Length–length and length–weight relationships for 48 fish species from reservoirs of the Paraná State, Brazil

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Abstract

Length–length and length–weight relationships was estimated for 48 fish species collected in 30 neotropical reservoirs located in the State of Paraná, Brazil. Significant relations were found for all species. The values of the parameter slope (*b*) in the length–weight relationship ranged from 2.49 to 3.46 for grouped sexes, and from 2.66 to 3.15 for separated sexes. Differences between sexes (indication of sexual dimorphism) were verified for 20 species. Males exhibited greater lengths than females for *Astyanax janeiroensis*, *Bryconamericus iheringii*, *Geophagus brasiliensis*, *Glanidium ribeiroi* and *Hypostomus derbyi,* whereas females attained greater lengths than males for the other 15 species examined in this study.

Key words

fish, length–length relationships, length–weight relationships, neotropical reservoirs.

INTRODUCTION

Length–length and length–weight relationships of fish species are useful parameters for fishery scientists in sampling programmes, and in managing fishery resources. Estimation of the population size of a fish stock for the purpose of its rational exploitation often requires knowledge of these relationships (Le Cren 1951; Froese 2006). Length–weight relationships also can be used to estimate several components of fish population dynamics (Kohler *et al.* 1995). Examples include the conversion of growth-in-length equations to growth-in-weight in fish stock assessment models (Khaironizam & Norma-Rashid 2002; Gurkan & Taşkavak 2007; Özaydin & Taşkavak 2007; Cherif *et al.* 2008); the estimation of fish biomass from length frequency distributions (Anderson & Gutreuter 1983; Petrakis & Stergiou 1995); the inference of fish condition (Petrakis & Stergiou 1995) and comparison of life history and morphological aspects of fish populations inhabiting different regions (Gonçalves *et al.* 1997; Stergiou & Moutopoulos 2001).

Most studies focusing on the management and exploitation of fishery resources were initially developed for marine stock assessments (Beverton & Holt 1957; Ricker 1958; Gulland 1969). Large rivers are the most studied water systems in the freshwater environment (Bayley 1981). Studies are still sparse and/or incomplete for reservoirs, however, including several in the neotropical realm. The only exceptions are the studies of Benedito-Cecilio (1997) and Angelini and Agostinho (2005) for the Itaipu reservoir (Brazil) and adjacent areas. Thus, despite the utility of length–length and length–weight relationships in fishery science, and the importance of neotropical reservoirs for fisheries, information about length–length and length–weight relationships for fish in reservoir environments are very limited. Accordingly, this study estimates the length–length and length–weight relationship for 48 fish species collected from 30 neotropical reservoirs in the State of Paraná, south Brazil.

METHODS

The reservoirs in this study are located in six different basins (Paranapanema, Tibagi, Ivaí, Piquiri, Iguaçu and Leste), all within the State of Paraná and bordering states (Fig. 1). Although these basins represent different uses, water supply, fishery exploitation and energy production are common to most of them. The study reservoirs were

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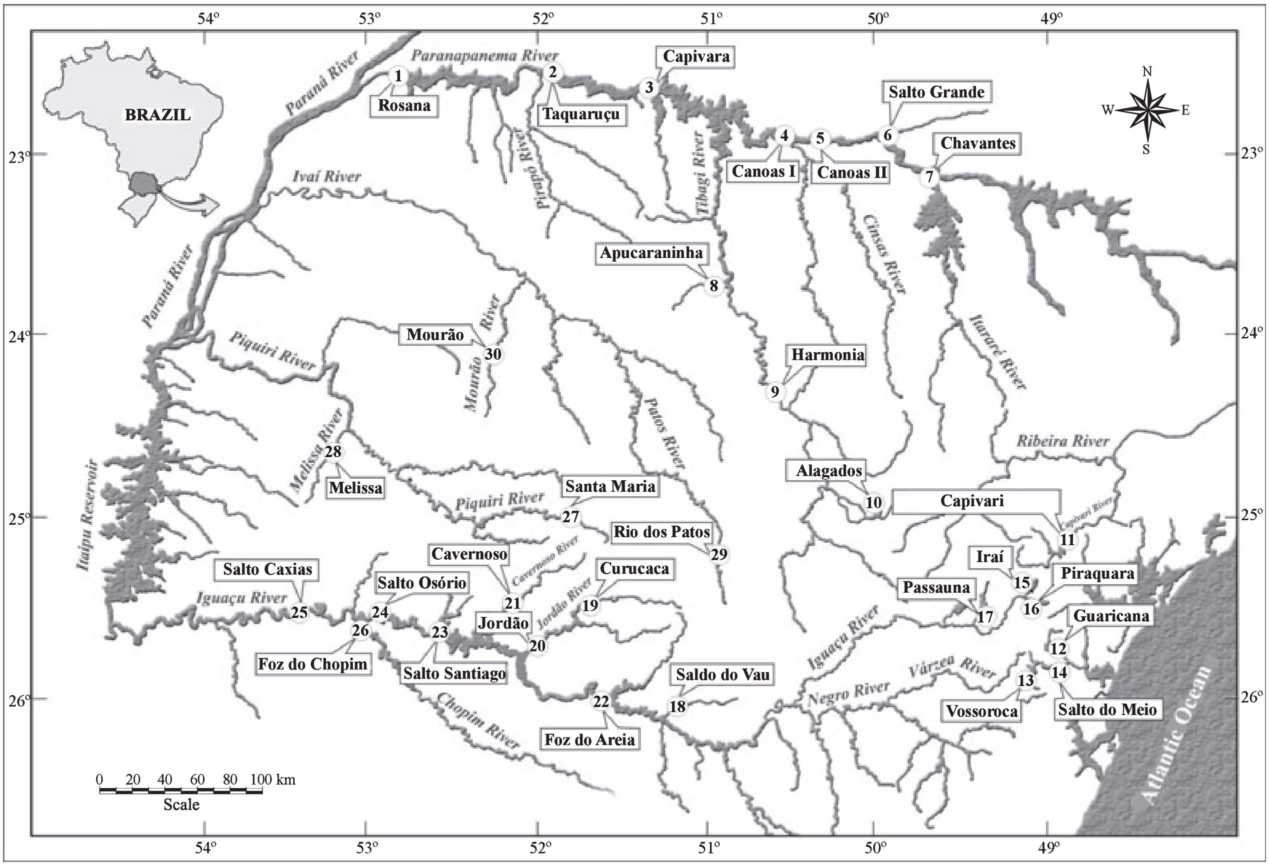

