Biology and dominance relationships of the main fish species in the Lake Encantada, Ilhéus, Brazil

Biologia e relações de dominância das principais espécies de peixes na Lagoa Encantada, Ilhéus, Brasil

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Abstract: Aim: Lake Encantada, in the basin of Almada River (State of Bahia), is inhabited by native and introduced species. The objective of this study was to report the species occurring in the lake and to detect dominance patterns. The species studied were *Prochilodus argenteus*, *Oreochromis niloticus*, *Clarias gariepinus*, *Genidens genidens*, *Eugerres brasilianus*, and *Centropomus parallelus*, the three former introduced, the latter ones native. **Methods:** Fish samples were obtained with gillnets from May/02 to February/04. Length-weight relationships and gonad maturity were estimated for all these species. **Results:** Temporal variations in the gonad maturity suggest reproductive activity occurring in summer for *P. argenteus* and *G. genidens*, with an average length at first maturity of 24.5 and 20.7 cm, respectively. However, for *P. argenteus* no evidence of spawning was observed in the lake. No reproductive activity was observed for *C. parallelus*, *E. brasilianus*, and *O. niloticus*, as all individuals were immature. **Conclusions:** The abundance/biomass comparison curve showed a moderately disturbed configuration that could be associated with the introduction of species.

Keywords: freshwater, non-native species, reproduction, length-weight relationship, ABC curve.

Resumo: Objetivo: A Lagoa Encantada, na Bacia do Rio Almada (Estado da Bahia), é habitada por espécies nativas e introduzidas. O objetivo deste estudo foi determinar as espécies que ocorrem na lagoa e detectar padrões de dominância. As espécies estudadas foram *Prochilodus argenteus*, *Oreochromis niloticus*, *Clarias gariepinus*, *Genidens genidens*, *Eugerres brasilianus* e *Centropomus parallelus*, as três primeiras introduzidas e as três últimas nativas. **Métodos:** Amostras de peixes foram obtidas com redes de espera, de maio/02 a fevereiro/04. A relação peso-comprimento e o estágio de maturidade foram avaliados para todas estas espécies. **Resultados:** Variações temporais de maturação gonadal indicam atividade reprodutiva no verão para *P. argenteus* e *G. genidens*, cujos comprimentos médios de primeira maturação foram de 24,5 e 20,7 cm, respectivamente. Contudo, para *P. argenteus* nenhuma evidência de desova foi observada na lagoa. Nenhuma atividade reprodutiva foi observada para *C. parallelus*, *E. brasilianus* e *O. niloticus*, uma vez que todos os indivíduos eram imaturos. **Conclusões:** A curva de abundância/biomassa mostrou um padrão moderado de distúrbio, possivelmente associado à introdução de espécies.

Palavras-chave: água doce, espécies não nativas, reprodução, relação peso-comprimento, curva ABC.

Biological Limnology

1. Introduction

Introduced species may compete directly with native species for food or physical habitat, may interfere in the reproduction or maintenance of native species, or may prey upon or hybridize with native species (Stohlgren et al., 2006). In an analysis of the freshwater fauna in the U.S., Richter et al. (1997) concluded that the introduction of species was the second most common cause of threats.

According to Agostinho and Julio (1996), the European Inland Fisheries Advisory Commission (EIFAC) adopts the FAO definition of an introduced species as any (non native) species intentionally or accidentally transported and released by humans into an environment beyond its present range, which includes both allochthonous (originating from another river basin in the same country) and exotic species (originating from another country or continent). The introduction of fish species in Brazilian inland waters is a serious threat, which has affected different river basins (Agostinho and Julio, 1996). Most of the studies conducted in natural and artificial reservoirs indicated that the introduced species were unimportant both in number of species and abundance. In the Itutinga Reservoir (State of Minas Gerais), e.g., only one species out of the twenty-five species recorded was introduced (Alves et al., 1998). Two species were introduced out of thirty-nine in nine reservoirs located in the State of São Paulo and out of fifteen reported in the Lajes Reservoir (State of Rio de Janeiro) (Castro and Arcifa, 1987; Araújo and Santos, 2001). In the Segredo Reservoir (State of Paraná), exotic species represented only 3.5% of the total number of individuals recorded (Agostinho et al., 1997).

