"W	Alfredo Wagner, SC, Brazil	Rio Itajaí do Sul, Bacia do Atlântico do Leste
	MCP 16494	27°02'00.0"S 49°23'00.0"W	Apiúna, SC, Brazil	Ribeirão São Luís, Bacia do rio Itajaí-Açu

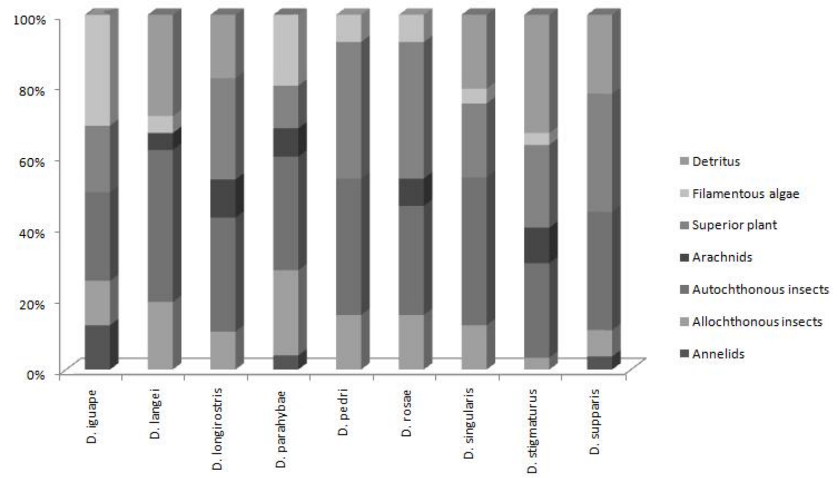

Fig. 1: Percent composition of dietary items found in the stomachs of nine *Deuterodon* species analyzed.

Table 2: Range of standard length (SL - mm), frequency of occurrence (FO) and percent composition (PC) of *Deuterodon* species.

	D. iguape		*D. langei*		*D. longirostris*		*D. parahybae*		*D. pedri*		*D. rosae*		*D. singularis*		*D. stigmaturus*		*D. supparis*	
SL Range	(64.8 – 77.6)		(34.2 – 69.2)		(33.2 – 83.3)		(51.0 – 67.0)		(33.6 – 48.9)		(41.0 – 85.5)		(36.6 – 69.4)		(42.8 – 81.7)		(40.9 – 86.5)	
	FO	PC	FO	PC	FO	PC	FO	PC	FO	PC	FO	PC	FO	PC	FO	PC	FO	PC
Oligochaeta	40,0	10,5					10,0	2,6									10,0	2,9
Hydracarina					33,3	5,5									30,0	9,1		
Aranae			10,0	2,0			20,0	5,3	20,0	3,8	16,7	4,8						
Coleoptera aquatic	20,0	5,3	20,0	3,9	11,1	1,8	10,0	2,6										
Curculionidae					11,1	1,8					16,7	4,8						
Elmidae			10,0	2,0	22,2	3,6	10,0	2,6	20,0	3,8			10,0	3,4				
Diptera larvae					11,1	1,8												
Chironomidae	40,0	10,5	70,0	13,7	77,8	12,7	40,0	10,5	80,0	15,4			30,0	10,3	70,0	21,2	70,0	20,6
Ceratopogonidae	20,0	5,3	20,0	3,9	11,1	1,8	10,0	2,6										
Psychodidae			10,0	2,0														
Simuliidae																	10,0	2,9
Ephemeroptera larvae			10,0	2,0	22,2	3,6												
Baetidae			40,0	7,8	66,7	10,9			20,0	3,8	16,7	4,8	10,0	3,4	10,0	3,0	40,0	11,8
Camelobaetidius sp.							10,0	2,6										
Leptohyphidae					11,1	1,8												
Traverhyphes sp.							10,0	2,6										
Leptophlebiidae															10,0	3,0		
Hylister sp.							10,0	2,6										
Naucoridae									20,0	3,8	16,7	4,8						
Notonectidae			10,0	2,0														
Pyralidae			10,0	2,0					20,0	3,8			10,0	3,4				
Corydalus sp.			10,0	2,0														
Perlidae			10,0	2,0														
Coenagrionidae			10,0	2,0														
Trichoptera larvae			20,0	3,9	11,1	1,8									10,0	3,0		
Hydrobiosidae	20,0	5,3																
Hydropsychidae			40,0	7,8									10,0	3,4				
Smicridea sp.					11,1	1,8			20,0	3,8								
Hydroptilidae			20,0	3,9	11,1	1,8											10,0	2,9
Glossosomatidae					11,1	1,8												
Oecetis sp.					22,2	3,6												

Australian Journal of Basic and Applied Sciences, 9(5) March 2015, Pages: 192-198