Fig. 1. Location of 30 study reservoirs in the State of Paraná, Brazil.

selected on the basis of their surface area, morphometry, hydraulic retention time and location in different regions of the state (Júlio Júnior *et al.* 2005).

The reservoir fisheries were sampled in July and November 2001 in the lacustrine zone of the study reservoirs (sense Thornton *et al.* 1990) using 20 m long gillnets with different mesh sizes (2.4, 3, 4, 5, 6, 7, 8, 9, 10, 12 and 14 cm opposite knots). The nets were set for 24 h, and checked at 8-h intervals. We also operated seining nets (20 m long with 0.8 cm mesh sizes – opposite knots) during the day in marginal areas.

After the fish samplings were completed, all fish samples were fixed in formaldehyde (4%) and stored in polyethylene containers, being identified with regard to date and capture site. They were then forwarded to laboratories of the Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura (Nupelia) of Universidade Estadual de Maringá (UEM) for analyses. All the fish were identified (accordingly to Severi & Cordeiro 1994; Ingenito *et al.* 2004; Oyakawa *et al.* 2006; Graça & Pavanelli 2007; Menezes *et al.* 2007), measured to the nearest 0.1 cm (total length, TL; standard length; SL) and weighed to the nearest 0.01 g (total weight or TW). Further, most of the fish had their gonads checked macroscopically to determine their sex.

Length–length relationships were determined by the following equation:

$$\mathrm{TL} = a + b * \mathrm{SL}, \quad (1)$$

where TL is the total length, SL is the standard length, a is the intercept and b is the slope.

The length–weight relationships were determined by the following equation:

$$\mathrm{TW} = a * \mathrm{SL}^b, \quad (2)$$

where TW is the total weight, SL is the standard length, a is the intercept and b is the slope; increment in weigh for unit increment in length of the species.

The parameters of both relationships were estimated by a linear regression model based on the least-square method (Zar 1999), using $\log_{10}$-transformed total weight and SL (for linearized relations; $\log(\mathrm{TW}) = \log(a) + b \log(\mathrm{SL})$ for length–weight relationships). The degree of adjustment of the models was determined by the coefficient of determination (R^2). The Student's t-test (Zar 1999) was used to test possible significant differences in

Table 1. Standard length (cm) and weight (g) characteristics for 48 species caught in the 30 neotropical reservoirs, Paraná State, Brazil, during July and November 2001

