


Body condition factor and diet the endemic ichthyofauna in streams of the Atlantic Forest inside and outside in an environmental protection area

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ABSTRACT. This is paper we analyze the diet and body condition factor (Mi) of three endemic species inside and outside an environmental protection area, to compare the effectiveness of the protection area in providing a greater spectrum of food items and greater environmental well-being to ichthyofauna. The study area comprised streams of the Ribeira do Iguape River basin, Campos Gerais National Park (CGNP), Paraná state and its surroundings. Eleven streams were sampled inside and outside, using electric fishing. A Permutational Multivariate Analysis of Variance to investigate the composition of food items and a Permutational Analysis of Multivariate Dispersions was used to investigate the variability between food items. The Scaled Mass Index (Mi) of the body condition was used to determine the relative condition factor of each individual of each species. Regarding the diet, there were no significant differences between inside and outside in the composition and variability of food items, this similarity may be associated with existing environmental degradation inside. However, the Mi was significant, and only one species presented greater well-being inside, because inside streams receive greater allochthonous intake of riparian vegetation, but, when it comes to the two species that perform the link of the aquatic food web with the terrestrial, the opposite occurred. These results indicate that the studied fragment, under anthropic pressures, is currently unable to conserve its biodiversity. The inside has no Management Plan, the manager must elaborate and implement it as a first step so that the situation can be reverted and the conservation effectiveness ensured in this highly threatened area, characterized by being one of the most important remnants of the Atlantic Forest, having relevant ecosystem services from a rare humid forest of Araucaria.

KEYWORDS. Freshwater endemism, conservation of species, mixed ombrophilous forest, national park, food variability.

RESUMO. Fator de condição corporal e dieta da ictiofauna endêmica em riachos da Mata Atlântica dentro e fora de uma área de proteção ambiental. Neste trabalho, analisamos dieta e fator de condição corporal (Mi) de três espécies endêmicas dentro e fora de uma área de proteção ambiental, para comparar a efetividade da área protegida em subsidiar maior espectro de itens alimentares e maior bem-estar ambiental à ictiofauna. A área de estudo compreendeu riachos que fazem parte da bacia hidrográfica do Rio Ribeira de Iguape, interior e imediações do Parque Nacional dos Campos Gerais (PNCG), estado do Paraná. Foram amostrados 11 riachos dentro e fora, com auxílio de pesca elétrica. A Análise de Variância Multivariada Permutacional foi usada para investigar a composição dos itens alimentares e a Análise Permutacional de Dispersões Multivariadas para investigar a variabilidade entre os itens alimentares. O Índice de Massa Escalonado (Mi) de condição corporal foi usado para determinar o fator de condição relativo de cada indivíduo de cada espécie. Para a dieta analisada não houve diferenças significativas entre dentro e fora, na composição e na variabilidade de itens alimentares, esta similaridade pode estar associada a degradação ambiental existente dentro. Entretanto, o Mi foi significativo, sendo que somente uma espécie apresentou maior bem-estar dentro, porque os riachos de cabeceira de dentro recebem maior aporte alóctone de vegetação ripária, porém, quando se trata das duas espécies que realizam o elo da teia alimentar aquática com a terrestre ocorreu o contrário. Esses resultados indicam que o fragmento estudado, submetido a pressões antrópicas, apresenta-se incapaz de conservar essa biodiversidade. O interior não tem plano de manejo, o gestor deve elaborá-lo e implementá-lo como um primeiro passo para que a situação possa ser revertida e a efetividade da conservação assegurada nessa área altamente ameaçada, caracterizada por ser um dos remanescentes mais importantes da Mata Atlântica, possuindo relevantes serviços ecossistêmicos oriundos de uma rara floresta úmida de Araucária.

PALAVRAS-CHAVE. Endemismo de água doce, conservação de espécies, floresta ombrófila mista, parque nacional, variabilidade alimentar.

The Atlantic Forest Biome is considered as a biodiversity hotspot as it supports both high species richness of multiple taxa, high endemism rates, but it is simultaneously threatening by anthropic actions (MYERS *et al.*, 2000), being

one of five priority areas for conservation in Brazil (BRAZIL, 2004) and one of the 35 biodiversity hotspots for conservation prioritization (MYERS *et al.*, 2000). The creation of areas for conversation is needed as without it occurs a disorderly

exploitation of natural resources and human land appropriation (PINTO *et al.*, 2006), which have led to changes in chemical, physical (ALLAN *et al.*, 1997) and biological properties of inland aquatic ecosystems (ENGLERT *et al.*, 2015). Therefore, environmental protection areas in the Atlantic Forest are considered vital to prevent and mitigate pervasive anthropic impacts on biodiversity (MARGULES & PRESSEY, 2000).