However, in some of these places the importance of the introduced fish species has increased. In the Guarapiranga Reservoir (State of São Paulo), five species were introduced out of the twenty recorded, with tilapia *Oreochromis niloticus* being the most frequent (Barbieri et al., 2000). In the four lakes of the Rio Doce Valley (State of Minas Gerais), six out of the 27 species were introduced, *Pygocentrus* sp. alone representing 43% of the total abundance (Sunaga and Verani, 1997). In the State of Paraná, in the Taquaruçu Reservoir, the three most abundant species were among the fourteen introduced (Britto and Carvalho, 2006).

In most examples of intentional or accidental introductions, it is difficult to determine the effects of the introduction on other species because we have no information of the pre-introduction condition. However, successful conservation of biodiversity relies on a solid knowledge of the ecological requirements of native species, the causes of their loss, and the survival requirements of the remaining threatened species. The Abundance/Biomass Comparison curve (ABC) was proposed as a technique to assess the occurrence of disturbance on invertebrate communities by comparing dominance in terms of abundance and biomass (Warwick, 1986). ABC curves have been used to assess impacts as diverse as pollution and fishing on marine (Yemane et al., 2005) and freshwater (Coeck et al., 1993) communities. Considering that the introduction of exotic species may alter the community structure of invaded areas, ABC curves could be used to assess this impact.

The occurrence of introduced species in the Lake Encantada (Ilhéus, Bahia) was reported by Rocha and Schiavetti (2007); however, the effects of this introduction were not assessed. The aim of the present study is to improve our understanding of the biology of the dominant fish species and to investigate possible effects of the introduced species on the dominance relationships in the Lake Encantada.

2. Material and Methods

2.1. Study area

The Basin of the Almada River, located in the south of the State of Bahia, has a drainage area of 1,545 km² and a perimeter of 252 km. The main watercourse is the Almada River with an extension of 138 km. Lake Encantada (14° 36' 38" S and 39° 08' 33" W) is formed by a depression in the basin of the Almada River, and has an area of 650.5 ha and a perimeter of 13.3 km (Figure 1). The region has an average annual temperature of 23.3 °C and a highly seasonal pattern of rainfall, occurring mainly from November to April and an annual average of 1,717 mm (Bahia, 2001).

2.2. Biological data and analyses

One fish sample was monthly obtained from 10:00 PM to 6:00 AM from May/02 to February/04. Gillnets 34-61 m long with a stretched mesh size of 75-90 mm were used. Fish species were identified according to Menezes and Figueiredo (1980), and Bizerril (1994).

We only studied species for which more than 20 specimens were sampled: the introduced *Prochilodus argenteus* Spix and Agassiz, 1829 (Prochilodontidae), *Clarias gariepinus* (Burchell, 1822) (Clariidae), and *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae), and the native *Centropomus parallelus* Poey, 1860 (Centropomidae), *Eugerres brasilianus* (Cuvier, 1830) (Gerreidae), and *Genidens genidens* (Cuvier, 1829) (Ariidae). Voucher specimens were deposited in the fish collection at the Museum of Zoology, Universidade Federal da Bahia (UFBA).

In the laboratory, each specimen was weighed to the nearest 0.1 g (total weight - TW) and measured (total length - TL; cm). The length-weight relationship was calculated as $TW = a \cdot TL^b$ using a linear algorithm applied to the natural logarithm of both weight and length. Relationships were estimated for males and females separately whenever their numbers were higher than 20 and combined otherwise.