		Length (cm) characteristics			Weight (g) characteristics		
Species	*n*	Mean	Min.	Max.	Mean	Min.	Max.
Apareiodon affinis (Steindachner, 1879)†	1086	7.9	1.5	13.4	12.53	0.04	47.64
Astyanax altiparanae (Garutti & Britski, 2000)†	3461	6.9	1.9	13.0	12.69	0.29	77.02
Astyanax fasciatus (Cuvier, 1819)	50	6.7	2.4	13.0	14.56	0.45	91.70
Astyanax janeiroensis (Eigenmann, 1908)†	126	7.2	3.1	11.5	11.79	1.01	39.77
Acestrorhynchus lacustris (Lütken, 1875)	108	16.2	10.2	24.5	70.36	12.12	268.46
Auchenipterus osteomystax (Ribeiro, 1918)†	271	16.4	8.3	24.0	62.36	7.13	180.06
Astyanax aff. *paranae* (Eigenmann, 1914)†	1312	7.3	2.7	13.0	10.37	0.50	66.36
Apareiodon piracicabae (Eigenmann, 1907)†	39	5.1	2.1	9.2	4.13	0.17	16.98
Apareiodon vittatus (Garavello, 1977)†	168	8.8	2.0	12.0	13.85	0.19	33.70
Bryconamericus iheringii (Boulenger, 1887)†	897	3.9	1.1	6.7	1.64	0.01	7.16
Bryconamericus stramineus (Eigenmann, 1908)†	614	3.1	1.4	6.8	0.54	0.06	5.95
Crenicichla haroldoi (Luengo & Britski, 1974)†	67	9.6	2.7	17.0	19.80	0.40	91.29
Crenicichla iguassuensis (Hanseman, 1911)†	72	9.5	7.1	25.0	22.24	8.60	380.25
Cyphocharax modestus (Fernández-Yépez, 1948)†	114	11.4	9.0	17.1	44.49	19.75	171.92
Crenicichla niederleinii (Holmberg, 1891)†	52	9.7	7.0	19.5	20.03	8.29	159.09
Corydoras cf. *paleatus* (Jenyns, 1842)†	503	5.0	4.0	6.3	5.89	3.50	11.95
Deuterodon iguape (Eigenmann, 1907)†	1044	6.7	1.8	12.0	8.15	0.13	41.72
Geophagus brasiliensis (Quoy & Gaimard, 1824)†	956	9.4	1.4	21.5	58.33	0.14	482.90
Galeocharax knerii (Steindachner, 1879)†	49	17.4	8.3	24.0	97.24	10.09	262.13
Glanidium ribeiroi Hanseman, 1911†	113	7.7	5.4	19.7	16.73	4.91	232.06
Hypostomus ancistroides (Ihering, 1911)†	27	14.3	8.6	17.8	87.50	23.40	131.64
Hypostomus commersoni (Valenciennes, 1836)†	68	20.4	12.2	27.5	252.31	56.69	493.20
Hypostomus derbyi (Hanseman, 1911)†	110	19.8	13.8	28.3	219.62	76.26	579.80
Hoplias aff. *Malabaricus* (Bloch, 1794)	427	25.7	7.0	45.7	484.52	6.90	2395.10
Hypostomus myersi (Gosline, 1947)†	34	12.8	6.3	17.5	80.20	10.30	162.71
Hypostomus regani (Ihering, 1905)†	23	14.8	4.8	18.6	105.69	3.18	199.34
Iheringichthys labrosus (Lütken, 1874)†	566	16.5	9.5	26.5	87.60	15.33	341.08
Leporinus obtusidens (Valenciennes, 1836)	27	24.0	9.8	32.0	431.21	19.69	984.00
Loricaria prolixa (Isbrücker & Nijssen, 1978)†	63	26.2	19.0	34.4	166.75	60.46	377.45
Moenkhausia aff. *intermedia* (Eigenmann, 1908)†	165	7.2	5.7	8.3	10.59	4.70	17.48
Metynnis lippincottianus (Cope, 1870)†	23	10.0	7.0	12.7	50.60	19.90	79.60
Mimagoniates microlepis (Steindachner, 1877)†	42	3.3	2.6	4.2	0.74	0.32	1.63
Odontesthes bonariensis (Valenciennes, 1835)	53	19.1	7.2	35.5	127.29	3.77	675.30
Oligosarcus longirostris (Menezes & Géry, 1983)†	1690	10.9	5.1	24.9	41.20	2.35	361.85
Oligosarcus paranensis (Menezes & Géry, 1983)†	1307	8.3	6.4	23.4	16.13	5.62	298.60
Phalloceros harpagos (Lucinda, 2008)†	140	1.9	1.1	3.1	0.21	0.01	1.00
Parauchenipterus galeatus (Linnaeus, 1766)†	66	14.8	11.5	17.5	139.97	55.14	213.33
Psalidodon gymnodontus (Eigenmann, 1911)†	59	7.0	5.5	12.8	10.72	5.40	57.98
Prochilodus lineatus (Valenciennes, 1836)	61	33.4	13.2	54.3	1325.04	73.61	4312.40
Pimelodus maculatus (La Cepède, 1803)	262	21.6	12.0	31.5	261.28	35.29	951.40
Piaractus mesopotamicus (Holmberg, 1887)	49	29.0	16.6	43.0	975.86	182.47	3014.90
Pimelodus ortmanni (Hanseman, 1911)†	192	11.6	5.4	31.0	52.28	2.49	621.70
Plagioscion squamosissimus (Heckel, 1840)	287	17.6	5.5	40.7	151.94	4.48	1402.00
Rhamdia quelen (Quoy & Gaimard, 1824)	125	20.8	9.0	32.0	236.08	14.58	766.80

Table 1. (*Continued*)

Species	*n*	Length (cm) characteristics Mean	Min.	Max.	Weight (g) characteristics Mean	Min.	Max.
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)†	36	9.9	7.4	13.5	29.12	9.89	77.33
Serrasalmus maculatus Kner, 1858†	69	11.1	4.8	19.0	61.59	3.19	266.99
Schizodon nasutus Kner, 1858†	225	19.5	7.8	28.4	173.86	9.38	533.50
Tilapia rendalli (Boulenger, 1897)	219	4.8	1.0	24.0	28.48	0.03	624.50

†Species for which the information is new for FishBase (http://www.fishbase.org; Froese & Pauly 2009).
n, total number of fish caught; Min., minimum; Max., maximum.

Table 2. Parameters of the relationship between total length (cm) and standard length (cm) for 48 species caught in the 30 neotropical reservoirs, Paraná State, Brazil, during July and November 2001