Campos Gerais National Park (CGNP), IUCN's category II (PFAFF *et al.*, 2015), is one area of Atlantic Forest characterized by a vegetation categorized as mixed ombrophilous forest and steppes by VELOSO *et al.* (1991), predominantly of araucaria moist forest and southern fields, considered the largest natural remnant protected by law (BRAZIL, 2006), comprising the less fragmented portions of the regional native fields as well (ALVES *et al.*, 2019). The surroundings and interior of the CGNP present singular hydrography and land relief, as a result of the conjugation of a variety of geological, climatic, topographic factors (MELO *et al.*, 2010). The aquatic ecosystems of the region run through deep and mountainous areas, composing a unique scenic beauty and a valuable biodiversity heritage (MELO *et al.*, 2010). The streams of the CGNP region are in the Paraná River and Ribeira do Iguape River basins (MELO *et al.*, 2010). The variations in abiotic factors, such as water temperature, light and pH in streams of these region, provided different micro habitats and harbor a diversity of organisms, underlying the emergence of endemism areas. The streams constitute a large part of the drainage areas in the Neotropical region (BERKOWITZ *et al.*, 2014) and despite their small size, they are constituted by a rich aquatic fauna with peculiar characteristics (DUDGEON *et al.*, 2010) and that present a high level of vulnerability when it comes to habitat degradation (ALVES *et al.*, 2016).

Endemism is directly related to the historical and ecological characteristics of each species, which are observed within the evolutionary process of the entire local biota (CARVALHO, 2009). In freshwater streams, endemism is recurrent due to the existence of natural barriers, or even lack of connection between biomes, habitats reduction, changes in relief or the presence of reservoirs (RICKLEFS, 2011), which isolate the species in a given place, causing directional selection and originating an endemic species (BURLAKOVA *et al.*, 2011).

The food items ingested by fish (trophic ecology) may inform which resources available in the environment are being exploited (ABELHA *et al.*, 2008) and its relation to fish weight-length relationships, a proxy for the growth type of fish (LE CREN, 1951; GOMIERO & BRAGA, 2006). Protected areas have a greater diversity of fauna and flora (MARGULES & PRESSEY, 2000), and are usually limited by freshwater, which ends up being also conserved (THIEME *et al.*, 2016), in addition, ensuring the input of allochthonous resources into the aquatic system, especially in headwaters streams

(VANNOTE *et al.*, 1980), providing more food resources available to fauna.

In this context, we investigated the diet and body condition factor of endemic fish species from the Campos Gerais region, and we hypothesized that the diversity in fish diet and the degree of well-being in stream fish are related to the existence of areas for conservation. If so, then we would observe greater variability of food items in their diet and higher values of body condition factor in endemic fish species sampled in streams within than outside the protected areas. This information will be fundamental for identifying the effectiveness of this protected area of the Atlantic Forest. Furthermore, it will allow the taking of actions aimed at ensuring the maintenance of this area, its management and monitoring, as well as identifying the need to create new fragments for protection.

MATERIAL AND METHODS

Study area. The study area comprised streams that are part of the Ribeira do Iguape River basin, Campos Gerais National Park (CGNP) and its surroundings (Fig. 1), which covers part of the municipalities of Castro, Carambeí and Ponta Grossa, Paraná state (MELO *et al.*, 2010). The area of the studied basin is highly relevant for the preservation of remnants of the Atlantic Forest, its high levels of diversity and fish endemism explain the river dynamics promoted by the Ponta Grossa Arc, a geological structure that promotes headwater species retention events, which promote isolation between the drainages of the upper Paraná River, the Iguape River and the Ribeira de Iguape River (FROTA *et al.*, 2019).

Sampling stretches were previously selected in the ArcGIS Program, through the delimitation of the watersheds of first, second and third order streams. SRTM images with spatial resolution of 100m were used to generate the water network and later the drainage basins, corrected with procedures for filling depressions and sinks. The water network was identified using images and classified using STRAHLER (1953) ordering assigning orders to its segments.

Twenty-two streams were selected, 11 in the protected area of the Campos Gerais National Park (inside) and 11 in the unprotected area (outside), quarterly samplings were carried out from July 2016 to April 2017 (Fig. 1). The streams within the inside have land occupation of these streams is native forest, fish farming, rural properties and pasture fields (ALMEIDA & MORO, 2007). Land occupation outside is characterized by reforestation of *Pinus* sp., fish farming, pasture fields, forestry and rural properties (ALMEIDA & MORO, 2007).

