

## Estimates of population parameters and consumption/biomass ratio for fishes in reservoirs, Paraná State, Brazil

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Consumption, natural mortality, and growth are important parameters for the construction for both fisheries and ecosystems models. We estimated  $k$  (growth constant of the von Bertalanffy's function),  $L_{\infty}$  (asymptotic length),  $W_{\infty}$  (asymptotic weight),  $Ar$  (caudal fin index),  $M$  (natural mortality), and  $Q/B$  (consumption/biomass ratio) for several fish species inhabiting reservoirs. We explored possible relationships among these parameters for 135 fish species sampled in thirty reservoirs in the State of Paraná, southern Brazil. Maximum length ( $L_{max}$ ) varied from 2.60 to 79.00 cm,  $L_{\infty}$  from 2.73 to 85.05 cm,  $W_{\infty}$  from 0.23 to 9,490.26 g,  $k$  from 0.01 to 2.38 yr<sup>-1</sup>,  $Ar$  from 0.03 to 3.60,  $M$  from 0.16 to 2.82 yr<sup>-1</sup>, and  $Q/B$  from 3.31 to 67.18. Significant correlations were observed between most pairs of parameters, except for  $Ar$  and  $k$ ,  $Ar$  and  $L_{\infty}$ , and for  $M$  and  $Q/B$ . The estimates presented here may be useful for constructing Ecopath models, both in Brazil and other tropical regions, where the use of ecosystem modeling is growing.

O consumo, a mortalidade natural e as estimativas de crescimento são parâmetros importantes para a construção de modelos pesqueiros e ecossistêmicos. Dessa forma, neste trabalho foram calculados os parâmetros  $k$  (constante de crescimento da equação de von Bertalanffy),  $L_{\infty}$  (comprimento assintótico),  $W_{\infty}$  (peso assintótico),  $Ar$  (índice da nadadeira caudal),  $M$  (mortalidade natural) e  $Q/B$  (consumo/biomassa) para peixes em reservatórios. Além disso, foram exploradas possíveis relações entre esses parâmetros para 135 espécies de peixes amostradas em 30 reservatórios no estado do Paraná, sul do Brasil. O comprimento máximo ( $L_{max}$ ) variou de 2,60 a 79,00 cm,  $L_{\infty}$  de 2,73 a 85,05 cm,  $W_{\infty}$  de 0,23 a 9.490,26 g,  $k$  de 0,01 a 2,38 ano<sup>-1</sup>,  $Ar$  de 0,03 a 3,60,  $M$  de 0,16 a 2,82 ano<sup>-1</sup>, e  $Q/B$  de 3,31 a 67,18. Correlações significativas foram observadas entre todos os pares de parâmetros, exceto para  $Ar$  e  $k$ ,  $Ar$  e  $L_{\infty}$  e para  $M$  e  $Q/B$ . As estimativas aqui apresentadas podem ser úteis para a construção de modelos Ecopath, tanto em outras regiões tropicais, como no Brasil, onde os modelos ecossistêmicos estão em amplo estágio de desenvolvimento.

**Key words:** Ecosystem approach, Lentic ecosystems, Population's variables.

### Introduction

Estimates of growth parameters for fish species are important not only to understand their life history and behavior, but also to manage fishery resources, since they allow estimating the potential productivity (Nikolsky, 1969; Gulland, 1977). Several studies point out to the lack of important biological parameters to estimate yield and give support to management, especially for tropical fish (Pauly, 1998a, 1998b; Beverton, 1998; Holt, 1998). Worldwide, it is known approximately 28,000 fish species (Nelson, 2006), among these only 1,400 (5%) have information on growth available (Binohlan & Pauly, 2000); in the Neotropical region such information should be even less available.

The knowledge of growth parameters (*e.g.* von Bertalanffy growth constant  $k$  and asymptotic length  $L_{\infty}$ , maximum reported length and age ( $L_{max}$  and  $t_{max}$ , respectively) as well as the consumption/biomass ratio ( $Q/B$ ), and natural mortality ( $M$ ) are important parameters for building ecosystems models (*e.g.* Ecopath; Christensen & Pauly, 1993), several other fishery models and, consequently, managing fishery resources (Froese & Pauly, 2000; Froese & Binohlan, 2000, 2003). In addition, these parameters allow testing life history theories and obtaining preliminary estimates of other parameters from those already available (Froese & Binohlan, 2000, 2003; Stergiou & Karpouzi, 2002; Stergiou & Karachle, 2006).

Examples of use of empirical equations for parameters estimation described above include asymptotic length from

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maximum reported length, natural mortality from growth parameters, optimum exploitation length from asymptotic length or length at first maturity, length at first maturity from asymptotic length and/or von Bertalanffy growth constant, trophic level from maximum reported length (Pauly, 1980; Froese & Binohlan, 2000; Stergiou & Karpouzi, 2002; Angelini & Agostinho, 2005a).

Recently, there has been an increase in the number of studies using the ecosystem approach, which justifies compiling the cited parameters values for future use in the building of Ecopath models. Moreover, information on Neotropical fishes can be uploaded to online databases, such as the FishBase (Froese & Pauly, 2010). Thereby, in this study, we estimated/compiled the parameters  $k$  (growth constant of the VBGF),  $L_{\infty}$  (asymptotic length),  $L_{\max}$  (maximum reported length),  $W_{\infty}$  (asymptotic weight),  $Ar$  (caudal fin index),  $M$  (natural mortality) and  $Q/B$  (consumption/biomass) for 135 Neotropical fish species collected in 30 reservoirs in the State of Paraná, southern Brazil. In addition, we evaluated possible significant relationships between  $k$  and  $L_{\max}$ ,  $k$  and  $L_{\infty}$ ,  $k$  and  $W_{\infty}$ ,  $k$  and  $M$ ,  $k$  and  $Ar$ ,  $k$  and  $Q/B$ ,  $L_{\infty}$  and  $Q/B$ ,  $W_{\infty}$  and  $L_{\max}$ ,  $M$  and  $Ar$ , and  $M$  and  $L_{\max}$ . Finally, we made a trophic categorization for all species considered in this study. All analyses were performed aiming at detecting patterns in the life history of those fish species.

### Material and Methods

**Study area.** The study reservoirs were located in six river basins (Paranapanema, Tibagi, Ivaí, Piquiri, Iguaçu, and Leste) throughout the State of Paraná and its borders with the States of São Paulo and Santa Catarina (Fig. 1; Table 1). Although the main purpose of these reservoirs is energy production, they are also used for water supply, and for fishing and leisure. Reservoirs were selected to include a diversity of areas, morphometries, hydraulic retention times and distribution throughout the state. More detailed description of some characteristics of each reservoir is presented in Table 1.

**Sampling.** Fishes were sampled in 30 studied reservoirs (Table 1); two samplings were carried out, one in July and another in November 2001. Samplings were conducted in the lacustrine zone of the reservoirs (following Thornton *et al.*, 1990) with 20-m-long gillnets of diverse mesh sizes (2.4, 3, 4, 5, 6, 7, 8, 9, 10, 12, and 14 cm opposite knots), set for 24 h and checked every 8 h. Seine nets (20 m long and 0.8 cm mesh) were used during the day in the littoral.

All fishes caught were fixed in formalin (4%), stored in polyethylene containers identified with date and capture site, and then sent to the laboratory of Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (Nupélia; Universidade Estadual de Maringá- UEM) for further analysis. Fish were identified according to Severi & Cordeiro (1994), Ingenito *et al.* (2004), Oyakawa *et al.* (2006), Graça & Pavanelli (2007) and Menezes *et al.* (2007), measured for length (total and standard, cm), and weight (total body weight, g).

**Data analyses.** Trophic categorization of most species was based on studies conducted in the reservoirs evaluated here. However, when it was not possible we used information from the literature. For this, additional references included Fugi & Hahn (1991), Hahn *et al.* (1991, 1992, 1997a, 1997b, 1998, 1999), Andrian *et al.* (1994), Souza-Stevaux *et al.* (1994), Andrian & Barbieri (1996), Ferreti *et al.* (1996), Lolis & Andrian (1996), Loureiro & Hahn (1996), Agostinho *et al.* (1997), Almeida *et al.* (1997), Gealh & Hahn (1998), Abujanra *et al.* (1999), Fugi *et al.* (2001, 2005), Ortêncio Filho *et al.* (2001), Cassemiro *et al.* (2002, 2003, 2005), Abelha & Goulart (2004), Russo *et al.* (2004), Abelha *et al.* (2005, 2006), Bennemann *et al.* (2005, 2006), Loureiro-Crippa & Hahn (2006), Oricolli & Bennemann (2006), and Cantanhêde *et al.* (2008).