Species	Parameters of relationship *a*	*b*	SE(*b*)	CI	R^2
Apareiodon affinis (Steindachner, 1879)	0.277	1.147	0.003	±0.013	0.990
Astyanax altiparanae (Garutti & Britski, 2000)	0.585	1.180	0.002	±0.009	0.990
Astyanax fasciatus (Cuvier, 1819)	0.230	1.199	0.008	±0.032	0.990
Astyanax janeiroensis (Eigenmann, 1908)	0.457	1.181	0.011	±0.042	0.990
Acestrorhynchus lacustris (Lütken, 1875)	0.857	1.115	0.011	±0.042	0.990
Auchenipterus osteomystax (Ribeiro, 1918)	1.990	1.036	0.012	±0.048	0.960
Astyanax aff. *paranae* (Eigenmann, 1914)	0.641	1.147	0.004	±0.016	0.980
Apareiodon piracicabae (Eigenmann, 1907)	0.153	1.185	0.010	±0.040	0.990
Apareiodon vittatus (Garavello, 1977)	0.583	1.155	0.015	±0.058	0.970
Bryconamericus iheringii (Boulenger, 1887)	0.099	1.228	0.005	±0.020	0.980
Bryconamericus stramineus (Eigenmann, 1908)	0.057	1.185	0.009	±0.034	0.970
Crenicichla haroldoi (Luengo & Britski, 1974)	0.227	1.170	0.011	±0.045	0.990
Crenicichla iguassuensis (Hanseman, 1911)	0.184	1.189	0.014	±0.055	0.990
Cyphocharax modestus (Fernández-Yépez, 1948)	1.281	1.176	0.021	±0.085	0.960
Crenicichla niederleinii (Holmberg, 1891)	0.589	1.118	0.018	±0.074	0.990
Corydoras cf. *paleatus* (Jenyns, 1842)	1.018	1.109	0.020	±0.080	0.860
Deuterodon iguape (Eigenmann, 1907)	0.274	1.189	0.007	±0.026	0.970
Geophagus brasiliensis (Quoy & Gaimard, 1824)	0.128	1.264	0.003	±0.010	0.990
Galeocharax knerii (Steindachner, 1879)	0.566	1.142	0.017	±0.068	0.990
Glanidium ribeiroi (Hanseman, 1911)	0.295	1.211	0.015	±0.058	0.980
Hypostomus ancistroides (Ihering, 1911)	1.452	1.239	0.074	±0.305	0.920
Hypostomus commersoni (Valenciennes, 1836)	3.563	1.287	0.034	±0.135	0.960
Hypostomus derbyi (Hanseman, 1911)	1.237	1.326	0.032	±0.128	0.940
Hoplias aff. *malabaricus* (Bloch, 1794)	1.027	1.162	0.006	±0.022	0.990
Hypostomus myersi (Gosline, 1947)	2.852	1.141	0.046	±0.189	0.950
Hypostomus regani (Ihering, 1905)	0.580	1.268	0.048	±0.201	0.970
Iheringichthys labrosus (Lütken, 1874)	1.712	1.143	0.011	±0.043	0.950
Loricaria prolixa (Isbrücker & Nijssen, 1978)	4.522	0.981	0.067	±0.269	0.780
Leporinus obtusidens (Valenciennes, 1836)	0.627	1.170	0.030	±0.126	0.980
Moenkhausia aff. *intermedia* (Eigenmann, 1908)	0.927	1.086	0.029	±0.113	0.900
Metynnis lippincottianus (Cope, 1870)	1.920	1.025	0.059	±0.249	0.940

Table 2. (*Continued*)

	Parameters of relationship				
Species	*a*	*b*	SE(*b*)	CI	R^2
Mimagoniates microlepis (Steindachner, 1876)	−0.018	1.250	0.049	±0.197	0.940
Odontesthes bonariensis (Valenciennes, 1835)	0.064	1.184	0.006	±0.023	0.990
Oligosarcus longirostris (Menezes & Géry, 1983)	0.665	1.192	0.002	±0.007	0.990
Oligosarcus paranensis (Menezes & Géry, 1983)	0.531	1.177	0.002	±0.009	0.990
Phalloceros harpagos (Lucinda, 2008)	−0.040	1.263	0.016	±0.065	0.970
Parauchenipterus galeatus (Linnaeus, 1766)	2.138	1.054	0.048	±0.192	0.880
Psalidodon gymnodontus (Eigenmann, 1911)	0.775	1.176	0.016	±0.066	0.990
Prochilodus lineatus (Valenciennes, 1836)	0.383	1.241	0.026	±0.103	0.980
Pimelodus maculatus (La Cépède, 1803)	0.216	1.215	0.018	±0.071	0.950
Piaractus mesopotamicus (Holmberg, 1887)	1.743	1.218	0.025	±0.102	0.980
Pimelodus ortmanni (Hanseman, 1911)	0.136	1.275	0.006	±0.024	0.990
Plagioscion squamosissimus (Heckel, 1840)	1.546	1.114	0.006	±0.025	0.990
Rhamdia quelen (Quoy & Gaimard, 1824)	−0.199	1.223	0.011	±0.045	0.990
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)	0.281	1.207	0.019	±0.076	0.990
Serrasalmus maculatus (Kner, 1858)	0.670	1.113	0.014	±0.055	0.990
Schizodon nasutus (Kner, 1858)	0.781	1.149	0.009	±0.037	0.980
Tilapia rendalli (Boulenger, 1897)	−0.009	1.276	0.003	±0.013	0.990

SE(*b*), standard error of slope *b*; CI, confidence Interval; R^2, coefficient of determination.

the isometric condition ($b = 3$ for length–weight relationships). Analysis of covariance (ANCOVA; Goldberg & Scheiner 1993) was used to test for differences between parameters of the fitted curves, for males and females (species with $n > 30$ individuals by sex), and for length–weight relationships. Further, the Student's *t*-test was used to test for differences in mean length values between sexes. The assumptions of normality and homoscedasticity were evaluated, using the Shapiro–Wilk and Levene tests, respectively. The Mann–Whitney *U*-test (similar non-parametric; Zar 1999) was used if these assumptions were not met. The regressions, Student's *t*-test, Mann–Whitney *U*-test and ANCOVA were performed using the software Statistica™ (Statsoft Inc., Tulsa, Oklahoma, USA) for Windows 7.1. The statistical significance level adopted for all analysis was $P < 0.05$.