Sampling sites. The abiotic variables of water temperature, dissolved oxygen concentration, pH and electrical conductivity were measured inside and outside the

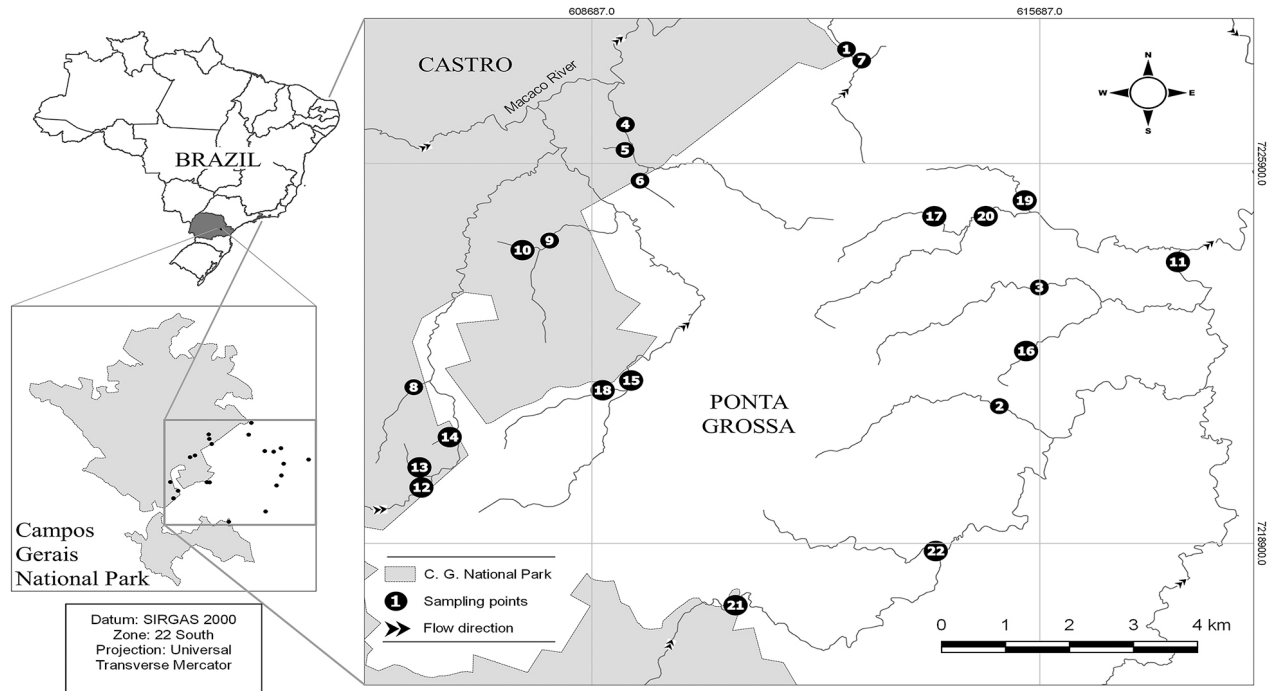


Fig. 1. Study area with the location of sampling points (numbered black circles) in streams from the Ribeira de Iguape river basin. The gray area corresponds to the Campos Gerais National Park.

protected area, using an analog thermometer, portable digital oximeter and portable digital potentiometers, respectively.

Fish collections were carried out in 2016, from July 17 to 23 and October 10 to 15, and in 2017, from January 23 to 27 and April 14 to 29 using electric fishing (maximum power of 3.8 Kw, max. 2A) with three constant and consecutive efforts (MAZZONI & LOBÓN-CERVIÁ, 2000) in a 30m stretch. The stretch was closed with a locking net (mesh 2.5 mm) at both ends to avoid fish escape and electrodes were kept at a distance of 1–2 m. Fishes were anesthetized with hydrochloride benzocaine solution (Ethics Committee on the Use of Experimental Animals process of Universidade Estadual de Maringá, nº 38981407/16) and fixed in 10% formaldehyde solution. Specimens were deposited in the Ichthyological Collection of the Núcleo de Pesquisa de Limnologia, Ictiologia e Aquicultura (Nupélia) of the Universidade Estadual de Maringá (UEM). Throughout the study, 15 and 23 species were sampled in the inside and outside areas, respectively, with *Coptodon rendalli* (Boulenger, 1897) being a recent invasive species (see FROTA *et al.*, 2019). Among the sampled species, the endemic that occurred both inside and outside were selected: *Deuterodon iguape* Eigenmann, 1907, *Geophagus iporangensis* Haseman, 1911 and *Isbrueckerichthys duseni* (Miranda Ribeiro, 1907), they stand out among the most frequent for the study area (LIMA *et al.*, 2003). From each sampled individual, standard length (Ls) and total weight (Wt) were obtained. The standard length was measured with a digital caliper (Absolite Mitutoyo) with

an accuracy of 0.1 mm, while the total weight was obtained with an electronic scale, with an accuracy of 0.1g.