For species with more than 50 individuals the parameters  $k$  and  $L_{\infty}$  were estimated from the sampled data. Growth parameters were obtained by fitting von Bertalanffy's growth constant function (VBGF; Ricker, 1975), which calculates the parameters  $k$  (growth constant) and  $L_{\infty}$  (asymptotic length), as follows:

$$L_t = L_{\infty} \times (1 - e^{-k(t-t_0)}),$$

where  $L_t$  is the total fish length (cm) at age  $t$ ,  $L_{\infty}$  is the asymptotic length (cm),  $k$  is VBGF's inclination or growth rate (year<sup>-1</sup>), and  $t_0$  is the age intercept (fish age is assumed to be zero).

Asymptotic length ( $L_{\infty}$ ) and  $k$  were calculated, whenever possible, using length-frequency data and FISAT's ELEFAN I routine (Sparre *et al.*, 1989; Gayanilo & Pauly, 1997), with the option of scanning for  $k$ -values. This routine estimates VBGF's adherence to length frequency data. Sometimes, the best-fitted  $k$  value was corroborated by the literature or by FISAT's routine "by eye", which fits the VBGF visually. When the collected data did not allow fitting, we used published data (Perez Lizama & Vazzoler, 1993; Angelini & Agostinho, 2005a; Froese & Pauly, 2010; Table 2). When it was not possible to obtain VBGF parameters,  $L_{\infty}$  was estimated using the length of the largest individual of the population sample:  $L_{\infty} = L_{\max} * 1.05$  (Angelini & Agostinho, 2005a).

Production, according to Ivlev (1945), is the "total quantity of tissue elaborated by a fish population during a stated period of time, although not all individuals survive until the end of that period". As the production/biomass (P/B) ratio is hard to estimate directly, it can be considered equivalent to total mortality [ $Z =$  fishing mortality (F) + natural mortality (M)] (Pauly *et al.*, 2000). The study reservoirs have negligible fishing activity, if any. Thus, as shown by Allen (1971) under equilibrium conditions, the P/B ratio is similar to natural mortality (M), which was calculated with the empiric regression of Pauly (1980):

$$M = k^{0.65} \times L_{\infty}^{-0.279} \times T^{0.463}$$

where  $M$  is natural mortality (year<sup>-1</sup>),  $k$  and  $L_{\infty}$  are the VBGF's parameters, and  $T$  is the average annual water temperature (average for the 30 reservoirs; in °C).

There are several empirical approaches to estimate consumption/biomass ratio (Q/B), and this parameter is

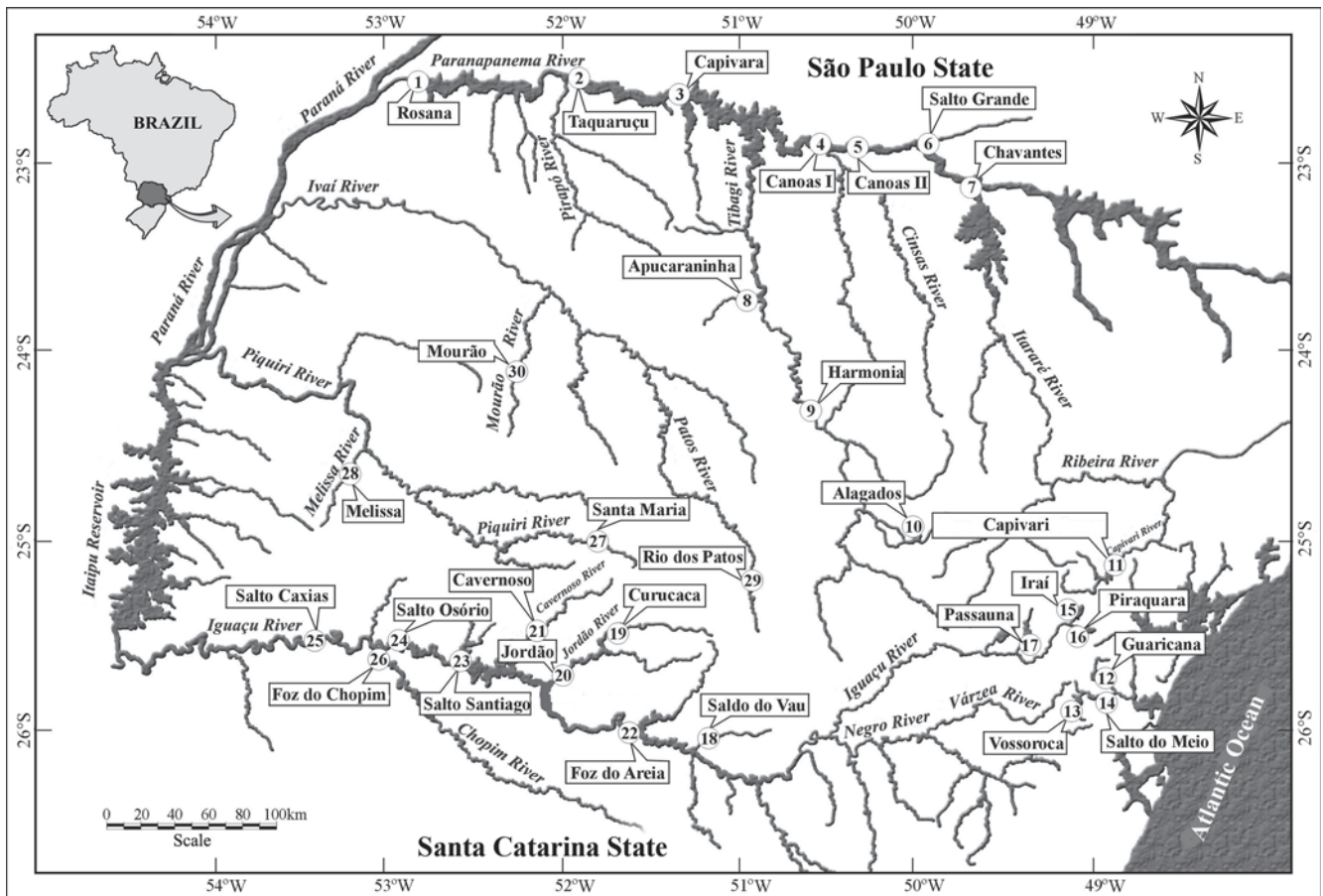


Fig. 1. Location of the 30 reservoirs in the State of Paraná sampled in July and November 2001.

relatively easy to estimate for fish populations (Palomares & Pauly, 1989, 1998; Pauly, 1989; Pauly *et al.*, 1990; Jarre *et al.*, 1991). It is interesting to notice that Q/B values for the same species vary as a result of using different empirical formulas and predictor parameters; for example, there might be variation in measurements of proportion and asymptotic weight, as well as in the type of food consumed by a species. To estimate Q/B we used the empiric regression model proposed by Palomares & Pauly (1998), as follows:

$$\log Q/B = 7.964 - 0.204 \log W_{\infty} - 1.965 T' + 0.083 Ar + 0.532 H + 0.398 D$$

where Q/B is consumption/biomass rate ( $\text{year}^{-1}$ ),  $W_{\infty}$  is the asymptotic weight (wet weight in g, estimated based on the length/weight relationship for  $L_{\infty}$ );  $T'$  is the inverse of the average annual water temperature ( $T' = 1000/G + 273.15$ ), where G is the average water temperature of the 30 reservoirs ( $^{\circ}\text{C}$ ); Ar is the caudal fin index ( $Ar = h^2/s$ , where h is the caudal fin height (mm) and s is the caudal fin surface area ( $\text{mm}^2$ ), extending to the narrowest part of the caudal peduncle) and a measure of the swimming and metabolic activity of the fish (Palomares & Pauly, 1998). Ar values were estimated by measurements of five individuals, when possible, per species (analyzed individuals were deposited in the collection of Museu de Ictiologia, Nupélia). Variables H and D refers to feeding behavior, *i.e.*, H=1 for

herbivorous, D=1 for detritivorous and H=D=0 for carnivorous. Values of average annual water temperature, for both equations listed above, were provided by the limnology laboratory of Nupélia (Table 1).

We tested significant relationships between k and  $L_{\max}$ , k and  $L_{\infty}$ , k and  $W_{\infty}$ , k and M, k and Ar, k and Q/B,  $L_{\infty}$  and Q/B,  $W_{\infty}$  and  $L_{\max}$ , M and Ar, and M and  $L_{\max}$  with linear regressions. All these relationships are relevant to the study of life history (Jensen, 1997; Froese & Pauly, 2000; Froese & Binohlan, 2000, 2003).