RESULTS

A total of 17 517 individual fish length and weight observations were recorded in this study. The sample size ranged from 23 (for *Hypostomus regani* and *Metynnis lippincottianus*) to 3.461 (for *Astyanax altiparanae*) individuals. The mean SL varied between 1.94 cm (*Phalloceros harpagos*) and 33.43 cm (*Prochilodus lineatus*). These species also presented the smallest and greatest mean weights (0.21 and 1325.04 g, respectively; Table 1). The minimum SL corresponded to 1.0 cm (*Tilapia rendalli*), whereas the maximum SL was 54.3 cm (*P. lineatus*). The weight limits were 0.01 g (*Bryconamericus iheringii*) to 4312.4 g (*P. lineatus*). Overall, the studied species were medium-sized; 31 species had a maximum SL between 10 and 30 cm; 7 species had a maximum SL greater than 10 cm; and 10 species had a maximum SL less than 30 cm (Table 1).

Table 2 summarizes the relationships between TL and SL. The overall regressions were significant for *Crenicichla iguassuensis*, *Galeocharax knerii*, *Hypostomus ancistroides*, *Hypostomus derbyi*, *H. regani*, *Leporinus obtusidens*, *Mimagoniates microlepis*, *Odontesthes bonariensis*, *P. harpagos*, *P. lineatus*, *Pimelodus maculatus*, *Pimelodus ortmanni*, *Rhamdia quelen*, *Steindachnerina brevipinna* and *T. rendalli*. The intercepts (*a*) were not significant. The R^2 values ranged from 0.78 (for *Loricaria prolixa*) to 0.99 (for other 22 species; see Table 2).

For length–weight relationships, the values of R^2 ranged from 0.78 (for *Parauchenipterus galeatus*) to 0.99 (for *Astyanax fasciatus*, *Apareiodon piracicabae*, *O. bonariensis*, *P. ortmanni*, *Serrasalmus maculatus* and *T. rendalli*). All the regressions were highly significant ($P < 0.05$). The values of *b* ranged from 2.494, for *Hypostomus commersoni*, to 3.463, for *M. lippincottianus*. The mean value of *b* was 3.001 (±SD = 0.2495), whereas the median was 3.034.

Fifty per cent of the values of *b* ranged between 2.849 and 3.161 (Tables 3 and 5).

It was possible to analyse the data for separate sexes for 25 species ($n > 30$; Table 4), totalling 5032 males and 5512 females. The sample sizes for these species ranged from 37 for females of *Astyanax janeiroensis*, to 1102 for males of *A. altiparanae*. The greater differences in mean lengths between sexes were observed for *Acestrorhynchus lacustris* ($U = 364.5$; $P < 0.05$) and *Plagioscion squamosissimus* ($U = 4765.0$; $P < 0.05$). The males were greater than the females only for *B. iheringii* ($U = 4488.5$; $P = 0.0587$), *Geophagus brasiliensis* ($U = 73\,579.5$; $P = 0.0042$) and *H. derbyi* ($t = 0.548$; $P = 0.585$; Table 4).

Pronounced sexual dimorphism in the length–weight relationships was not observed only for *A. lacustris*, *Hoplias* aff. *malabaricus*, *P. ortmanni*, *P. squamosissimus* and *R. quelen* (non-significant ANCOVA). Thus, only the general equations for both sexes are presented (Table 3; 28 species). Females of *A. lacustris* and *P. squamosissimus* attained greater sizes than males, however, indicating that both sexes grow similarly until reaching a certain size. After that point, the males stop growing. For the other 20 species, the ANCOVA was

Table 3. Parameters of the relationship between total weight (g) and standard length (cm) for 28 species caught in the 30 neotropical reservoirs, Paraná State, Brazil, during July and November 2001

	Parameters of relationship				
Species	*a*	*b*	SE(*b*)	CI	R^2
Astyanax fasciatus (Cuvier, 1819)	0.025	3.030	0.135	±0.271	0.99
Acestrorhynchus lacustris (Lütken, 1875)	0.006	*3.288*	0.064	±0.128	0.98
Apareiodon piracicabae (Eigenmann, 1907	0.023	2.951	0.064	±0.129	0.99
Bryconamericus stramineus (Eigenmann, 1908)	0.022	*2.804*	0.019	±0.038	0.88
Crenicichla haroldoi (Luengo & Britski, 1974)	0.031	*2.812*	0.087	±0.173	0.96
Crenicichla iguassuensis (Hanseman, 1911)	0.021	2.983	0.030	±0.059	0.93
Crenicichla niederleinii (Holmberg, 1891)	0.026	*2.862*	0.043	±0.087	0.95
Galeocharax knerii (Steindachner, 1879)	0.012	3.091	0.097	±0.195	0.98
Hypostomus ancistroides (Ihering, 1911)	0.108	*2.499*	0.179	±0.368	0.94
Hypostomus commersoni (Valenciennes, 1836)	0.128	*2.494*	0.131	±0.262	0.92
Hoplias aff. *malabaricus* (Bloch, 1794)	0.016	*3.117*	0.033	±0.064	0.98
Hypostomus myersi (Gosline, 1947)	0.099	*2.595*	0.148	±0.302	0.96
Hypostomus regani (Ihering, 1905)	0.038	2.911	0.193	±0.402	0.97
Leporinus obtusidens (Valenciennes, 1836)	0.012	3.243	0.273	±0.563	0.98
Loricaria prolixa (Isbrücker & Nijssen, 1978)	0.006	3.098	0.107	±0.214	0.95
Metynnis lippincottianus (Cope, 1870)	0.011	*3.463*	0.152	±0.316	0.83
Mimagoniates microlepis (Steindachner, 1876)	0.012	*3.421*	0.196	±0.396	0.94
Odontesthes bonariensis (Valenciennes, 1835)	0.008	*3.155*	0.077	±0.155	0.99
Parauchenipterus galeatus (Linnaeus, 1766)	0.097	2.692	0.184	±0.368	0.78
Psalidodon gymnodontus (Eigenmann, 1911)	0.04	*2.800*	0.043	±0.087	0.97
Prochilodus lineatus (Valenciennes, 1836)	0.026	3.038	0.093	±0.185	0.98
Piaractus mesopotamicus (Holmberg, 1887)	0.054	2.880	0.072	±0.144	0.98
Pimelodus ortmanni (Hanseman, 1911)	0.091	*3.213*	0.045	±0.088	0.99
Plagioscion squamosissimus (Heckel, 1840)	0.024	2.961	0.024	±0.048	0.97
Rhamdia quelen (Quoy & Gaimard, 1824)	0.014	3.135	0.078	±0.155	0.97
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)	0.015	*3.256*	0.096	±0.195	0.96
Serrasalmus maculatus (Kner, 1858)	0.023	*3.178*	0.058	±0.116	0.99
Tilapia rendalli (Boulenger, 1897)	0.041	3.046	0.029	±0.057	0.99