The individuals had their stomachs dissected and their contents were analyzed with a stereoscope microscope. The diet of each species was evaluated and the food items were identified up to the lowest possible taxonomic level. The volumetric frequency methods (%V) (HYSLOP, 1980) were used, recording the volume of each food item, obtaining the percentage in relation to the total volume of stomach contents. The volume of each item was obtained in mm³ through a millimeter plate and later transformed into ml (HELLAWELL & ABEL, 1971).

Statistical analyses. The composition of food items of the specimens was investigated in the inside and outside. For this purpose, the permutational multivariate analysis of variance (PERMANOVA) (ANDERSON *et al.*, 2008) was used, applied on the matrix of food items data analyzed per stomach, with volume values of the food items. The variability between food items inside and outside was evaluated by the permutational analysis of multivariate dispersions (PERMDISP) (ANDERSON *et al.*, 2006). Thus, the beta diversity of the compositions of the food items was evaluated for the inside and outside, from the mean distance of each sample to the centroid in a multidimensional space.

Bray-Curtis dissimilarity was used in the permutation analyses as a distance measure with data transformed into square root, obtained with 999 random permutations, and the analyses were conducted in the software R (R CORE

TEAM, 2019) using the beta disper function in vegan package (OKSANEN *et al.*, 2020). This function is one of the ways for calculating PERMDISP (ANDERSON *et al.*, 2006). Variance tests were performed in the software Statistica 7.0 program (STATSOFT, 2005).

The weight-length relationship was estimated using the expression $Wt = a * Ls^b$, where Wt = total weight, Ls = standard length, a = intercept and b = angular coefficient (LE CREN, 1951). The value obtained from the growth coefficient (b) was used to identify the growth type of the species. For this, the values obtained were submitted to the Student's T Test ($p < 0.05$); $b = 3$ the growth was considered isometric; $b > 3$ positive allometric growth and $b < 3$ negative allometric growth (BENEDITO-CECILIO & AGOSTINHO, 1997; TAH *et al.*, 2012). This t was used in order to verify whether the angular coefficient of each species was significantly different from the isometric value of 3.

To determine the relative condition factor of each individual of each species, the Scaled Mass Index of the body condition, proposed by PEIG & GREEN (2009) was used, which is computed from the equation: $\hat{M}_i = M_i(L_i/L_0)^{bsma}$, where M_i and L_i are the body mass and body length of individual i , respectively; L_0 is an arbitrary value of Ls , such as the arithmetic mean for the population; $bsma$ is the exponent estimated by the regression of M and L ; and \hat{M}_i is the predicted body mass for an individual i when the linear body measurement is standardized to L_0 . Then, the $bsma$ was estimated by dividing the value of b by the r coefficient of Pearson's correlation (LABARBERA, 1989). For L_0 , the arithmetic mean of the standard length of the population was calculated.

The significant difference of each species \hat{M}_i , inside and outside, was verified through the analysis of variance (ANOVA One-Way), in Statistica® 7.0 program (STATSOFT, 2005).

RESULTS

Limnological characteristics. The limnological characteristics of the streams located inside and outside had similar mean values (Tab. I)

Diet. For the 89 analyzed stomachs, it was found that there were no significant differences between those sampled inside and outside for the three species, regarding

Tab. I. Limnological characteristics the streams localized inside and outside the environmental protection area - Campos Gerais National Park, state of Paraná, Brazil. [T°C, water temperature (°C); DO, dissolved oxygen (%); pH, hydrogen potential; Cond., water electrical conductivity ($\mu S/cm^{-1}$); Mean \pm SD, mean values and Standard Deviation].

	Inside	Outside
T°C (Mean \pm SD)	18.4 \pm 1.26	18.35 \pm 1.40
DO% (Mean \pm SD)	70.12 \pm 3.73	78.14 \pm 5.72
pH (Mean \pm SD)	9.15 \pm 1.60	9.09 \pm 1.51
Cond. $\mu S/cm^{-1}$ (Mean \pm SD)	275.59 \pm 69.91	339.50 \pm 41.26

both composition and the variability of food items (Tab. II), and the values of the mean distances to the centroid were similar between inside and outside for food items (Tab. III) (*I. duseni* MDC-inside=0.20 and MDC-outside=0.26; *D. iguape* MDC-inside=0.49 and MDC-outside=0.52; *G. iporangensis* MDC-inside=0.46 and MDC-outside=0.42) (Fig. 2).