Gonads were removed and the developmental stage was macroscopically determined following Vazzoler (1996):
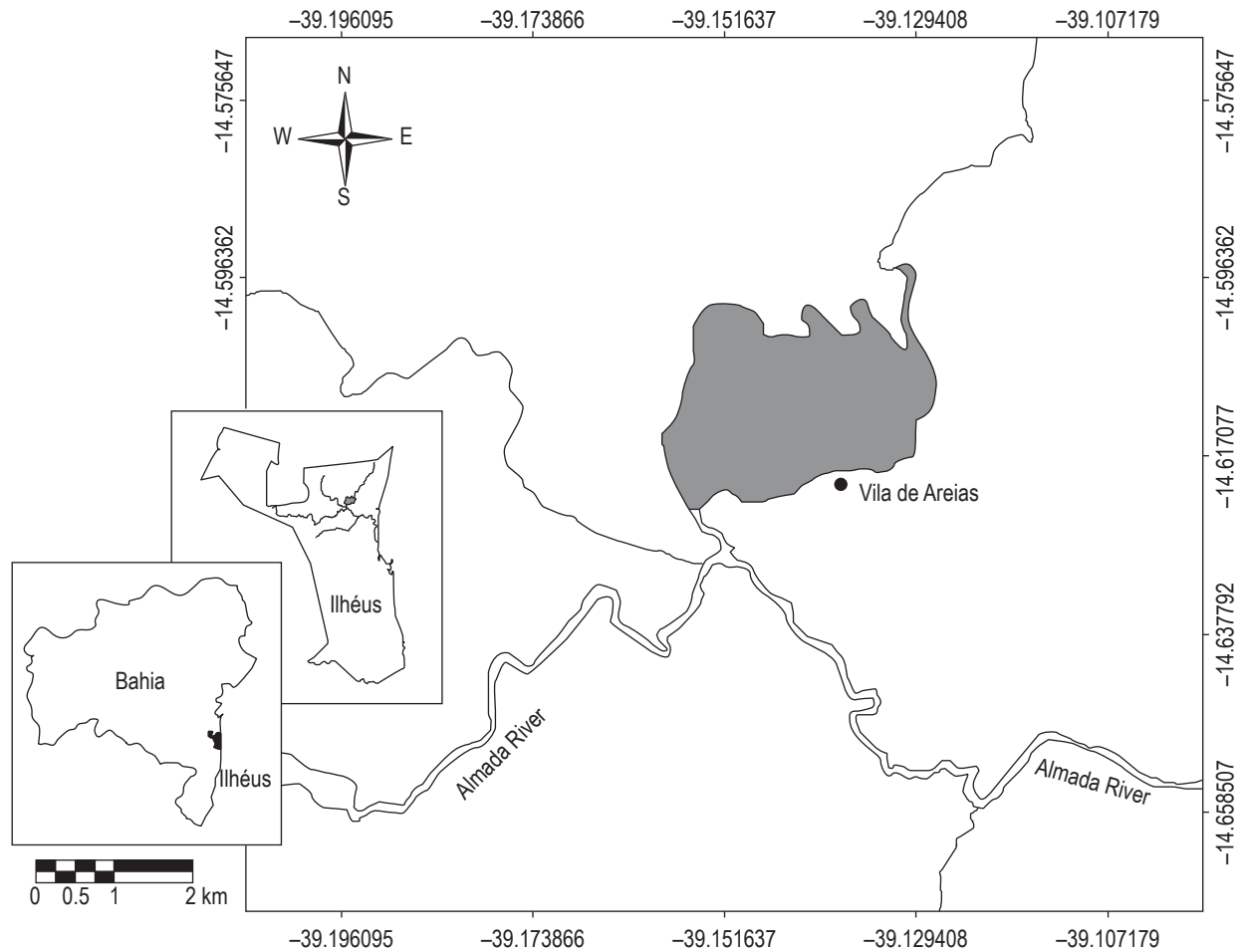
Figure 1. Map of Lake Encantada (right), Ilhéus (center), and State of Bahia (left).

I-Immature, II-Developing virgin or recovering-spent, III-Ripe, and IV-Spent. Undeveloped gonads were tiny transparent, thread-like, colourless organs. Following a gradual transition, fully-developed ovaries were large yellow structures, which almost fill the whole peritoneal cavity and have a grainy appearance due to the presence of mature oocytes. Maturing testes were white, long, and thick; sperm easily flows when pressed in the ripe testes.

The gonad-somatic index (GSI) was calculated for females using the gonad weight (GW; g) and the somatic weight (W; g) (Equation 1):

$$GSI = \frac{GW}{(W - GW)} \times 100 \tag{1}$$

The average total length at first maturity (TL_{50}) can be defined as the average length at which 50% of the individuals become mature. A logistic curve was fitted to the proportion of mature individuals estimated at length classes of 1 cm (Sparre and Venema, 1997) (Equation 2):

$$p = \frac{100}{1 + \exp(a + bTL)} \tag{2}$$

where p = percentage of mature individuals; TL = total length (cm), and a and b = specific parameters of the maturity curve.