SE(*b*), standard error of slope *b*; CI, confidence interval; R^2, coefficient of determination.

Values in italics indicate significant differences in isometric condition ($b = 3$; Student's *t*-test; $P < 0.05$; $b > 3$ is positively allometric; $b < 3$ is negatively allometric; and $b = 3$ is isometric).

Table 4. Standard length (cm) and weight (g) characteristics for males and females for 25 species caught ($n > 30$) in the 30 neotropical reservoirs, Paraná State, Brazil, during July and November 2001

			Length (cm) characteristics			Weight (g) characteristics		
Species	Sex	*n*	Mean	Min.	Max.	Mean	Min.	Max.
Apareiodon affinis (Steindachner, 1879)	Males	210	7.5	3.0	11.5	10.08	0.50	27.14
	Females	479	9.1	3.2	13.4	16.63	1.11	47.64
Astyanax altiparanae (Garutti & Britski, 2000)	Males	1102	6.5	2.4	13.0	10.54	0.60	59.70
	Females	1093	7.6	2.7	13.0	18.16	0.80	77.02
Astyanax janeiroensis (Eigenmann, 1908)	Males	47	6.7	3.7	8.2	8.36	1.57	15.00
	Females	37	8.2	3.6	11.5	17.08	1.44	39.77
Acestrorhynchus lacustris (Lütken, 1875)	Males	41	13.6	10.2	19.5	35.80	12.12	90.65
	Females	62	18.1	10.8	24.5	95.66	15.50	268.46
Auchenipterus osteomystax (Ribeiro, 1918)	Males	75	14.9	12.0	18.8	41.31	22.57	75.03
	Females	186	17.0	8.3	24.0	70.67	7.13	180.06
Astyanax aff. *paranae* (Eigenmann, 1914)	Males	361	7.1	3.8	10.5	8.82	1.38	30.29
	Females	439	7.9	4.3	13.0	14.00	1.90	66.36
Apareiodon vittatus (Garavello, 1977)	Males	75	8.5	6.9	9.8	12.59	6.29	18.90
	Females	89	9.2	4.8	12.0	15.35	2.26	33.70
Bryconamericus iheringii (Boulenger, 1887)	Males	99	4.1	2.2	5.5	2.10	0.30	5.08
	Females	107	4.00	1.9	6.6	1.72	0.14	6.12
Cyphocharax modestus (Fernández-Yépez, 1948)	Males	53	11.2	9.8	12.2	40.01	33.70	50.56
	Females	60	11.6	9.0	17.1	48.46	19.75	171.92
Corydoras cf. *paleatus* (Jenyns, 1842)	Males	172	5.00	4.0	6.0	5.57	3.52	8.78
	Females	138	5.2	4.2	6.3	6.78	3.60	11.95
Deuterodon iguape (Eigenmann, 1907)	Males	289	6.6	3.2	10.4	8.11	0.90	34.17
	Females	233	7.0	3.8	11.0	9.62	1.34	33.71
Geophagus brasiliensis (Quoy & Gaimard, 1824)	Males	402	10.1	2.7	21.5	70.83	0.85	482.90
	Females	414	9.1	2.9	19.5	50.90	1.05	332.70
Glanidium ribeiroi (Hanseman, 1911)	Males	56	7.5	6.0	10.0	11.68	5.31	32.90
	Females	55	8.0	5.4	19.7	22.15	4.91	232.06
Hypostomus derbyi (Hanseman, 1911)	Males	48	20.1	14.5	28.3	224.74	78.95	579.80
	Females	42	19.8	14.0	25.4	232.53	88.21	446.24
Hoplias aff. *malabaricus* (Bloch, 1794)	Males	173	26.0	10.2	43.5	484.40	19.71	2107.40
	Females	230	26.0	9.2	45.7	505.94	14.80	2395.10
Iheringichthys labrosus (Lütken, 1874)	Males	249	15.9	10.1	23.0	74.76	17.15	206.34
	Females	306	17.0	9.5	26.5	97.90	15.33	341.08
Moenkhausia aff. *intermedia* (Eigenmann, 1908)	Males	57	6.7	5.7	7.5	7.57	4.70	12.41
	Females	91	7.6	6.8	8.3	12.89	7.03	17.48
Oligosarcus longirostris (Menezes & Géry, 1983)	Males	600	10.2	5.1	23.3	26.41	2.35	269.21
	Females	639	13.4	7.0	24.9	76.78	6.15	361.85
Oligosarcus paranensis (Menezes & Géry, 1983)	Males	293	7.9	6.4	16.6	11.48	5.62	110.40
	Females	333	9.4	6.5	23.4	26.44	6.22	288.48
Phalloceros harpagos (Lucinda, 2008)	Males	45	1.8	1.4	2.5	0.12	0.03	0.31
	Females	42	2.4	1.3	3.0	0.38	0.06	0.88
Pimelodus maculatus (La Cépède, 1803)	Males	176	21.1	12.5	27.5	226.88	40.59	441.05
	Females	84	22.8	12.0	31.5	334.79	35.29	951.40
Pimelodus ortmanni (Hanseman, 1911)	Males	83	10.5	5.4	21.7	28.33	2.49	191.67
	Females	99	12.7	6.8	31.0	74.31	4.44	621.70