Tab. II. Average distances to the centroid obtained from Permdisp/Permanova with permutational analyses applied in the diet of species *Isbrueckerichthys duseni* (Miranda Ribeiro, 1907), *Deuterodon iguape* Eigenmann, 1907 and *Geophagus iporangensis* Haseman, 1911 between inside and outside of the environmental protection area - Campos Gerais National Park, state of Paraná, Brazil.

Species	Permanova	Permdisp
<i>I. duseni</i>	$F_{(1,28)}=1.09$; $p=0.31$	$F_{(1,28)}=0.63$; $p=0.44$
<i>D. iguape</i>	$F_{(1,27)}=1.55$; $p=0.10$	$F_{(1,27)}=0.20$; $p=0.66$
<i>G. iporangensis</i>	$F_{(1,28)}=1.34$; $p=0.21$	$F_{(1,28)}=0.42$; $p=0.53$

Body condition factor. A total of 497 individuals were measured and weighed. The weight-length relationship was significant for *I. duseni* in the inside and outside as positive allometric, with difference to the isometric standard value of 3, evaluated using the t -test (Tab. IV).

According to the ANOVA one-way, the M_i values differed between the inside and outside for the three species (ANOVA $p < 0.05$) (Fig. 3). The mean total weight and standard length values were lower for *I. duseni* outside and for *D. iguape* inside (Tab. IV).

DISCUSSION

The hypothesis proposed in this study was partially corroborated, because the variability of food items between the inside and outside did not differ. However, there was a significant difference in the body condition factor for the analyzed specimens, and only *I. duseni* presented higher body condition in the inside.

The diet of endemic species was similar between the inside and outside. This may be associated with environmental degradation in the inside, characterized by land use for forestry, fish farming, pasture fields and agriculture (ALMEIDA & MORO, 2007), which is one of the main causes of environmental homogenization (GOSSNER *et al.*, 2016). In aquatic ecosystems, biotic homogenization acts primarily by changing the physical, chemical and biological conditions of water, causing the loss of sensitive species and increasing tolerant species (e.g. LOUGHEED *et al.*, 2008). Besides, the fragmentation of the local landscape that occurs in the CGNP (ALMEIDA & MORO, 2007), directly influences local taxonomic diversity (alpha) (FERREIRA *et al.*, 2019), evidenced by the increase in similarity in the composition and variability of food items between the inside and outside. These impacts reduce the effectiveness of the environmental protection area, hence

Tab. III. Volumetric percentage (%) of the food items of *Isbrueckerichthys duseni* (Miranda Ribeiro, 1907), *Deuterodon iguape* Eigenmann, 1907 and *Geophagus iporangensis* Haseman, 1911 inside and outside the environmental protection area - Campos Gerais National Park, state of Paraná, Brazil. In parentheses the number of analyzed stomachs.

Items	Inside			Outside		
	<i>I. duseni</i> (7)	<i>D. iguape</i> (19)	<i>G. iporangensis</i> (13)	<i>I. duseni</i> (23)	<i>D. iguape</i> (10)	<i>G. iporangensis</i> (17)
<i>Aquatic</i>						
Amphipoda			3.12			0.32
Ceratopogonidae (Larva)		0.37	9.06	1.58		7.25
Chironomidae (Larva)	2.23	0.45	15	1.55	3.19	10.48
Coleoptera (Larva)		1.51	2.18		7.97	1.61
Debris/sediment	94.13	0.075		90.36	0.10	
Decapoda		2.5				1.61
Diptera (Larva)		0.68			0.42	
Diptera (Pupa)		1.36	6.25		9.04	1.29
Ephemeroptera	1.39	0.90	7.81	1.65	2.34	4.03
Filamentous algae (Zygnematophyceae)	0.83		0.93	1.07		1.93
Fish scale		0.75				
Mollusca						
Nematoda		0.22	0.93	0.77	1.17	
Odonata		4.54	6.25			9.67
Ostracoda			0.31			
Plecoptera			0.31		1.27	0.32
Simuliidae (Larva)	1.39			2.72	1.06	
Simuliidae (Pupa)				0.58		
Trichoptera (Larva)		0.75	36.87			44.35
<i>Terrestrial</i>						
Araneae		0.37			0.31	
Coleoptera (Adult)		7.12			5.10	0.80
Diptera (Adult)		0.30			1.59	
Hemiptera		2.65			5.31	1.61
Hymenoptera		9.92			9.46	0.48
Insecta		0.75			0.21	
Lepidoptera		8.33				4.03
Orthoptera		1.13				
Phanerogams		51.81	5.93	0.68	51.38	5.32
Trichoptera (Adult)						0.64
<i>Aquatic/Terrestrial</i>						
Acari			0.93			0.96
Insecta (Adult)		4.09				
Organic/Inorganic Matter			3.12			2.41

the resources available in the protected area did not provide a wider spectrum of food items for the analyzed endemic species, the first species to be affected by the simplification of freshwater ecosystems (BURLAKOVA *et al.*, 2011).