## Results

$L_{\max}$  varied from 2.60 to 79.00 cm.  $L_{\infty}$  from 2.73 to 85.05 cm. The values of  $L_{\infty}$  for 34 species (Table 2) were compiled from the literature; among these species *C. modestus*, *A. altiparanae*, *P. britskii*, *A. gymnogynys*, *G. brasiliensis*, *H. aff. malabaricus*, *R. quelen* and *S. melanodermatum* showed  $L_{\infty}$  less than the  $L_{\max}$  recorded in this study.  $W_{\infty}$  from 0.23 to 9,490.26 g, k from 0.01 to 2.38  $\text{yr}^{-1}$ , Ar from 0.03 to 3.60, M from 0.16 to 2.72  $\text{yr}^{-1}$ , and Q/B from 3.31 to 67.18 (Table 2).

The 135 fish species captured were categorized in six trophic categories (detritivorous, herbivorous, insectivorous,

**Table 1.** Some characteristics of the study reservoirs (<sup>a</sup> - Perimeter estimated in Google™ Earth. Depth = maximum depth, R.T. = Hydraulic retention time, A.A.W.T. = average annual water temperature). Consulted references: Júlio Jr. *et al.* (2005), Angelini & Gomes (2008), Companhia Paranaense de Energia Elétrica (2007), Comitê Brasileiro de Barragens (2007).

Reservoir	River	Basin	Damming Year	Basin area	Area (km <sup>2</sup> )	Perimeter <sup>a</sup> (km)	Depth (m)	R.T. (days)	Volume (km <sup>3</sup> )	A.A.W.T. (°C)
Taquaruçu	Paranapanema	Paranapanema	1992	88000	80.1	156.35 <sup>a</sup>	26.5	7.9	672.5	23.6
Capivara	Paranapanema	Paranapanema	1975	85000	419.3	738.93 <sup>a</sup>	52.5	126.8	10540.0	23.7
Canoas II	Paranapanema	Paranapanema	1999	39556	22.5	65.81 <sup>a</sup>	16.5	4.4	140.0	23.5
Canoas I	Paranapanema	Paranapanema	1999	40920	30.8	74.64 <sup>a</sup>	26.0	6.0	207.0	23.9
Salto Grande	Paranapanema	Paranapanema	1958	38600	12.0	24.91 <sup>a</sup>	9.2	1.4	44.2	21.9
Chavantes	Paranapanema	Paranapanema	1970	27500	400.0	401.84 <sup>a</sup>	78.0	352.7	8795.0	21.9
Rosana	Paranapanema	Paranapanema	1986	99000	220.0	230.32 <sup>a</sup>	26.0	18.6	1920.0	24.1
Alagados	Pitangui	Tibagi	1945	377	7.2	47.20	9.2	46.0	0.03	19.8
Apucarantina	Apucarantina	Tibagi	1958	513	2.0	16.90	-	12.0	0.015	20.3
Harmonia	Harmonia	Tibagi	1950	-	3.0	7.49 <sup>a</sup>	12.0	-	8.0	20.9
Patos	Patos	Ivaí	1949	1086	1.3	3.20	5.7	0.2	0.0008	18.5
Mourão	Mourão	Ivaí	1964	573	11.3	60.00	12.7	70.0	0.065	20.9
Cavernoso	Cavernoso	Iguaçu	1965	1460	2.9	3.73 <sup>a</sup>	8.3	-	-	19.5
Salto Santiago	Iguaçu	Iguaçu	1979	43900	208.0	376.99 <sup>a</sup>	78.0	-	6753.0	21.6
Salto Osório	Iguaçu	Iguaçu	1975	45800	51.0	180.16 <sup>a</sup>	43.0	-	1270.0	21.2
Salto Caxias	Iguaçu	Iguaçu	1998	57000	124.0	267.14 <sup>a</sup>	53.0	-	3573.0	21.8
Foz do Chopim	Chopim	Iguaçu	1970	3800	2.9	5.25 <sup>a</sup>	6.0	-	-	20.1
Jordão	Jordão	Iguaçu	1996	4700	3.4	21.74 <sup>a</sup>	60.0	-	110.0	18.4
Curucaca	Jordão	Iguaçu	1982	-	2.0	3.70 <sup>a</sup>	10.5	-	-	17.5
Foz do Areia	Iguaçu	Iguaçu	1980	29900	139.0	288.67 <sup>a</sup>	135.0	-	5779.0	20.7
Passauna	Passaúna	Iguaçu	1978	-	14.0	35.30 <sup>a</sup>	-	420.0	-	16.5
Piraquara	Piraquara	Iguaçu	1979	-	3.3	40.00	18.0	438.0	0.5	19.9
Salto do Vau	Palmital	Iguaçu	1959	340	2.0	-	3.5	-	0.0003	16.2
Iraí	Iraí	Iguaçu	2000	-	15.0	20.12 <sup>a</sup>	8.5	240.0	-	20.0
Santa Maria	Piquiri	Piquiri	1950	-	0.1	-	4.3	-	-	16.7
Melissa	Melissa	Piquiri	1962	368	2.9	-	5.3	-	-	17.9
Guaricana	Arraial	Leste	1957	-	7.0	7.20	17.0	13.0	0.00683	19.9
Vossoroca	São João	Leste	1949	160	5.1	18.49 <sup>a</sup>	12.5	-	0.04	19.0
Salto do meio	Cubatão	Leste	1931	252	0.1	3.90 <sup>a</sup>	6.2	-	0.0004	18.3
Capivari	Capivari	Leste	1970	-	12.0	123.50	43.0	48.0	156.0	19.9

invertivorous, omnivorous, and piscivorous; Table 2). Insectivorous (30 species), detritivorous (29 species) and piscivorous (26 species) were the trophic categories with higher number of species, respectively. Omnivorous (23 species), invertivorous (15 species) and herbivorous (12 species) showed smaller number of species (Table 2).

Various relationships were apparent with the VBGF. In this sense,  $k$  was significant negatively related to maximum length, and asymptotic length and weight ( $F = 45.00$ ,  $F = 62.80$  and  $F = 59.60$ , respectively; Figs. 2a, b, c). The piscivorous species *R. quelen* showed low annual growth rate ( $k = 0.01$  year<sup>-1</sup>; Table 2) and low natural mortality, whereas *O. niloticus* ( $k = 2.38$  year<sup>-1</sup>; Table 2) showed the opposite trend; both were considered outliers (Fig. 2). On the other hand, relationships between  $k$  and caudal fin index, and natural mortality ( $F = 458.38$ ; Fig. 2e) and consumption/biomass ratio ( $F = 30.43$ ; Fig. 2f) were positive.

The relationship between  $k$  and caudal fin index was not significant ( $F = 0.02$ ; Fig. 2d). The fin shape of knifefishes *G. sylvius* and *E. trilineata* strongly affected the relationship (Fig. 2d); but even after their exclusion the relationship was still non-significant ( $F = 0.16$ ;  $p = 0.68$ ). *Rhamdia quelen* and *O. niloticus* did not follow the general relationship between  $k$  and consumption/biomass ratio (Fig. 2f).

The relationship between asymptotic length and consumption/biomass ratio was negative ( $F = 78.33$ ; Fig. 3a).

Interestingly, the species above the regression line in Figure 3a represent small- and medium-sized species that are mostly detritivorous and have high population growth rates. The relationship between maximum length and asymptotic weight was positive ( $F = 563.14$ ; Fig. 3b). The species *M. salmoides* (located below the regression line) and *L. macrocephalus* (located above the regression line) were outliers.

The relationship between natural mortality and maximum length was negative ( $F = 136.37$ ; Fig. 3c). The species *L. macrocephalus* was an outlier; when this fish was removed, the relationship showed stronger non-linear tendency (Spearman  $\rho = -0.80$ ;  $p < 0.05$ ). The relationship between natural mortality and caudal fin index was not significant ( $F = 0.09$ ; Fig. 3d), following the same trend observed for the relationship between  $k$  and caudal fin index. Similarly, after exclusion of the knifefishes, the relationship was still non-significant ( $F = 0.06$ ;  $p = 0.80$ ).