Table 4. (*Continued*)

Species	Sex	*n*	Length (cm) characteristics			Weight (g) characteristics		
			Mean	Min.	Max.	Mean	Min.	Max.
Plagioscion squamosissimus (Heckel, 1840)	Males	185	16.8	6.3	30.4	121.62	5.49	691.00
	Females	80	20.2	9.0	40.7	232.48	15.80	1402.00
Rhamdia quelen (Quoy & Gaimard, 1824)	Males	49	20.9	9.4	31.0	228.44	20.83	747.00
	Females	57	21.4	9.0	32.0	267.33	14.58	766.80
Schizodon nasutus (Kner, 1858)	Males	92	18.6	8.9	24.0	137.07	12.52	277.33
	Females	117	20.3	9.3	28.4	203.37	16.63	533.50

n, total number of fish caught; Min., minimum; Max., maximum.

Table 5. Parameters of the relationship between total weight (g) and standard length (cm) for males and females for 20 species (significant differences between sexes, ANCOVA) in the 30 neotropical reservoirs, Paraná State, Brazil, during July and November 2001

Species	Sex	Parameters of relationship					
		a	*b*	SE(*b*)	CI	R^2	*P*
Apareiodon affinis (Steindachner, 1879)	Males	0.027	*2.859*	0.051	±0.1004	0.985	0.0020
	Females	0.021	2.987	0.044	±0.0868	0.982	
Astyanax altiparanae (Garutti & Britski, 2000)	Males	0.061	*2.682*	0.011	±0.0220	0.987	<0.0001
	Females	0.036	2.978	0.019	±0.0366	0.982	
Astyanax janeiroensis (Eigenmann, 1908)	Males	0.025	3.034	0.083	±0.1677	0.984	0.0001
	Females	0.027	3.030	0.102	±0.2072	0.982	
Auchenipterus osteomystax (Ribeiro, 1918)	Males	0.034	*2.623*	0.118	±0.2342	0.933	0.0042
	Females	0.014	2.985	0.068	±0.1351	0.964	
Astyanax aff. *paranae* (Eigenmann, 1914)	Males	0.014	*3.273*	0.043	±0.0848	0.965	<0.0001
	Females	0.011	*3.403*	0.027	±0.0533	0.984	
Apareiodon vittatus (Garavello, 1977)	Males	0.050	*2.586*	0.156	±0.3106	0.894	0.0002
	Females	0.032	*2.773*	0.095	±0.1885	0.954	
Bryconamericus iheringii (Boulenger, 1887)	Males	0.024	3.088	0.123	±0.2445	0.949	0.0007
	Females	0.034	*2.778*	0.075	±0.1495	0.954	
Cyphocharax modestus (Fernández-Yépez, 1948)	Males	0.429	1.878	0.193	±0.3883	0.802	<0.0001
	Females	0.020	*3.165*	0.074	±0.1481	0.974	
Corydoras cf. *paleatus* (Jenyns, 1842)	Males	0.163	*2.194*	0.112	±0.2216	0.832	<0.0001
	Females	0.115	*2.461*	0.133	±0.2627	0.855	
Deuterodon iguape (Eigenmann, 1907)	Males	0.026	2.990	0.032	±0.0637	0.981	0.0279
	Females	0.024	3.049	0.042	±0.0835	0.975	
Geophagus brasiliensis (Quoy & Gaimard, 1824)	Males	0.025	*3.201*	0.033	±0.0656	0.989	0.0071
	Females	0.035	*3.092*	0.032	±0.0633	0.987	
Glanidium ribeiroi (Hanseman, 1911)	Males	0.010	*3.481*	0.146	±0.2921	0.940	0.0446
	Females	0.032	3.020	0.082	±0.1646	0.984	
Hypostomus derbyi (Hanseman, 1911)	Males	0.065	*2.699*	0.126	±0.2540	0.951	0.0063
	Females	0.131	*2.495*	0.202	±0.4079	0.906	
Iheringichthys labrosus (Lütken, 1874)	Males	0.029	*2.815*	0.042	±0.0824	0.974	<0.0001
	Females	0.021	2.959	0.040	±0.0797	0.971	
Moenkhausia aff. *intermedia* (Eigenmann, 1908)	Males	0.078	*2.403*	0.254	±0.5094	0.790	<0.0001
	Females	0.056	2.668	0.224	±0.4443	0.804	
Oligosarcus longirostris (Menezes & Géry, 1983)	Males	0.013	*3.162*	0.020	±0.0385	0.991	<0.0001

Table 5. (*Continued*)