The standard length of the analyzed specimens, with low thresholds, characterize the individuals as fish of streams

(CASTRO, 1999), since they do not exceed 20 cm in length, corresponding to small-sized fish (VAZZOLER, 1996), typical of low-order streams, with low predominance of introduced species. This characteristic of ichthyofauna still indicates that ecosystem restoration measures can be implemented, especially regarding the landscape.

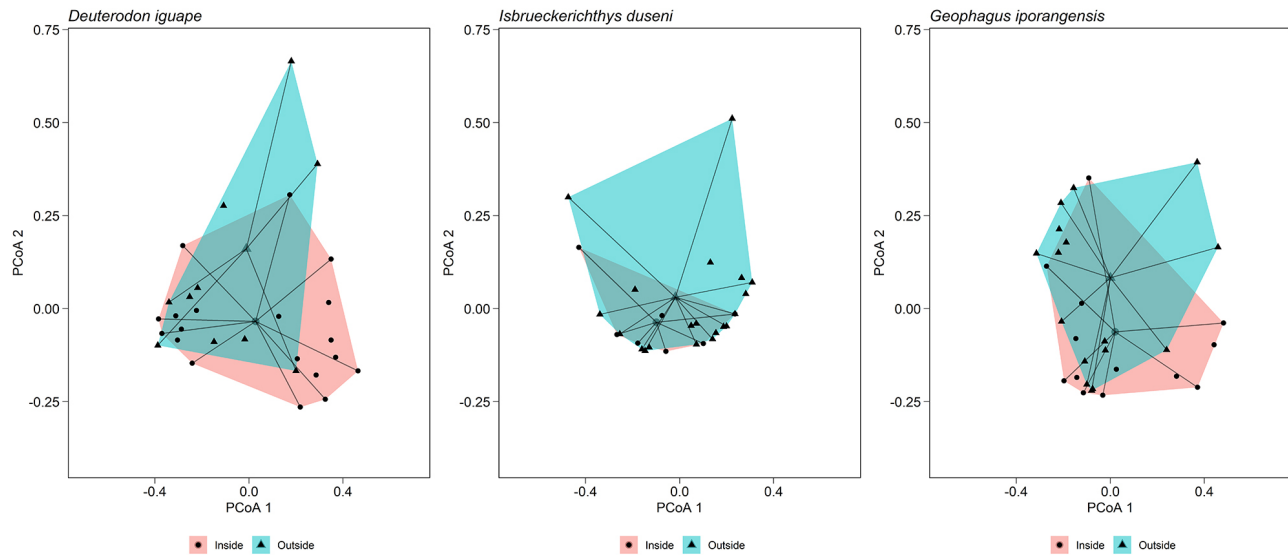


Fig. 2. Variability of food items of each species inside and outside of the Campos Gerais National Park, Paraná State, Brazil.

Tab. IV. Values of the weight-length relationship obtained for each species inside and outside the environmental protection area - Campos Gerais National Park, state of Paraná, Brazil. Number of individuals (N); mean values and Standard Deviation (SD) of standard length (Ls); total weight (Wt); coefficient b; Test *t* value (*t*); significance of the Test *t* (*p*-value), Pearson coefficient and exponent bsma (value of b by the coefficient r of Pearson's correlation).

Species	N	Ls (cm) (Mean±SD)	Wt (g) (Mean±SD)	Coefficient b	<i>t</i>	<i>p</i> -value	r ²	Exponent bsma
Inside								
<i>Isbrueckerichthys duseni</i>	24	6.90±1.38	9.61±6.59	3.1276	3.899	0.000	0.97	3.21
<i>Deuterodon iguape</i>	182	5.22±1.05	3.31±1.05	3.0173	0.067	0.946	0.97	3.11
<i>Geophagus iporangensis</i>	74	5.17±2.29	8.62±12.33	3.0563	1.357	0.177	0.99	3.08
Outside								
<i>Isbrueckerichthys duseni</i>	119	4.83±2.02	4.63±6.27	3.0627	3.104	0.002	0.99	3.09
<i>Deuterodon iguape</i>	12	7.63±1.02	10.34±4.29	2.7467	-4.302	3.999	0.88	3.11
<i>Geophagus iporangensis</i>	86	6.62±2.13	13.84±12.75	3.0412	0.611	0.542	0.98	3.08