Abundance/biomass comparison (ABC) curves were used following Warwick (1986) and the W value was calculated as (Equation 3):

$$W = \sum_{i=1}^{s} \frac{(B_i - A_i)}{50(S-1)} \tag{3}$$

where B_i = biomass of each species rank i, A_i = abundance of each species rank i, and S = number of species (Clarke, 1990). The W values range from −1 to +1; when W is positive, the biomass curve is above the abundance curve, when W is negative the opposite occurs.

3. Results

For each species studied, the number of specimens caught, length-weight relationships, size ranges, and length and weight mean values with standard deviation are given in Table 1 and Figure 2. The frequency distribution of length for each species is shown in Figure 3.

Table 1. Length-weight relationship parameters (a, b, r²), size ranges in length (cm) and weight (g), with minimum (min.) and maximum (max.), mean and standard deviation (sd) values observed per species in Lake Encantada (Ilhéus, Bahia). n = sample size; parameters were estimated only for species/sex with more than 20 individuals.

Species	n	a	b	r²	Total length (cm)			Weight (g)		
					min.	max.	mean (sd)	min.	max.	mean (sd)
Prochilodus argenteus	314	0.0264	2.860	93.7	15.1	44.8	27.5 (3.3)	44.9	1301.0	358.9 (122.0)
Male	20	0.0255	2.857	93.7	22.6	32.3	27.9 (3.1)	194.4	536.8	361.7 (102.9)
Female	221	0.0344	2.781	92.2	21.3	36.0	28.0 (2.9)	152.9	749.8	375.6 (108.6)
Genidens genidens	213	0.0044	3.135	91.7	16.0	32.0	22.6 (2.2)	26.5	272.3	80.3 (28.1)
Male	60	0.0079	2.951	90.4	16.0	28.5	22.9 (2.0)	32.4	160.9	84.0 (23.7)
Female	92	0.0025	3.313	92.5	16.5	32.0	22.7 (2.2)	27.7	272.3	81.8 (31.5)
Oreochromis niloticus	50	0.0102	3.219	96.0	17.0	28.5	24.6 (2.6)	94.2	497.0	316.7 (93.2)