## Discussion

In this study we obtained significant relationships among various biological parameters. These relationships can be useful to obtain other estimates, such as yield per recruit ( $Y/R$ ), which can be easily calculated from  $L_{max}$ ,  $W_{max}$ ,  $t_{max}$ , and  $Ar$ , among others. Significant negative relationships were established between the parameters  $k$  and  $L_{max}$ ,  $k$  and  $L_{\infty}$  and  $k$  and  $W_{\infty}$ . On

**Table 2.** Demographic and biological attributes of 135 fish species captured in 30 reservoirs in the State of Paraná, southern Brazil, in July and November 2001. N = number of individuals captured, TC = species' trophic category,  $L_{max}$  = maximum length (cm),  $L_{\infty}$  = asymptotic length (cm; values with asterisk were obtained of the literature),  $W_{\infty}$  = asymptotic weight (g), k = growth constant from von Bertalanffy's equation ( $year^{-1}$ ), Ar = caudal fin index (Palomares & Pauly, 1998), M = natural mortality ( $year^{-1}$ ) and Q/B = consumption/biomass ratio ( $year^{-1}$ ). <sup>a</sup> - Froese & Pauly (2010), <sup>b</sup> - Angelini & Agostinho (2005a), <sup>c</sup> - Perez Lizama & Vazzoler (1993). \*For species in which k was calculate, Rn (goodness of fit index) was greater than 0.6.

Species	N	TC	$L_{max}$	$L_{\infty}$	$W_{\infty}$	k*	Ar	M	Q/B
<i>Apareiodon affinis</i> (Steindachner, 1879)	1096	detritivorous	15.70	16.48	55.35	0.50	1.26	1.17	30.54
<i>Apareiodon ibitiensis</i> Campos, 1944	3	detritivorous	4.80	5.00	1.42	0.50 <sup>a</sup>	1.17	1.63	63.37
<i>Astyanax minor</i> Garavello & Sampaio, 2010	5564	detritivorous	13.50	13.65*	156.18	0.50	2.18	1.08	29.46
<i>Apareiodon piracicabae</i> (Eigenmann, 1907)	39	detritivorous	11.00	11.55	18.37	0.50 <sup>a</sup>	1.27	1.29	38.29
<i>Apareiodon vittatus</i> Garavello, 1977	170	detritivorous	14.60	17.64*	56.60	0.95	1.37	1.73	31.04
<i>Astyanax jordanensis</i> Alcaraz, Pavanelli & Bertaco, 2009	1	detritivorous	15.40	9.90	9.95	0.50 <sup>a</sup>	1.20	1.35	42.85
<i>Cyphocharax modestus</i> (Fernández-Yépez, 1948)	115	detritivorous	22.00	18.00*	180.52	0.80 <sup>b</sup>	0.81	1.80	27.72
<i>Deuterodon</i> sp. B ( <i>sensu</i> C.S Pavanelli)	945	detritivorous	11.70	12.28	26.13	0.80	0.94	1.72	33.45
<i>Deuterodon</i> sp. D ( <i>sensu</i> C.S Pavanelli)	1985	detritivorous	12.80	13.44	33.88	0.80	1.17	1.68	33.19
<i>Hypostomus ancistroides</i> (Ihering, 1911)	27	detritivorous	23.30	24.46	161.07	0.45 <sup>a</sup>	0.52	0.98	21.33
<i>Hypostomus commersoni</i> Valenciennes, 1836	68	detritivorous	38.20	44.62*	2270.64	0.24	2.09	0.55	16.77
<i>Hypostomus derbyi</i> (Hanselman, 1911)	110	detritivorous	40.00	42.00	638.00	0.51	2.09	0.92	21.73
<i>Hypostomus hermanni</i> (Ihering, 1905)	1	detritivorous	11.50	12.10	27.86	0.50 <sup>a</sup>	0.71	1.27	31.65
<i>Hypostomus margaritifer</i> (Regan, 1908)	1	detritivorous	16.20	17.00	58.66	0.30 <sup>a</sup>	0.75	0.83	27.37
<i>Hypostomus myersi</i> (Gosline, 1947)	34	detritivorous	22.50	25.20*	188.05	0.49	1.77	1.02	26.23
<i>Hypostomus nigromaculatus</i> (Schubart, 1964)	1	detritivorous	11.50	12.10	23.08	0.50 <sup>a</sup>	0.57	1.27	31.98
<i>Hypostomus regani</i> (Ihering, 1905)	23	detritivorous	24.30	25.50	215.49	0.25 <sup>a</sup>	0.46	0.66	19.87
<i>Hypostomus topavae</i> (Godoy, 1969)	51	detritivorous	20.00	21.00	142.00	0.50	0.94	1.09	23.70
<i>Hypostomus multidentis</i> Jerep, Shibatta & Zawadzki, 2007	10	detritivorous	29.60	31.08	385.25	0.50	0.94	0.98	19.33
<i>Hypostomus iheringii</i> (Regan, 1908)	5	detritivorous	29.60	36.33*	468.03	0.20 <sup>a</sup>	0.35	0.52	16.60
<i>Hypostomus strigaticeps</i> (Regan, 1908)	1	detritivorous	20.40	21.40	146.84	0.50 <sup>a</sup>	0.71	1.09	22.52
<i>Proloricaria proluxa</i> (Isbrücker & Nijssen, 1978)	63	detritivorous	38.60	40.53	359.87	0.20 <sup>a</sup>	0.41	0.50	17.72
<i>Loricaria</i> sp.	15	detritivorous	27.70	29.10	110.00	0.55	1.16	1.06	26.04
<i>Loricariichthys platymetopon</i> Isbrücker & Nijssen, 1979	10	detritivorous	31.40	33.00	254.44	0.55 <sup>b</sup>	1.16	1.10	21.95
<i>Megalancistrus parananus</i> (Peters, 1881)	4	detritivorous	35.50	37.30	865.82	0.26 <sup>b</sup>	1.56	0.60	18.47
<i>Prochilodus lineatus</i> (Valenciennes, 1836)	61	detritivorous	63.70	85.05*	9490.26	0.34	2.16	0.60	12.70
<i>Rhinelepis aspera</i> Spix & Agassiz, 1829	3	detritivorous	34.50	36.20	825.70	0.39 <sup>b</sup>	0.76	0.80	16.00
<i>Rineloricaria</i> sp.	71	detritivorous	16.30	20.58*	52.56	0.43	0.45	0.99	26.41
<i>Steindachnerina brevipinna</i> (Eigenmann & Eigenmann, 1889)	42	detritivorous	16.80	17.64	85.60	0.86 <sup>b</sup>	1.39	1.63	28.62
<i>Astyanax bifasciatus</i> Garavello & Sampaio, 2010	7351	herbivorous	19.00	19.16*	69.74	1.00	1.40	1.81	40.73
<i>Astyanax dissimilis</i> Garavello & Sampaio, 2010	8	herbivorous	13.80	16.28*	57.40	0.44 <sup>a</sup>	1.50	1.00	43.20
<i>Astyanax longirhynchus</i> Garavello & Sampaio, 2010	1163	herbivorous	8.40	8.80	9.60	0.80	1.05	1.89	57.07
<i>Bryconamericus iheringii</i> (Boulenger, 1887)	905	herbivorous	8.00	8.40	7.68	0.70 <sup>a</sup>	1.66	1.75	67.18
<i>Ctenopharyngodon idella</i> (Valenciennes, 1844)	1	herbivorous	43.20	45.40	965.06	0.15 <sup>a</sup>	1.56	0.40	24.59
<i>Hypophthalmichthys molitrix</i> (Valenciennes, 1844)	1	herbivorous	40.00	42.00	1151.20	0.16 <sup>a</sup>	0.93	0.48	31.78
<i>Hypophthalmus edentatus</i> Spix & Agassiz, 1829	4	herbivorous	47.80	50.20	1874.82	0.28 <sup>a</sup>	2.04	1.60	27.48
<i>Leporinus lacustris</i> Campos, 1945	1	herbivorous	15.50	16.30	91.00	0.80 <sup>a</sup>	1.15	1.59	36.79
<i>Metynnus lippincottianus</i> (Cope, 1870)	24	herbivorous	14.70	15.43	92.64	0.70 <sup>a</sup>	1.26	1.48	37.45
<i>Schizodon borellii</i> (Boulenger, 1900)	8	herbivorous	28.00	29.40	516.00	0.42 <sup>b</sup>	2.03	1.40	30.54
<i>Schizodon nasutus</i> Kner, 1858	234	herbivorous	33.70	35.38	567.49	0.34 <sup>a</sup>	1.41	0.73	26.62
<i>Tilapia rendalli</i> (Boulenger, 1897)	228	herbivorous	31.50	39.27*	3064.45	0.31	1.48	0.42	19.12
<i>Aphyocharax anisitsi</i> Eigenmann & Kennedy, 1903	2	insectivorous	4.50	4.70	1.30	0.90 <sup>a</sup>	0.80	2.43	24.06
<i>Aphyocharax dentatus</i> Eigenmann & Kennedy, 1903	6	insectivorous	7.50	7.90	5.00	0.80 <sup>a</sup>	1.37	1.95	20.36
<i>Apteronotus</i> sp.	1	insectivorous	30.00	30.20*	224.00	0.60 <sup>a</sup>	0.53	1.11	7.99
<i>Astyanax altiparanae</i> Garutti & Britski, 2000	3550	insectivorous	15.90	14.70*	80.87	0.79	1.24	1.35	12.34
<i>Astyanax fasciatus</i> (Cuvier, 1819)	50	insectivorous	16.00	16.80	96.29	0.25 <sup>c</sup>	0.86	0.74	10.69