Species	Sex	Parameters of relationship *a*	*b*	SE(*b*)	CI	R^2	*P*
	Females	0.010	*3.249*	0.037	±0.0734	0.986	
Oligosarcus paranensis (Menezes & Géry, 1983)	Males	0.021	2.985	0.030	±0.0598	0.968	<0.0001
	Females	0.014	3.151	0.032	±0.0628	0.990	
Phalloceros harpagos (Lucinda, 2008)	Males	0.035	*2.119*	0.421	±0.8484	0.567	0.0027
	Females	0.020	3.272	0.366	±0.7404	0.870	
Pimelodus maculatus (La Cépède, 1803)	Males	0.068	*2.651*	0.101	±0.1999	0.910	<0.0001
	Females	0.005	*3.503*	0.121	±0.2416	0.990	
Schizodon nasutus (Kner, 1858)	Males	0.061	*2.618*	0.118	±0.2344	0.951	0.0014
	Females	0.010	*3.236*	0.072	±0.1418	0.982	

SE(*b*), standard error of slope *b*; CI, confidence interval; R^2, coefficient of determination; *P*, probability of rejection.

Values in italics indicate significant differences in isometric condition ($b = 3$; Student's *t*-test; $P < 0.05$; $b > 3$ is positively allometric; b < 3 is negatively allometric; b = 3 is isometric).

significant, with the parameters (intercepts and slopes) presented in Table 5.

DISCUSSION

Information derived in this study will facilitate the ability of fish biologists and fishery managers to derive weight estimates for fish that are measured, but not weighed. The length–weight parameters reported herein may be useful in ongoing studies of fish landings from commercial fisheries. Further, weight is a good indicator of the health or condition of fish (Le Cren 1951; Vazzoler 1996), and these parameter estimates are currently important for constructing ecosystem models that use specific software (e.g. ECOPATH software; Christensen & Pauly 1993).

For the 48 species examined in this study, 38 species provided no information on length–length and length–weight relationships in FishBase (http://www.fishbase.org; Froese & Pauly 2009). The length–length relationship for *L. prolixa*, however, exhibited the smaller coefficient of determination. Species of this genus have an elongated slender filament extending from the caudal fin (Ferraris 2007; Thomas & Rapp Py-Daniel 2008). This filament may cause mistakes in measuring the total length of these fish, therefore, resulting in a low coefficient of determination.

For length–weight relationships, the value of the parameter *b* depends primarily on the shape and fatness of the fish species. According to Bagenal and Tesch (1978), however, the parameter *b*, unlike the parameter *a*, may vary temporally and spatially. Thus, the length–weight relationship in fish is affected by a number of factors, including gonad maturity, gender, diet, stomach fullness, health and preservation techniques, as well as season and habitat (Pauly 1984; Froese 2006). Except for gender, however, none of these factors were considered in this study.

Values of *b* that are close to 3 indicate that the fish grow isometrically, whereas values different from 3 indicate allometric growth. Where $b > 3$, the growth is positively allometric (increase in weight is larger than increase in length), whereas for $b < 3$, the growth is negatively allometric (increase in length is larger than increase in weight; Benedito-Cecílio & Agostinho 1997; Gurkan & Taşkavak 2007). Five fish species exhibited isometric growth in this study, whereas 11 exhibited negative allometric growth and 12 exhibited positive allometric growth. The parameter *b* varied between 2.49 and 3.46. An over-proportional increase in length, relative to growth in weight, is reflected when $b < 2.5$. In contrast, where $b > 3.5$, an over-proportional increase in weight relative to the growth in length is indicated (Froese 2006).

Other studies also reported values of *b* in the same range interval observed in this study (Dulčić & Kraljević 1996; Özaydin & Taşkavak 2007). Carlender (1977) demonstrated that values of $b < 2.5$ or $b > 3.5$ are often a consequence of small sample size and size range. Thus, because the same sizes in this study were less than 30 individuals for some species (e.g. *H. ancistroides*, *H. regani*, *L. Obtusidens* and *M. lippincottianus*), in addition to other 17 species with numbers less than 100 individuals, this may likely have influenced our results. Further, Gurkan and Taşkavak (2007) reported that variations in isometry in their analysis may be the result of the inclusion of several small individuals that had not yet reached adult body size. As pointed out by Petrakis and Stergiou (1995) and Dulčić and Kraljević (1996), therefore, the use of length–weight regressions should be limited to the sizes of fish used to estimate the parameters.

Pronounced sexual dimorphism in the length–weight relationship (significant differences in the slope) between males and females was observed for 20 fish species. The males were larger than the females for the same size for *A. janeiroensis*, *B. iheringii*, *G. brasiliensis*, *G. ribeiroi* and *H. derbyi*. In contrast, the females were larger for the other 15 fish species. For *A. lacustris* and *P. squamosissimus*, the females were 5 cm larger than the males on average. However, there were no verified difference between sexes, indicating weight growth is equal among the individual fish.

Differences in the standard length between male and female fish, with largest values being registered for females, also were observed for several other neotropical fish species, especially long-distance migratory species which have seasonal migrations for reproduction (Narahara *et al.* 1985; Canan & Gurgel 1997; Lopes *et al.* 2000; Rêgo *et al.* 2008). For this species, the females invest in large gonads, which induce an energy loss more pronounced than that for the males. These fish obviously need larger corporal proportions to contain bigger ovaries and reach larger fecundity (Vicentin *et al.* 2004). In agreement with Rêgo *et al.* (2008), other factors also can influence differences between the sexes, including sexual attraction (bigger lengths of the males), age (samplings contain more juveniles), genetic variability, metabolism and fishing.

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