Centropomus parallelus	45	0.0081	3.069	99.0	15.5	45.9	26.9 (9.4)	41.8	1069.9	282.0 (287.4)
Clarias gariepinus	33	0.0130	2.833	95.7	37.0	88.0	51.1 (11.3)	317.3	3938.8	1024.8 (811.6)
Eugerres brasilianus	32	0.0165	2.943	94.2	17.4	29.5	24.9 (2.8)	75.3	363.0	221.2 (68.4)
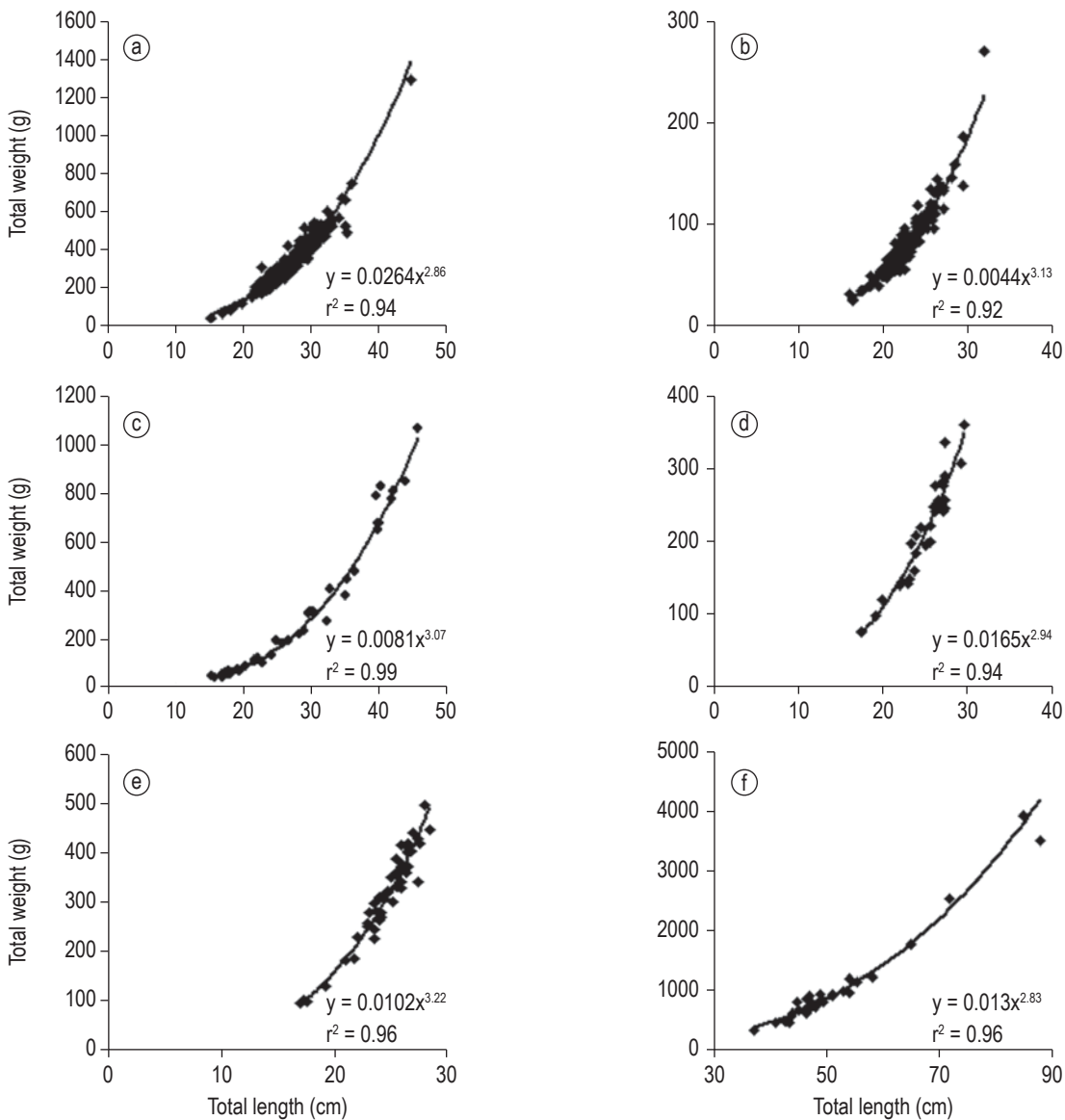
Figure 2. Length-weight relationships per species recorded in Lake Encantada (Ilhéus, Bahia): a) *Prochilodus argenteus*, b) *Genidens genidens*, c) *Centropomus parallelus*, d) *Eugerres brasilianus*, e) *Oreochromis niloticus*, and f) *Clarias gariepinus*.
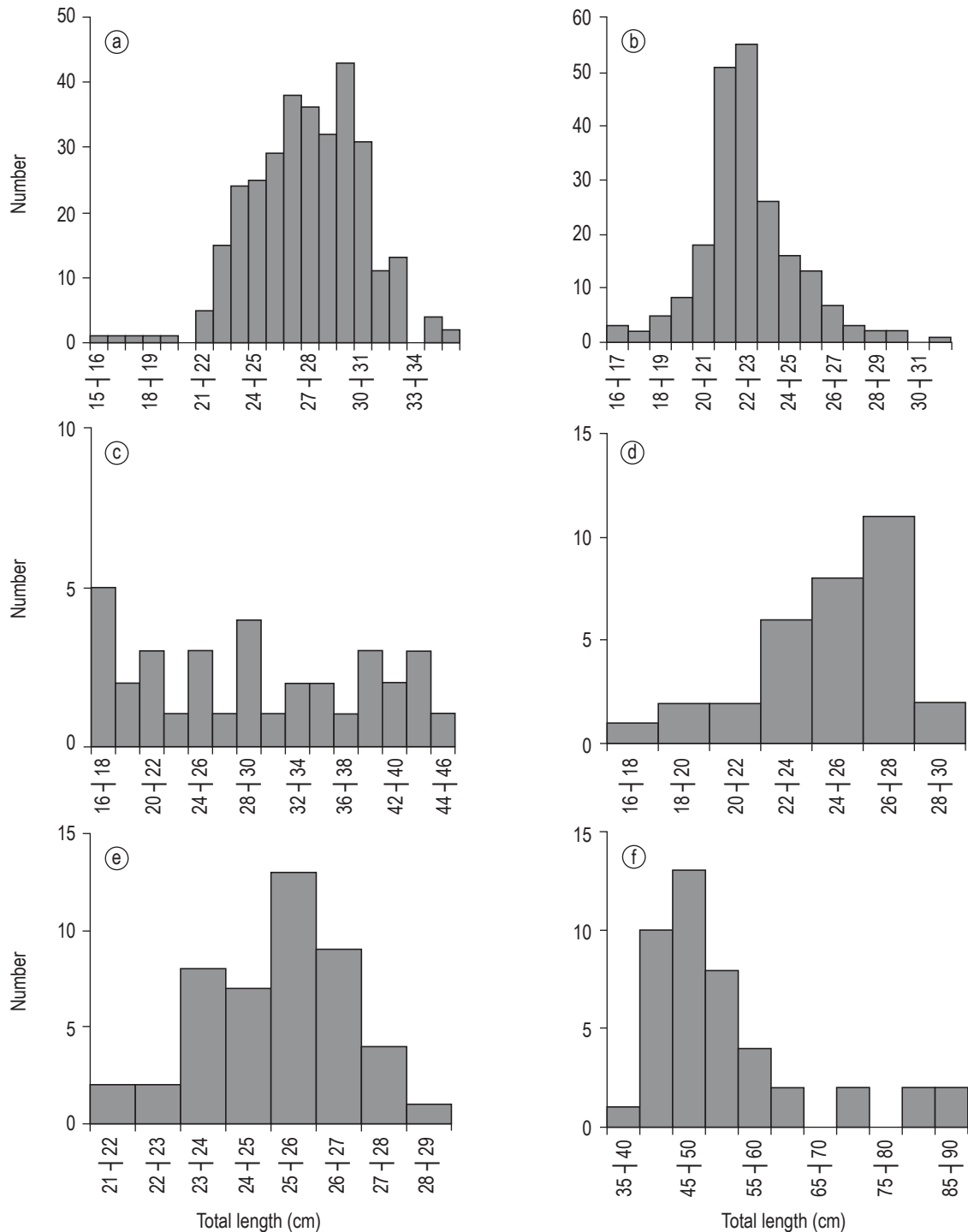
Figure 3. Frequency distribution of total length (cm) per species recorded in Lake Encantada (Ilhéus, Bahia): a) *Prochilodus argenteus*, b) *Genidens genidens*, c) *Centropomus parallelus*, d) *Eugerres brasilianus*, e) *Oreochromis niloticus*, and f) *Clarias gariepinus*.