the other hand, k and M and k and Q/B ratio showed significant positive relationships. The first relationship can be used for estimating k from the corresponding  $L_{max}$  values, which are easier to be obtained. Stergiou & Karachle (2006) also found significant negative relationship between k and  $L_{max}$  for 142 fish stocks from the Greek Seas. Perez Lizama & Vazzoler (1993), in a review on marine and freshwater fish growth in Brazil, observed the same trend in the relationship between  $L_{\infty}$  and k. The negative correlation between k and  $L_{\infty}$  and k and  $W_{\infty}$  seems to be a recurrent pattern in fishes (Beverton & Holt, 1959; Pauly, 1998a, 1998b; Froese & Pauly, 2000).

The relationship between k and  $L_{\infty}$  should provide the slope value equal to -0.33, when assuming the isometric growth (Jensen, 1997). Stergiou & Karachle (2006) updated the slope value for all Greek fish stocks and found the value of -0.3006, close to the theoretical -0.33. We found a slope value of -0.6195, which differed greatly from the theoretical value, as well as a correlation coefficient ( $r = -0.57$ ), which is higher than verified by Stergiou & Karachle (2006) for Greek Seas fish stocks ( $r = -0.34$ ). In addition, if we remove *R. quelen* and *O. niloticus* (which deviated from the regression line) from the analysis, the value of the slope becomes even higher (-0.8211;  $r = -0.64$ ).

**Table 2 (cont.).** Demographic and biological attributes of 135 fish species captured in 30 reservoirs in the State of Paraná, southern Brazil, in July and November 2001. N = number of individuals captured, TC = species' trophic category,  $L_{\max}$  = maximum length (cm),  $L_{\infty}$  = asymptotic length (cm; values with asterisk were obtained of the literature),  $W_{\infty}$  = asymptotic weight (g), k = growth constant from von Bertalanffy's equation ( $\text{year}^{-1}$ ), Ar = caudal fin index (Palomares & Pauly, 1998), M = natural mortality ( $\text{year}^{-1}$ ) and Q/B = consumption/biomass ratio ( $\text{year}^{-1}$ ). <sup>a</sup> - Froese & Pauly (2010), <sup>b</sup> - Angelini & Agostinho (2005a), <sup>c</sup> - Perez Lizama & Vazzoler (1993). \*For species in which k was calculate, Rn (goodness of fit index) was greater than 0.6.

Species	N	TC	$L_{\max}$	$L_{\infty}$	$W_{\infty}$	k*	Ar	M	Q/B
<i>Astyanax janeiroensis</i> Eigenmann, 1908	129	insectivorous	14.00	14.70	46.62	0.80 <sup>a</sup>	1.19	1.64	12.47
<i>Auchenipterus osteomystax</i> (Ribeiro, 1918)	286	insectivorous	26.50	27.82	194.51	0.50	1.47	1.01	9.84
<i>Bryconamericus ikaa</i> Casciotta, Almirón & Azpelicueta, 2004	105	insectivorous	8.20	8.61	8.56	0.60	0.76	1.64	16.24
<i>Bryconamericus</i> sp. C ( <i>sensu</i> C.S Pavanelli)	94	insectivorous	7.30	7.66	5.84	0.70	1.19	1.80	19.07
<i>Australoheros kaaygua</i> Casciotta & Britski, 2006	7	insectivorous	9.40	10.70*	30.60	0.40 <sup>a</sup>	0.73	1.14	12.46
<i>Corydoras ehrhardti</i> Steindachner, 1910	7	insectivorous	6.50	6.80	6.00	0.30 <sup>a</sup>	0.53	1.07	16.70
<i>Corydoras carlae</i> Nijssen & Isbrücker, 1983	71	insectivorous	6.70	7.03	7.14	0.34	0.53	1.15	16.12
<i>Crenicichla britskii</i> Kullander, 1982	16	insectivorous	13.50	14.17	32.43	0.70 <sup>a</sup>	0.57	1.52	11.94
<i>Crenicichla haroldoi</i> Luengo & Britski, 1974	70	insectivorous	19.90	20.89	97.49	0.60 <sup>a</sup>	0.60	1.23	9.60
<i>Crenicichla niederleini</i> (Holmberg, 1891)	53	insectivorous	22.80	23.94	164.51	0.65 <sup>a</sup>	0.62	1.25	8.65
<i>Deuterodon</i> sp. A ( <i>sensu</i> C.S Pavanelli)	782	insectivorous	13.70	14.38	51.01	0.75	1.10	1.58	12.05
<i>Gymnotus inaequilabiatus</i> (Valenciennes, 1836)	8	insectivorous	37.50	63.00*	842.11	0.31 <sup>c</sup>	1.50	0.50	7.34
<i>Hyphessobrycon eques</i> (Steindachner, 1882)	1	insectivorous	3.10	3.30	0.49	0.80 <sup>a</sup>	1.02	2.48	30.60
<i>Aristichthys nobilis</i> (Richardson, 1845)	3	insectivorous	25.70	27.00	151.20	0.16 <sup>a</sup>	0.75	0.48	9.02
<i>Leporellus vittatus</i> (Valenciennes, 1850)	11	insectivorous	20.00	21.00	98.06	0.34 <sup>a</sup>	0.66	0.85	9.69
<i>Moenkhausia</i> aff. <i>intermedia</i> Eigenmann, 1908	166	insectivorous	10.20	10.71	21.23	0.41 <sup>b</sup>	0.73	1.30	13.42
<i>Pimelodella gracilis</i> (Valenciennes, 1836)	31	insectivorous	21.40	22.47	82.25	0.60 <sup>a</sup>	0.59	1.21	9.91
<i>Pimelodus britskii</i> Garavello & Shibatta, 2007	979	insectivorous	37.60	35.49*	696.57	0.18	1.05	0.49	7.56
<i>Rhamphichthys hahni</i> (Meiken, 1937)	1	insectivorous	51.00	53.60	224.00	0.50 <sup>a</sup>	0.50	1.01	7.94
<i>Roebooides descalvadensis</i> Fowler, 1932	13	insectivorous	8.00	8.40	5.66	0.85 <sup>a</sup>	1.40	1.99	19.99
<i>Sternopygus macrurus</i> (Bloch & Schneider, 1801)	1	insectivorous	34.50	36.20	67.57	0.50 <sup>a</sup>	0.50	0.94	10.14
<i>Triporthus nematurus</i> (Kner, 1858)	5	insectivorous	24.00	25.20	187.00	0.70 <sup>a</sup>	1.09	1.29	9.22
<i>Bryconamericus pyahu</i> Azpelicueta, Casciotta & Almirón, 2004	1	insectivorous	2.60	2.70	0.23	0.80 <sup>a</sup>	1.24	2.62	37.25
<i>Bryconamericus</i> sp. D ( <i>sensu</i> C.S Pavanelli)	4	insectivorous	7.10	7.50	5.00	0.70	1.54	1.81	21.03
<i>Mimagoniates microlepis</i> (Steindachner, 1876)	42	insectivorous	5.30	5.56	1.91	0.75 <sup>a</sup>	0.61	2.06	21.45
<i>Astyanax gymnogonys</i> Eigenmann, 1911	1	invertivorous	15.60	16.40	5.82	0.74 <sup>a</sup>	0.74	1.90	17.52
<i>Callichthys callichthys</i> (Linnaeus, 1758)	1	invertivorous	13.30	14.00	50.39	0.70 <sup>a</sup>	0.52	1.52	10.81
<i>Characidium</i> sp.	1	invertivorous	5.20	5.50	1.45	0.80 <sup>a</sup>	0.67	2.15	22.95
<i>Corydoras</i> cf. <i>paleatus</i> (Jenyns, 1842)	504	invertivorous	8.40	8.93*	12.93	0.74	1.29	1.78	16.52
<i>Eigenmannia trilineata</i> Lopes & Castello, 1966	3	invertivorous	35.00	36.80	103.75	0.50 <sup>a</sup>	0.06	0.93	8.54
<i>Geophagus brasiliensis</i> (Quoy & Gaimard, 1824)	979	invertivorous	27.90	23.84*	507.05	0.37	1.20	1.54	8.53
<i>Hemigrammus marginatus</i> Ellis, 1911	3	invertivorous	3.80	4.00	0.73	0.80 <sup>a</sup>	0.78	2.35	26.92
<i>Hoplosternum litorale</i> (Hancock, 1828)	1	invertivorous	22.00	23.10	273.27	0.52 <sup>b</sup>	1.68	1.20	9.55
<i>Iheringichthys labrosus</i> (Lütken, 1874)	571	invertivorous	33.50	35.17	439.55	0.55 <sup>b</sup>	1.63	1.10	8.59
<i>Leporinus amblyrhynchus</i> Garavello & Britski, 1987	18	invertivorous	19.00	19.95	96.58	0.50 <sup>a</sup>	0.83	1.11	10.04
<i>Odontesthes bonariensis</i> (Valenciennes, 1835)	53	invertivorous	41.80	52.50*	4138.51	0.24	0.85	0.48	4.68
<i>Rhinodoras dorbignyi</i> (Kner, 1855)	2	invertivorous	19.00	20.00	157.82	0.30 <sup>a</sup>	0.86	0.79	9.13
<i>Satanoperca pappaterra</i> (Heckel, 1840)	7	invertivorous	20.00	21.00	190.99	0.75 <sup>a</sup>	0.56	1.42	8.30
<i>Gymnotus sylvius</i> Albert & Fernandes-Matioli, 1999	2	invertivorous	26.60	27.90	90.18	0.70 <sup>a</sup>	0.03	1.25	8.74
<i>Odontostilbe</i> sp.	1	invertivorous	5.80	6.10	2.78	0.80 <sup>a</sup>	1.29	2.09	22.61
<i>Astyanax</i> aff. <i>paranae</i> Eigenmann, 1914	1334	omnivorous	15.60	16.38	70.42	0.75 <sup>a</sup>	1.80	1.52	12.89
<i>Astyanax serratus</i> Garavello & Sampaio, 2010	8	omnivorous	14.20	14.90	50.26	0.70 <sup>a</sup>	1.10	1.49	12.07
<i>Astyanax gymnodontus</i> (Eigenmann, 1911)	59	omnivorous	14.00	14.70	56.83	0.70 <sup>a</sup>	1.07	1.50	11.71
<i>Bryconamericus stramineus</i> Eigenmann, 1908	620	omnivorous	8.40	8.82	6.25	0.80 <sup>a</sup>	1.45	1.89	19.96
<i>Colossoma macropomum</i> (Cuvier, 1818)	18	omnivorous	40.50	42.50	1246.46	0.23 <sup>a</sup>	3.60	0.54	9.93