Philopotamidae			10,0	2,0														
Coleoptera (terrestrial)							20,0	5,3	20,0	3,8	16,7	4,8						
Diptera (adult)			20,0	3,9	22,2	3,6											10,0	2,9
Formicidae (terrestrial)	20,0	5,3			11,1	1,8	30,0	7,9	40,0	7,7	50,0	14,3						
Rests of aquatic insects	40,0	10,5	70,0	13,7	66,7	10,9	80,0	21,1	100,0	19,2	66,7	19,0	80,0	27,6	50,0	15,2	30,0	8,8
Rests of terrestrial insects	20,0	5,3	20,0	3,9	22,2	3,6	40,0	10,5	60,0	11,5	33,3	9,5	30,0	10,3	10,0	3,0	10,0	2,9
Filamentous algae	100,0	26,3	10,0	2,0			50,0	13,2			16,7	4,8	10,0	3,4	10,0	3,0		
Plant debris	60,0	15,8			88,9	14,5	30,0	7,9	100,0	19,2	100,0	28,6	50,0	17,2	60,0	18,2	90,0	26,5
Detritus			60,0	11,8	55,6	9,1							50,0	17,2	70,0	21,2	60,0	17,6
Total of stomachs	5		10		9		10		5		6		10		10		10	

The dendrogram of the cluster analysis based on composition percentage of the food items defined two distinct groups (Figure 2), indicating 56% of shared of food resouces. However it did not show a good data adjustment (cophenetic correlation value, r = 0.77). The first group was represented by four species into two subgroups. And the second, was grouped by one subgroup plus two other separate species.

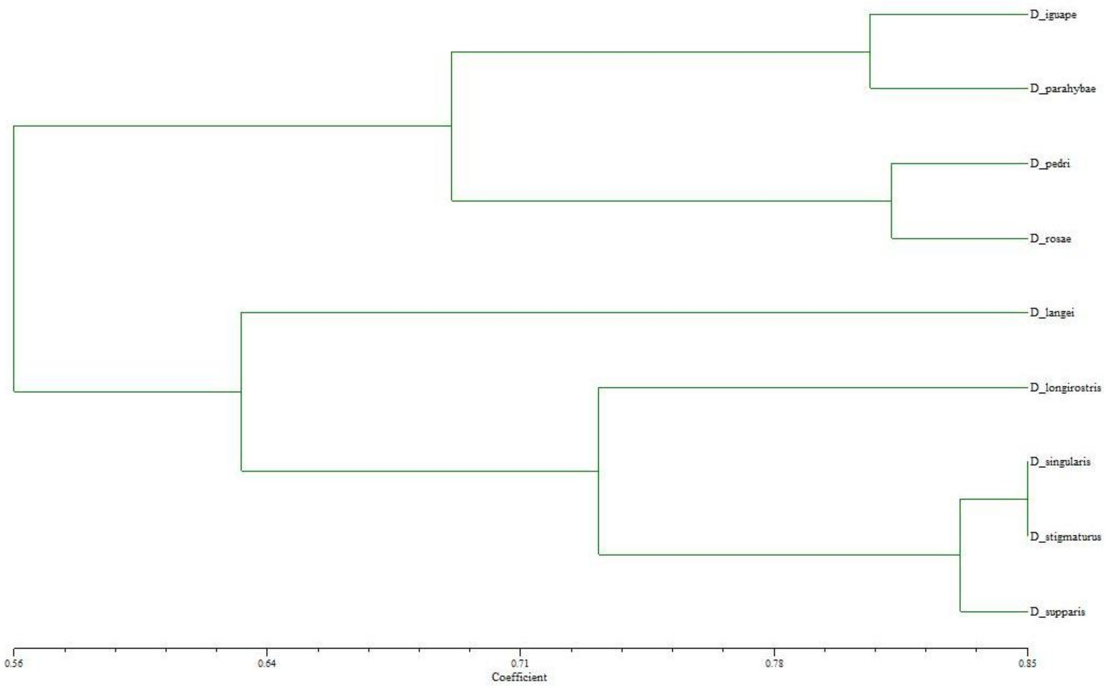

Fig. 2: Diet similarity based on categories of food items found in the stomachs of nine *Deuterodon* species analyzed.