This fact is corroborated by the analysis of the structure in length of the species, allowing inferences about the previous environmental conditions, which are reproduced in their current growth (BENEDITO-CECILIO & AGOSTINHO, 1997). Thus, the presence of individuals in varying lengths of size, for both species mainly in outside, indicates that there are coexisting age groups, in space and time (CIONEK *et al.*, 2012), suggesting that these streams have potential and favorable conditions for their development. The reduced dimensions of the body of the individuals favor their movement in streams, besides the ease of using substrates as shelter (CASTRO & MENEZES, 1998), since the streams of the Ribeira de Iguape River basin, surroundings of Campos Gerais National Park (outside), have numerous allochthonous substrates, forming micro-habitats (OYAKAWA *et al.*, 2006), resulting in the survival success of the species.

In fish, weight-length relationship parameters may vary according to the season, being affected by eating habits, sex and gonadal maturation (BAGENAL & TESCH, 1978). In this scenario, the analysis of coefficient b provides

information on fish growth, through the weight-length relationship (LE CREN, 1951). *Geophagus iporangensis* and *D. iguape*, growth was characterized as isometric, indicating that weight is directly proportional to the standard length of the individual (FERREIRA *et al.*, 2017), and for *I. duseni* the positive allometric growth found indicates that the population acquires greater biomass in relation to length, both in inside and in outside. This difference between the growth types may be associated with the different population size thresholds or with the differences in the feeding of these individuals.

The analysis of the body condition factor indicated that *I. duseni* presents higher Mi in the inside. This may be associated with the fact that the CGPN headwater streams receive greater allochthonous intake of riparian vegetation, having a higher availability of organic matter, and as this species has a detritivore diet it is possible to infer that this directly influences the greater well-being in the environment, due to the availability of better quality resources from native vegetation inside the National Park.