The parameters estimated here are consistent with other studies, which found that smaller species have higher k values (Pauly, 1998a, 1998b; Angelini & Agostinho, 2005a). According to Pauly (1998a), the same asymptotic size may be associated with various k values. In addition, the same author showed that tropical fishes tend to be confined within a space defined by the smaller asymptotic size and higher k values than fish from temperate regions. Angelini & Agostinho (2005a) estimated the k values for 35 fish species from the upper Paraná River floodplain and Itaipu reservoir and verified that fishes with smaller asymptotic lengths showed higher k values. In this study, 55% of species

showed k value greater than 0.50; among these, except *H. derbyi* and *P. mesopotamicus*, all are considered small and medium-sized species. In addition, in reservoirs, the fish assemblage is composed basically by small-sized fishes (Dias *et al.*, 2005; Agostinho *et al.*, 2007). Those findings intensified the pattern highlighted by Pauly (1998a) for tropical fish. The large number of small and medium-sized species with fast growth is associated with the higher temperatures recorded in the tropics. Pauly (1998a) affirm that metabolic rates increase with temperature and that growth is limited by respiratory metabolism. Thus, tropical fishes should generally remain small.

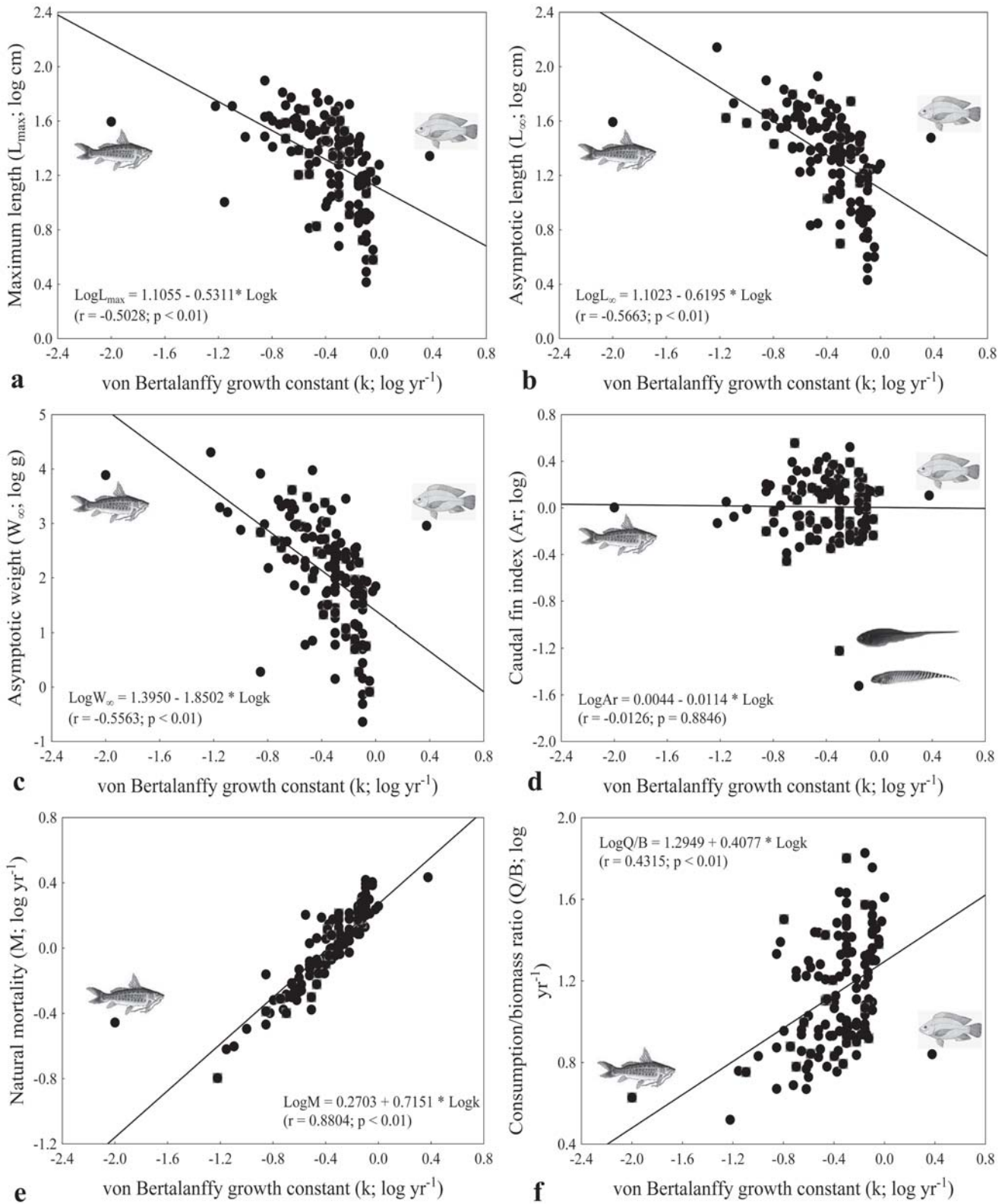
**Table 2 (cont.).** Demographic and biological attributes of 135 fish species captured in 30 reservoirs in the State of Paraná, southern Brazil, in July and November 2001. N = number of individuals captured, TC = species' trophic category,  $L_{max}$  = maximum length (cm),  $L_{\infty}$  = asymptotic length (cm; values with asterisk were obtained of the literature),  $W_{\infty}$  = asymptotic weight (g), k = growth constant from von Bertalanffy's equation ( $year^{-1}$ ), Ar = caudal fin index (Palomares & Pauly, 1998), M = natural mortality ( $year^{-1}$ ) and Q/B = consumption/biomass ratio ( $year^{-1}$ ). <sup>a</sup> - Froese & Pauly (2010), <sup>b</sup> - Angelini & Agostinho (2005a), <sup>c</sup> - Perez Lizama & Vazzoler (1993). \*For species in which k was calculate, Rn (goodness of fit index) was greater than 0.6.