Only *P. argenteus* and *G. genidens* had enough numbers to have their GSI and TL_{50} values determined. GSI values between 1.5 and 22.1 were observed for ripe females of *P. argenteus*; nevertheless, spent gonads were not recorded, suggesting that spawning does not occur in the lake. Its average total length at first maturity was 24.5 cm (Figure 4a). For *G. genidens,* the macroscopic ovarian stages and GSI

values between 3.1 and 10.9 for ripe females indicated a reproductive period in summer; a TL_{50} of 20.7 cm was estimated (Figure 4b). Brooding males were observed in the lake, but were not caught by gillnets.

No reproductive activity was observed for *C. parallelus* and *E. brasilianus*, as all individuals caught were immature. Most of the individuals of *O. niloticus* were females at stage

II and no spent gonad was observed. Data of gonad developmental stage of *C. gariepinus* were presented elsewhere (Rocha, 2008).

A total of thirteen species were recorded in the Lake Encantada during the sampling period. The dominance relationships represented by the ABC curve showed a moderately disturbed configuration with the abundance and the biomass curves superimposed over most of their length (W = 0.0; Figure 5).
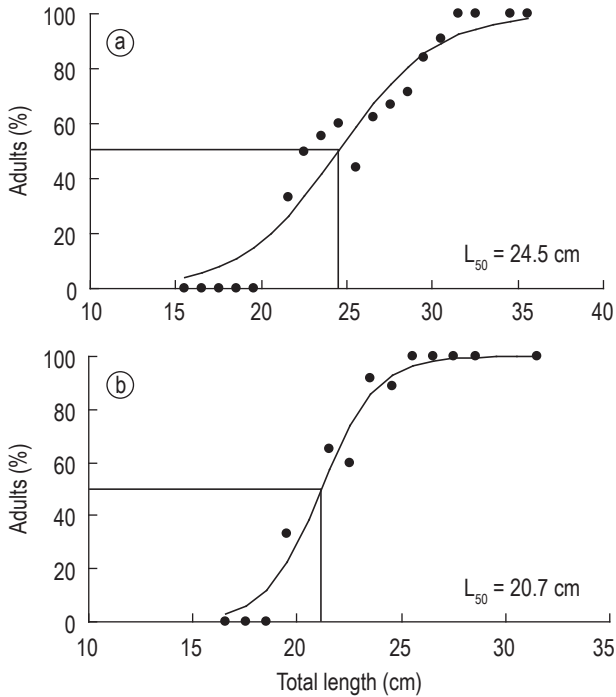
Figure 4. Frequency of adults (%) per total length (cm) and TL$_{50}$ for a) *Prochilodus argenteus*, and b) *Genidens genidens* caught by gillnets in Lake Encantada (Ilhéus, Bahia).
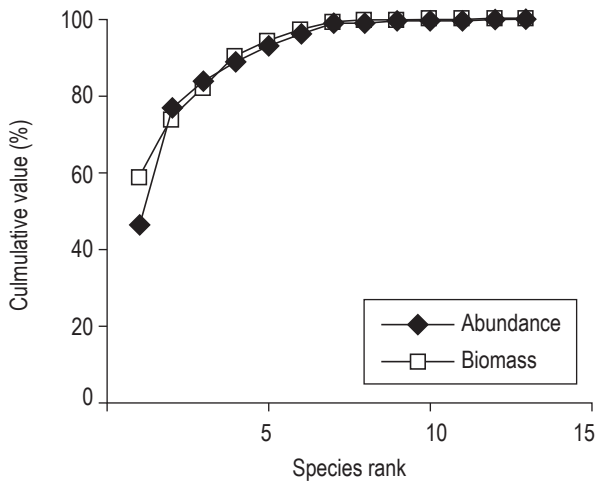
Figure 5. Abundance/biomass comparison (ABC) curve for fish species recorded in Lake Encantada (Ilhéus, Bahia).

4. Discussion

Even though weight and length are basic data obtained in most research programs, length is usually more rapidly measured and converted to weight using length-weight relationships. In the vast majority of instances where this relationship has been estimated, the 'b' value was different from three. Thus, most fish species do change their shape as they grow and a perfect cube law relationship between length and weight would hardly be expected (Le Cren, 1951). In fact, Carlander (1969) considered 2.5-3.5 as a more usual range for this relationship, as we have found in the Lake Encantada for all species studied. Froese (2006) suggested that values differing from this range could indicate growth stanzas, which were not observed here. It is worth noting that no length-weight relationship was available in FishBase (www.fishbase.org) for these species in Brazil, except for *G. genidens*.

The curimatá-pacu, *P. argenteus*, has been poorly studied, even in its endemic occurrence area. The maximum length caught in the Lake Encantada was far from the maximum length of 71 cm observed in the São Francisco River (Bazzoli, 2003). In the lower reaches of the Abaeté River, close to Três Marias Reservoir, GSI values between 7.3 and 22.9 were observed for ripe females of *Prochilodus marggravii* (= *P. argenteus*) (Sato et al., 2003). According to Bazzoli (2003), in the São Francisco River, the smallest stage-III male and female observed were 27.0 and 27.1 cm long, respectively, close to the TL$_{50}$ value we found. Even though the maturity size and GSI values found here are similar to the São Fransciso River, *P. argenteus* does not spawn in the Lake Encantada.

According to Stohlgren et al. (2006), climate and habitat matching, weak competition for resources from native species, and the use of previously under-used resources are some of the potential causes for the success of non-indigenous species, factors that added to the ileophagous habit of *P. argenteus* might have contributed to the success of this species in the Lake Encantada.