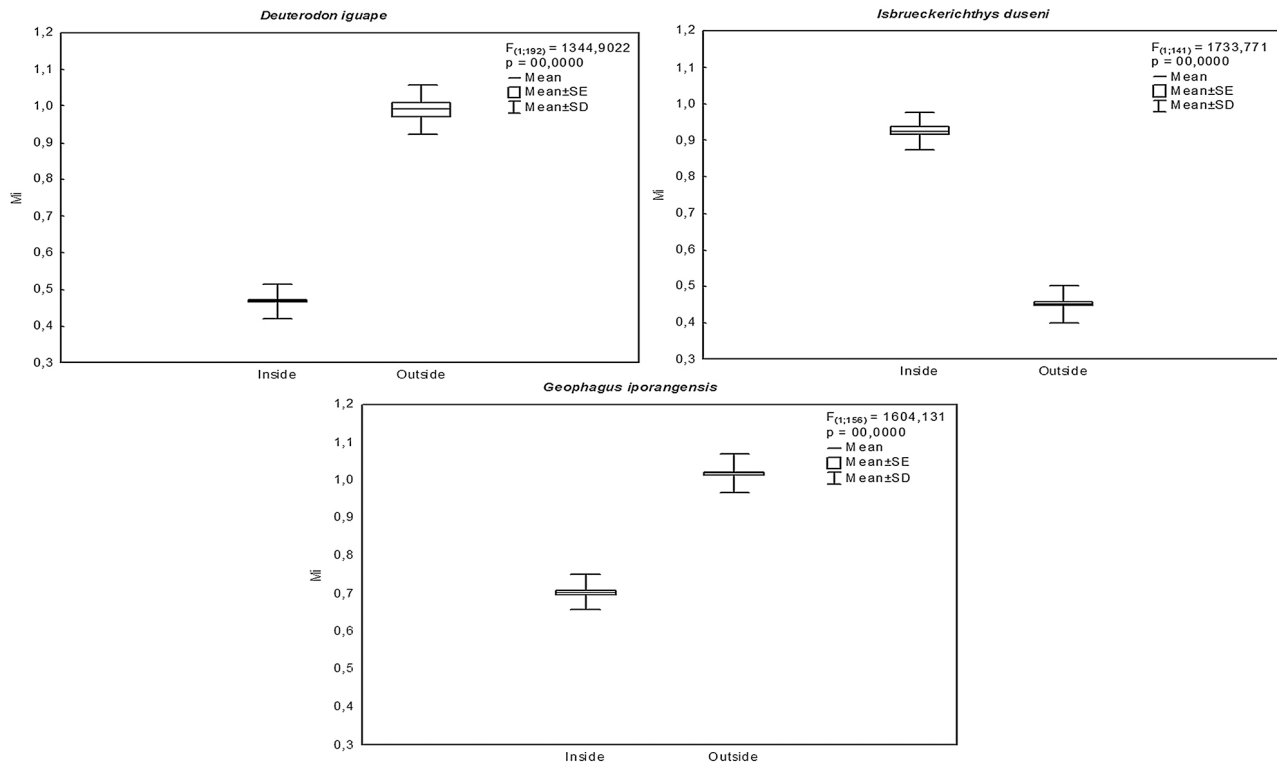


Fig. 3. Values of the body condition factor of the species inside and outside the environmental protection area - Campos Gerais National Park, Paraná state, Brazil.

The body condition factor is an index that reflects the recent nutritional conditions and/or expenses of reserves in cyclical activities, and it is possible to relate it to environmental conditions and behavioral aspects of the species (GOMIERO *et al.*, 2010). This index is used in the study of fish biology, mainly to evaluate feeding and reproduction processes (LIMA-JUNIOR *et al.*, 2002). Variations in the body condition of individuals may be influenced by intrinsic factors of the species (*i.e.* organic reserves, reproductive stage, individual size), and by extrinsic factors (*i.e.* availability of food resources, water temperature, photoperiod) (GURGEL *et al.*, 1997).

However, for the other two species, *G. iporangensis* and *D. iguape* the *Mi* was lower in the inside, indicating that this is a reflection of biotic and abiotic alterations of the area, since the inside suffers anthropic influences, such as the presence of rural property and forestry (*e.g.* ALMEIDA & MORO, 2007; DALAZOANA & MORO, 2011). Thus, changes in pristine landscapes, caused by anthropization, can modify the natural morphology of aquatic channels (MEDEIROS *et al.*, 2008), water properties (OMETO *et al.*, 2000), substrate type (BELTRÃO *et al.*, 2009), and the characteristics of the riparian zone (ALLAN, 2004). All these changes result in variations in the flow of energy between the terrestrial and aquatic environment, influencing the food items present inside the streams (JONSSON & STENROTH, 2016). The invertivorous

and omnivorous feeding habits of *G. iporangensis* and *D. iguape*, respectively, highlight this effect of the landscape on the structure of the food chains of the analyzed streams (OYAKAWA *et al.*, 2006). Invertivore species, when feeding on invertebrates, promote the connection between terrestrial and aquatic environment (FIGUEIREDO *et al.*, 2019), as well as omnivorous species that, when using carbon from animal and plant sources, transfer energy from different lower levels of the chain to higher trophic consumers (BRANDÃO-GONÇALVES *et al.*, 2010).

Another factor that is capable of altering well-being is the presence of the invasive species *Coptodon rendalli* (tilapia), probably introduced by the fishery production that occurs in the inside (FROTA *et al.*, 2019). Invasive individuals such as tilapia are able to alter the entire local structure, because of competition for space and food (RUARO *et al.*, 2020), modification of the substrate, increase in eutrophication and changes in limnological parameters (CÓRDOVA-TAPIA *et al.*, 2015). This invasion directly affects native species, causing them to have to allocate the energy obtained from the food consumed for survival, even for isometric growth. Thus, the lower condition factor recorded for these species in the inside may reflect on their energy expenditure, which may be caused by factors extrinsic to the aquatic environment (*e.g.* KLONTZ, 1995). In view of this, it is explicit that although the location of the headwater streams

are in the Ponta Grossa Arc and at high altitudes that assist in the development of endemic fauna, the Campos Gerais National Park is not effectively fulfilling its role as a National Park (*i.e.* protecting the integrity of endemic species, since the areas inside and outside the park have suffered constant threats about its exuberant biota (ALVES *et al.*, 2018)), and thus anthropic actions lead to exacerbated environmental homogenization. The results presented here show that this fragment, due to the different anthropic pressures to which it is subjected, is insufficient to protect the biodiversity of the Biome. Expanding this protected area or even allowing the protection of more fragments can reduce the impacts on the regional biota, especially regarding the aquatic organisms.

Moreover, the lack of a management plan for the Campos Gerais National Park increases the loss of effectiveness in the protection of biodiversity. This plan, once written and implemented, will be an important tool for the conservation of one of the most important remnants of the Atlantic Forest, that possesses a rare Araucaria moist forest with relevant ecosystem services. It is worth noting that the frequent threat that this ecosystem has been suffering (ALVES *et al.*, 2018; FROTA *et al.*, 2019) requires that more studies occur in the area, in order to support managers and governmental agencies, especially regarding the aquatic biota, considering that this is the first study conducted in the area.

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