Species	N	TC	$L_{max}$	$L_{\infty}$	$W_{\infty}$	k*	Ar	M	Q/B
<i>Cyprinus carpio</i> Linnaeus, 1758	43	omnivorous	79.00	79.28*	8254.38	0.14	1.60	0.34	4.69
<i>Deuterodon iguape</i> Eigenmann, 1907	1060	omnivorous	14.50	15.22	50.23	0.80 <sup>a</sup>	0.80	1.62	11.41
<i>Deuterodon</i> sp. C	12	omnivorous	9.70	10.20	14.18	0.70 <sup>a</sup>	0.95	1.66	15.20
<i>Glanidium ribeiroi</i> Hanseman, 1911	113	omnivorous	23.80	25.73*	465.88	0.22	1.73	0.60	8.65
<i>Leporinus friderici</i> (Bloch, 1794)	11	omnivorous	36.60	38.40	1091.00	0.40 <sup>b</sup>	1.37	0.80	6.79
<i>Leporinus macrocephalus</i> Garavello & Britski, 1988	1	omnivorous	10.1	42.00*	1983.96	0.07 <sup>a</sup>	1.13	0.24	5.74
<i>Leporinus obtusidens</i> (Valenciennes, 1836)	28	omnivorous	37.10	38.95	1033.20	0.26 <sup>b</sup>	1.37	0.55	6.97
<i>Leporinus octofasciatus</i> Steindachner, 1915	21	omnivorous	23.80	24.99	226.20	0.22 <sup>c</sup>	1.25	0.61	9.14
<i>Oreochromis niloticus</i> (Linnaeus, 1758)	3	omnivorous	22.00	30.00*	907.28	2.38 <sup>a</sup>	1.28	2.72	6.93
<i>Parauchenipterus galeatus</i> (Linnaeus, 1766)	67	omnivorous	21.00	22.05	259.23	0.50 <sup>b</sup>	1.44	1.15	9.22
<i>Phalloceros harpagos</i> Lucinda, 2008	153	omnivorous	3.80	3.99	0.82	0.90 <sup>a</sup>	0.58	2.54	25.31
<i>Piaractus mesopotamicus</i> (Holmberg, 1887)	49	omnivorous	53.00	55.65	3165.65	0.60 <sup>a</sup>	2.46	0.94	6.87
<i>Pimelodus microstoma</i> Steindachner, 1877	1	omnivorous	28.76	30.20	223.76	0.60 <sup>a</sup>	0.72	1.11	8.28
<i>Pimelodus maculatus</i> La Cépède, 1803	264	omnivorous	40.60	42.63	1050.45	0.43 <sup>b</sup>	1.64	0.90	7.20
<i>Pimelodus ornatus</i> Kner, 1858	2	omnivorous	32.50	34.10	542.24	0.30 <sup>a</sup>	0.56	0.68	6.71
<i>Pimelodus ortmanni</i> Hanseman, 1911	193	omnivorous	39.50	41.50	652.79	0.44	1.60	0.85	9.00
<i>Pterodoras granulosus</i> (Valenciennes, 1821)	12	omnivorous	54.80	57.50	2006.55	0.35 <sup>b</sup>	1.35	0.70	6.03
<i>Astyanax bockmanni</i> Vari & Castro, 2007	769	omnivorous	11.10	12.30*	32.00	0.44 <sup>a</sup>	2.30	1.20	16.66
<i>Acestrorhynchus lacustris</i> (Lütken, 1875)	126	piscivorous	28.50	29.92	281.88	0.40 <sup>b</sup>	2.73	0.90	11.65
<i>Ageneiosus militaris</i> Valenciennes, 1836	14	piscivorous	24.19	25.40	133.32	0.35	2.49	0.80	12.91
<i>Astronotus crassipinnis</i> (Heckel, 1840)	1	piscivorous	22.00	23.10	352.22	0.50 <sup>a</sup>	0.94	1.06	7.87
<i>Cichla kelberi</i> Kullander & Ferreira, 2006	2	piscivorous	23.00	24.20	203.63	0.30 <sup>a</sup>	0.78	0.75	8.54
<i>Clarias gariepinus</i> (Burchell, 1822)	1	piscivorous	64.70	67.90	2706.27	0.19 <sup>a</sup>	0.62	0.42	4.89
<i>Crenicichla iguassuensis</i> Hanseman, 1911	75	piscivorous	30.40	38.54*	759.27	0.10	0.98	0.32	6.78
<i>Crenicichla yaha</i> Casciotta, Almirón & Gómez, 2006	47	piscivorous	30.60	36.75*	688.94	0.14	1.39	0.41	7.48
<i>Galeocharax knerii</i> (Steindachner, 1879)	55	piscivorous	28.00	29.40	275.24	0.70 <sup>a</sup>	1.12	1.24	8.62
<i>Hoplias aff. malabaricus</i> (Bloch, 1794)	433	piscivorous	56.80	53.13*	2514.86	0.42	1.30	0.90	5.70
<i>Hoplias aff. lacerdae</i> Ribeiro, 1908	1	piscivorous	51.30	53.90	1607.45	0.08 <sup>a</sup>	0.84	0.25	5.67
<i>Ictalurus punctatus</i> (Rafinesque, 1818)	4	piscivorous	51.30	138.60*	20367.36	0.06 <sup>a</sup>	0.74	0.16	3.31
<i>Micropterus salmoides</i> (Lacépède, 1802)	14	piscivorous	42.70	44.84	1730.40	0.14 <sup>a</sup>	0.63	0.69	21.50
<i>Oligosarcus longirostris</i> Menezes & Géry, 1983	1768	piscivorous	30.40	30.98*	379.94	0.72	1.50	1.22	8.71
<i>Oligosarcus paranensis</i> Menezes & Géry, 1983	1359	piscivorous	28.30	31.19*	341.48	0.70	2.02	1.22	9.74
<i>Pinirampus pirinampu</i> (Spix & Agassiz, 1829)	25	piscivorous	59.40	62.37	2368.59	0.22 <sup>b</sup>	2.48	0.50	7.19
<i>Plagioscion squamosissimus</i> (Heckel, 1840)	294	piscivorous	46.90	49.24	1768.44	0.47 <sup>b</sup>	1.43	0.90	6.22
<i>Rhamdia branneri</i> Hanseman, 1911	19	piscivorous	36.50	49.77*	1822.22	0.24	1.17	0.53	5.88
<i>Rhamdia quelen</i> (Quoy & Gaimard, 1824)	125	piscivorous	39.40	39.17*	7746.39	0.01	1.01	0.35	4.25
<i>Rhaphiodon vulpinus</i> Spix & Agassiz, 1829	3	piscivorous	44.00	46.20	508.19	0.39 <sup>b</sup>	1.76	0.70	8.55
<i>Salminus brasiliensis</i> (Cuvier, 1816)	7	piscivorous	52.00	54.60	2077.30	0.20 <sup>b</sup>	1.43	0.40	6.02
<i>Serrasalmus maculatus</i> Kner, 1858	69	piscivorous	22.00	23.10	325.81	0.45 <sup>b</sup>	2.35	1.50	10.48
<i>Serrasalmus marginatus</i> Valenciennes, 1837	11	piscivorous	23.70	24.90	294.22	0.60 <sup>b</sup>	3.33	1.30	12.90
<i>Steindachneridion scriptum</i> (Miranda-Ribeiro, 1918)	3	piscivorous	38.00	51.50*	1847.27	0.25 <sup>a</sup>	0.70	0.54	5.36
<i>Steindachneridion melanoderdatum</i> Garavello, 2005	1	piscivorous	49.00	43.60*	1613.64	0.25 <sup>a</sup>	0.70	0.57	6.19
<i>Tatia neivai</i> (Ihering, 1930)	20	piscivorous	9.50	10.00	11.78	0.60	0.55	1.51	14.63
<i>Tatia jaracatia</i> Pavanelli & Bifi, 2009	5	piscivorous	6.60	6.90	6.00	0.50 <sup>a</sup>	0.80	1.49	17.60

*Rhamdia quelen* is a catfish species, prefers calmer and deeper water along banks and vegetation with a sand or mud bottom (Silva *et al.*, 2011). Despite the large distribution of this species, from northern Mexico to southern Argentina (Graça & Pavanelli, 2007), studies on the biological aspects of this species have been primarily conducted on captive adult fish for farming purposes (Silva *et al.*, 2011). Thus, comparative studies on the growth parameters for *R. quelen* were not found in field. On the other hand, *Oreochromis niloticus* showed rapid growth, reaching adult size in small interval of time, exhibit relatively short reproductive cycles, tolerate a variety of environmental conditions, have high capacity for hybridization and high