The guri sea catfish, *G. genidens*, is one of the most common fish species in Brazilian estuarine bays and lagoons. It has been reported in Jacarepaguá Lagoon (Barbieri et al., 1992) and Sepetiba Bay (Araújo et al., 1998), in the State of Rio de Janeiro, in Guaratuba Bay in the State of Paraná (Chaves and Vendel, 1996), and in Patos Lagoon (Araújo, 1988) and Peixe Lagoon (Loebmann and Vieira, 2005), both in the State of Rio Grande do Sul.

In Patos Lagoon, the individuals of *G. genidens* were 4.5-30 cm long and were more abundant in the head of the estuary (Araújo, 1988). In the Guaratuba Bay, lengths between 10.7 and 35.7 cm were reported for *G. genidens*; the species was considered a generalist carnivore (Chaves and Vendel, 1996), a feeding habit similar to that observed in Lake Encantada (Lemes, 2006). The TL$_{50}$ observed for females in Lake Encantada was higher than in the Jacarepaguá Lagoon (18 cm) and in the Cananéia lagoon estuarine system (15.5 cm) (Barbieri et al., 1992 and Mishima and

Tanji, 1983, respectively). In both systems, as well as in Lake Encantada, spawning occurs in summer.

The first introduction of a fish species in Brazilian inland waters might have been the genus *Tilapia* in 1953 (Nomura et al., 1972); this species, together with other genus commonly known as tilapia, seems to be the most widespread case of fish introduction in Brazil. Even though, the presence of Nile tilapia *O. niloticus* in natural watersheds has rarely been considered important, high abundance in the Guarapiranga Reservoir (State of São Paulo) being an exception (Barbieri et al., 2000). According to these authors, *O. niloticus* first maturity size is 7.6 cm. In Lake Tana, Ethiopia, *O. niloticus* 15-30 cm long were caught. The length at first maturity was 18.1 cm for females and 20.7 cm for males (Wudneh, 1998).

Despite its commercial importance, *C. parallelus* has scarcely been studied in natural watersheds in Brazil. In Guaratuba Bay, in the State of Paraná, individuals 14 to 70 cm long were caught by anglers; ripe individuals were common in summer, but there was no indication of spawning in the estuary (Chaves and Bouchereau, 2006). Most of the studies of this species were directed to production in captivity. Tonini et al. (2007) have studied its natural diet in the Lake Encantada to give support to its cultivation. Its presence in a protected environment and its tolerance to freshwater could facilitate its cultivation in net-cages in Lake Encantada, instead of the current cultivation of *O. niloticus*, a commercially less valuable and non-native species.

Rocha (2008) reported the occurrence of *C. gariepinus* in maturation stages in the Lake Encantada; GSI values of 0.10 to 0.74% and of 0.13 to 9.35% were recorded for males and females, respectively. In the Lake Tana, Ethiopia, the average length at first maturity (TL$_{50}$) was 30.5 cm for females and 36.0 cm for males (Wudneh, 1998). The maximum length caught in the Lake Encantada was similar to the maximum length of 87 cm observed in the Lake Tana. Large adult body size is one of the characteristics that distinguish a successful invading species, what might have contributed to the establishment of this species in the Lake Encantada (Rocha, 2008).

Biological invasions are recognized as a problem of growing severity, both from an ecological as well as an economic perspective. Introduced species thus appear to be additional threats for imperilled species whose distribution ranges and population sizes may have historically declined for some other reason.

The Almada River basin still maintains its natural hydrological regime and pollution sources are not reported in the area. Thus, we believe that the moderately disturbed configuration observed on the dominance curve in the Lake Encantada could be associated to the introduction of species. The effects of introduced species on the community dominance relationships have not been investigated in Brazilian aquatic ecosystems yet. However, some studies have reported changes in the dominance curves due to habitat degradation in some watersheds (Casatti et al., 2006; Pinto et al., 2006).

The occurrence of introduced species as dominant species in the Lake Encantada shows an alteration of the trophic structure of this ecosystem. The integration of *O. niloticus* and *C. gariepinus*, introduced no more than 15 years ago and now well-established in the lake, indicates how fast the effects of this introduction on other species could be felt, even if the lack of previous studies prevents determining the magnitude of these impacts. Because we cannot predict the effects of species introduction within food webs of aquatic ecosystems, preventing further introductions still is the best we can do to conserve native diversity.

Acknowledgements

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