Discussion:

The nine *Deuterodon* species showed a very similar composition of dietary items wich at least 56% of similarity (Figure 2). *Deuterodon iguape* feeds mostly on filamentous algae. Feeding patterns of *D. iguape* agree with those observed by Sabino and Castro (1990), who found that species from the Southeastern Brazil had an omnivorous diet, and algae are the organisms that occurred more frequently in percentage composition. According Esteves and Lobón-Cerviá (2001), this species was classified as herbivorous in a study conducted in São Paulo State. *D. rosae* consumed mostly superior plant material by also aquatic insects while *D. langei*, *D. longirostris*, *D. pahybae*, *D. pedri*, *D. singularis*, *D. stigmaturus* and *D. supparis* fed primarily on benthic aquatic insects. Twenty-two aquatic insects families were identified, with chironomids most abundant. Barreto and Aranha (2006) classified *D. langei* as an omnivorous species, with a tendency toward herbivory, based mainly on algae. In a stream in Paraná State, Aranha *et al*. (1998) also classified *D. langei* as omnivorous/herbivorous. Mazzoni and Rezende (2003), studying *Deuterodon* sp. in Rio de Janeiro State, classified the species as omnivorous, where an important shift in the use of feeding resources was also registered; animal and vegetal items had alternated importance between seasons studied.

Considering the autochthonous items, the analyzed species had preference by aquatic insects (mainly Chironomidae, Ephemeroptera, Trichoptera, and Odonata), and most of the other species, in some extent, complemented their diet with these food resources. Aquatic insects are important food resource for the fish community, demonstrating their high availability in the environment. Among the aquatic insects, the Chironomids were abundant in stomach contents. This fact could be associated with high abundance and diversity of this component of benthic macroinvertebrates community (Strixino and Trivinho-Strixino, 1998), playing an important role as prey for freshwater fish species.

The most representative item among the allochthonous ones was vegetal. According to Loureiro-Crippa and Hahn (2006) the high consumption of terrestrial plants by fishes occurred when there was an enhanced availability of this resource as immediate food.

In general, *Deuterodon* species are an omnivorous and opportunistic species with great diet flexibility. According Abelha *et al*. (2001), omnivory is widespread among stream fishes. The omnivorous diet, however, is only possible if the species has morphological and physiological adaptations in order to make use of the food item (Gerking, 1994).

The representatives that made up the old family Tetragonopterinae have visible changes in the mouth in relation to dentition (Britski, 1970), which makes these groups report to an omnivore diet (Rondineli *et al*., 2011). Also according to Rondineli *et al*. (2011), omnivory is not opportunist, which denotes a lack of preference; omnivory is a wide possibility in the intake of items available. The plasticity of species enables the use of a wide variety of food resources in adverse conditions, where less tolerant species would not be able to establish themselves (Teixeira *et al*., 2005).

In addition, these variations in diet composition may be associated with ontogenetic changes in the diet of this species, where insects are preferential items for fish in smaller length classes and fish for those of the largest length classes (Gomiero and Braga, 2005).

In contrast of traditional view of passivity of the Brazilian coast, some biogeography events, as earthquakes, are responsible to forge the pattern of distribution of many Characidae genus in Southern Brazilian coast, and probably, these patterns are arising from neighbor seismic events (Ribeiro, 2006). Some species of *Deuterodon*, *D. singularis*, *D. stigmaturus* and *D. supparis* are grouped in present analysis of diet similarity. Its perhaps due to similar environmental that living this species. This diet similarity is corroborated by phylogenetic pattern (Pereira & Castro, in preparation). Another one observed in present study is related to closeness of *D. iguape* (Iguape River drainage) and *D. parahybae* (Paraíba do Sul River drainage), its may be evidenced by recent lifted that produced the actual conformation of these drainages. These events have brought a high degree of overlap of species of basins, and transforming different areas into much similar in term of rate of endemism, and richness of fauna, and this way, similar areas in ecological attributes, resulting in an accessibility of alimentary source much greater. *Deuterodon langei* and *D. longirostris* are distributed Nhundiaquara (Paraná State), and Cubatão (Santa Catarina State) drainages, respectively. Both pattern of distribution are formed from vicariance events during Tertiary period, probably, this common origin may be related a similar diet. Another species of *Deuterodon* (*D. pedri* and *D. rosae*) inhabit streams a little height (usually 20 meters) in Atlantic Forest in comparison of remains species. Probability, the environmental structure enabled a shared of resource of approximately 80% between anteriorly two mentioned species. *Deuterodon langei* possess the lesser coefficient of similarity (approximately 60%) with remains species of the genus. In spite of this species inhabit is sympatric of *D. iguape* in some localities, maybe its event is responsible to dislocate feeding preference of both species to avoid intraspecific competition.

The results of this study reveal the importance of autochthonous items in the diet of the *Deuterodon* species analyzed. Although, *Deuterodon potaroensis* stomach contents are not analyzed in present study, we considered the genus, sensu Lucena and Lucena (2002) plus two nominated species as *incertae sedis* in Characidae, primarily characterized as omnivorous. Therefore, this is in accordance with previous studies that showed that a major of small characoids species known “lambaris” possess opportunistic behavior, many times feeding of resources available in the environmental.

Conclusion:

According to the previous authors, we also concluded *Deuterodon* species as omnivorous showing an opportunistic behavior, typical of “lambaris”. Autochthonous items were the most important in the diet of the *Deuterodon* species analyzed.

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