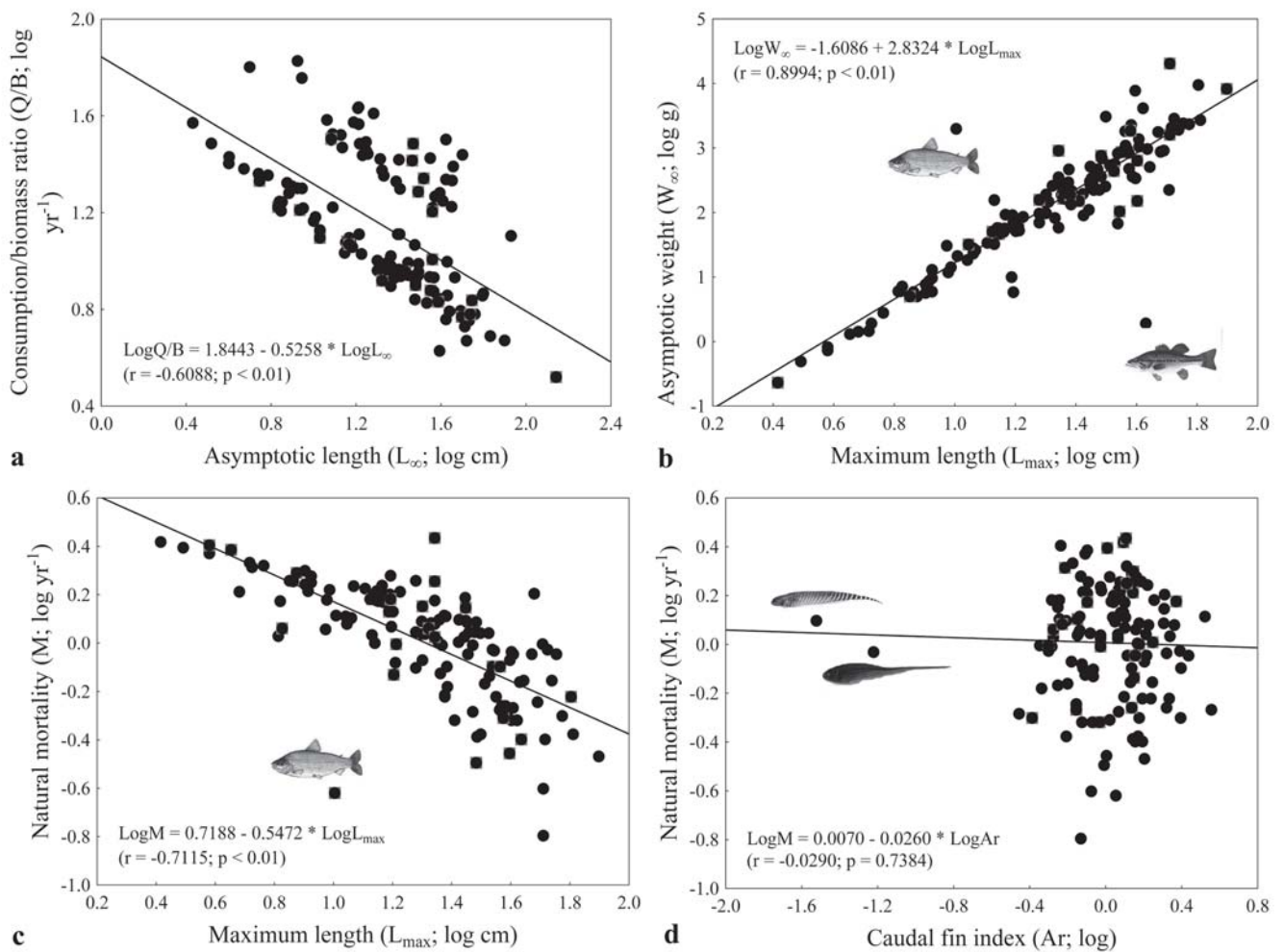
resistance to diseases and infection (Coward & Bromage, 2000). These biological features might have favored the rapid growth of *O. niloticus* populations in the reservoirs studied.

Natural mortality (M) in fish is difficult to estimate because its values are strongly correlated with growth parameters, as reported by Pauly (1998a). Fish with fast initial growth (higher k values) present higher M values, whereas fish with higher asymptotic lengths present lower M values. The von Bertalanffy's growth constant and natural mortality were stronger correlated in this study, consequence of the fact that M was calculated using the Pauly's equation and then totally dependent on k.



**Fig. 2.** Relationships between von Bertalanffy’s constant ( $k$ ; Growth rate) and maximum length ( $L_{max}$ ; **a**), asymptotic length ( $L_{\infty}$ ; **b**), asymptotic weight ( $W_{\infty}$ ; **c**), caudal fin index ( $Ar$ ; **d**), natural mortality ( $M$ ; **e**) and consumption/biomass ratio ( $Q/B$ ; **f**) for 135 fish species in reservoirs from the State of Paraná, southern Brazil, caught in July and November 2001.





**Fig. 3.** Relationships between some biological parameters of 135 fish species in the State of Paraná, southern Brazil, caught in July and November 2001. Asymptotic length ( $L_{\infty}$ ) and consumption/biomass ratio ( $Q/B$ ; **a**); maximum length ( $L_{\max}$ ) and asymptotic weight ( $W_{\infty}$ ; **b**); maximum length ( $L_{\max}$ ) and natural mortality ( $M$ ; **c**); and caudal fin index ( $Ar$ ) and natural mortality ( $M$ ; **d**).

The knifefishes species, as *G. sylvius*, *E. trilineata*, and *Rhamphichthys hahni*, showed the body shape highly specialized. The caudal portion of the body is elongate and it has a long anal fin, there are no dorsal, adipose, or pelvic fins, while the caudal fin is either small or absent (Albert, 2001). Thus, the caudal fin index for these species does not follow the specified pattern for other species. In addition, these species can present large maximum length, with such a high natural mortality, because on the shape of the body.

Consumption/Biomass ratio is defined as the number of times a population consumes its own weight within a year (Pauly, 1986, 1998a, 1998b; García & Duarte, 2002). García & Duarte (2002) studied  $Q/B$  ratio and estimates of  $Q/B$ -predictor parameters for Caribbean fish, and Angelini & Agostinho (2005a) studied parameter estimates for fish from the upper Paraná River Floodplain and from Itaipu Reservoir (Brazil), and they found that  $Q/B$  varies inversely with  $L_{\infty}$  and trophic levels (species from low trophic levels showed high  $Q/B$  ratio,

due to their fast life cycles). Small-sized species, which are normally  $r$ -strategists (*sensu* Winemiller, 1989), showed low asymptotic lengths, short life cycles, high growth rates, early first maturation, high natural mortality, and high fecundity (Vazzoler, 1996). These species usually form the base of food webs, as they are concentrated in the lower trophic levels. Thus, patterns found in this study are similar to those observed previously.

The correlations found between the parameters studied here corroborate the patterns described by Pauly (1998a) and Angelini & Agostinho (2005a), which indicated that  $k$  varies inversely with  $L_{\infty}$  and  $W_{\infty}$ , as well as  $Q/B$  ratio varies inversely with  $L_{\infty}$  and natural mortality has a high correlation with  $L_{\max}$ , for tropical fishes and also for fishes from other latitudes and ecosystems (Pauly, 1998b). Furthermore, we emphasize that, as suggested by Pauly (1998a), those correlations allow summarizing and comparing demographic and biological data of fish species from different biogeographic regions.

The estimates presented here should be useful for building Ecopath models. Ecological modeling is under development in tropical regions, such as Brazil (Angelini & Petrere, 1996; Wolff *et al.*, 2000; Angelini & Agostinho, 2005a, 2005b; Angelini *et al.*, 2006; Angelini & Gomes, 2008). Pauly (1998b) pointed out to the need for an adaptation or more precisely a “tropicalization” of the parameters from Beverton and Holt models. Moreover, García & Duarte (2002) suggested that it would be interesting to explore the consistency of published consumption/biomass ratio values for the same species in similar habitats. Those authors compared estimated Q/B values with three empirical models described by Palomares & Pauly (1989, 1998) and by Pauly *et al.*, (1990), and they concluded that parameters vary for a given fish species; this is a clear sign that empirical models must be used with caution. Thus, empirical models obtained with data from temperate areas should be analyzed with attention. Furthermore, we emphasize that empirical models described by Palomares & Pauly (1989, 1998) and by Pauly *et al.*, (1990) should be parameterized with data from tropical areas.

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