Parameter Estimates for Fishes of the Upper Paraná River Floodplain and Itaipu Reservoir (Brazil)

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Abstract

Estimates of the growth (K), natural mortality (M), consumption/biomass (Q/B) rate and trophic level (TL) for 35 species in the upper Paraná river floodplain and the Itaipu reservoir (interconnected ecosystems) are presented. A compilation of these biological statistics is made for comparison purposes and some general trends are briefly discussed.

Introduction

Consumption, natural mortality, trophic level and estimates of growth are very important parameters for the construction of Ecopath (trophic) models (Christensen and Pauly 1993). Consumption (Q) is the intake of food by a species over a certain time period. The ratio Q/B (Consumption/Biomass) has been defined as the number of times a population consumes its own weight in a year (García and Duarte 2002; Pauly 1998a).

According to Allen (1971), usually Natural Mortality (M), in equilibrium conditions, can be considered the production that is the "total quantity of tissue elaborated by a fish population during a stated period of time" (Ivlev 1945). Trophic Level (TL) defines the position of the fish on food web and can be estimated by stomach content analysis. Growth estimates can be described by the von Bertalanffy growth function (VBGF), which is expressed by the parameters K (growth constant) and L_∞ (asymptotic length).

In order to infer the population response to impacts from two different ecosystems during two periods, the parameters K, L_∞, M, QB and TL were estimated and compared for the 35 more abundant species from the upper Paraná river floodplain and the Itaipu reservoir.

Figure 1. Map of South America and Brazil identifying the Upper Paraná River floodplain and Itaipu reservoir.

Material and Methods

Study areas

The Itaipu reservoir is located on the border of Brazil and Paraguay. It has an area of 1 350 km^2 and a mean depth of 22 m (mean water residence time = 40 d) (Figure 1). The reservoir was closed in 1982. The Upper Paraná River includes approximately the first one-third of the Paraná river basin with a drainage area of 2.8 x 10^6 km^2 and 138 reservoirs with dams greater than 10 m in height. The study area is situated immediately above the Itaipu reservoir and represents as much as one-third of the original floodplain (230 km). It is the last stretch of the Paraná river in Brazilian territory that has not been impounded (Agostinho and Zalewski 1995; Gomes and Miranda 2001; Petrere et al. 2002).

Data sampling

From March 1992 to February 1995, sampling of fish was conducted every three months in the various habitats (river, channels and lakes) in the upper Paraná river floodplain. Gill nets (2-16 cm mesh) and trammel nets (6-8 cm mesh) were used for collecting the samples. Fishing gears were deployed for 24 hours during each sampling period, with inspections in the early morning, dusk and late evening.

At the Itaipu reservoir, species were collected monthly during January 1983 to December 1987 and January 1988 to December 1992. Gill nets (3-16 cm mesh) were deployed for 24 hours during each sampling period (with inspections in the early morning, dusk and late evening) at various sites (lotic and lentic environments; transitional zone).

The fishes were preserved with tricaine or oil of cloves before being sorted by species, counted and measured.

Data analysis

Length-frequency data for species from both environments (reservoir and floodplain) were analyzed. Growth parameters were calculated using VBGF equations:

$$L_t = L_\infty * (1 - e^{-K(t - to)}) \quad \textbf{(1)}$$

where L_t is fish length (cm) at age t, L_∞ is the Asymptotic Length (cm), K is the curvature of the VBGF or Growth Rate (year^{-1}), and t_0 ("t - zero") is the age intercept where fish age is assumed to be zero.

Parameter K (growth rate) of the VBGF was calculated using length-frequency data and the ELEFAN I routine of FISAT (Sparre et al. 1989; FAO-ICLARM 1996) (and with option to scan for K-values) because in tropical areas it is difficult, if not impossible, to count rings on hard parts (Lizama and Vazzoler 1993). In all cases, Asymptotic Length (L_∞) was calculated using maximum length (L_{max}), i.e., largest individual of the population sample ($L_\infty = L_{max} * 1.05$).

Natural Mortality (M) was calculated by empiric regression (Pauly 1980):

$$M = K^{0.65} * L_\infty^{-0.279} * T^{0.463} \quad \textbf{(2)}$$

where M is Natural Mortality (year^{-1}) and T is a mean temperature (23.4°C).

Palomares and Pauly (1998) proposed using empiric regression to estimate the Consumption/Biomass rate (Q/B) as follows:

$$\log QB = 7.964 - 0.204 \log W_\infty - 1.965 T' + 0.083 Ar + 0.532 H + 0.398 D \quad \textbf{(3)}$$

where QB is Consumption/Biomass rate (year^{-1}); W_∞ is Asymptotic Weight (g); T' is mean annual temperature of water body, expressed as T' = 1000/Kelvin (Kelvin = 23.4°C + 273.15), where 23.4 is the mean annual temperature of reservoir and floodplain; and Ar is the Aspect Ratio of the caudal fin (mm^2). H and D are related to feeding behavior, i.e., H =1 for herbivores, D=1 for detritivores.

The Ar value was estimated as the average measurement for three or four individuals per species. Trophic Level (TL) for each species was based on an approach used in Ecopath (Christensen and Pauly 1993), i.e., TL is equal to 1 plus the weighted mean of the prey's trophic level. Information about diet composition is provided in Hahn et al. (1997) and Agostinho et al. (1997).

Paired t-tests were performed to investigate K value differences between time periods within each ecosystem and among ecosystems, separating reproductive behavior (migratory and sedentary) (Zar 1996). Correlation analysis (Pearson r) was performed on all variable combinations. To control Type II error, p values were adjusted using the sequential Bonferroni test correction of Peres-Neto (1999). Overall, correlation coefficients between parameters are very weak and not significant ($p<0.001$), hence are not discussed in the results.

Results

Table 1 presents information and related estimated parameters for 35 species for different time periods and ecosystems, totaling 87 fish populations.

The auximetric plot (from the Greek *auxesis* - growth and *metron* - measure) shows that the smaller species have high values of K, while it is the opposite with the large ones. This pattern is not associated with the survey period (Figure 2). Paired t-test ($n = 8$, $p < 0.004$) demonstrated that K declined between time periods only for sedentary species such as *S. borelii*, *S. spilopleura* and *T. paraguayensis*. In the Itaipu reservoir, K values for sedentary species were more constant and showed no change for nine years after the closure of the dam ($n = 10$, $p<0.89$). Other comparisons, such as between ecosystems, time periods in the Itaipu reservoir, time periods of the migratory species, etc., showed no significant differences.

Discussion

The findings of this study are consistent with other studies that have proposed that smaller species have higher values of K (Pauly 1998a), for instance, the same asymptotic size, may be associated with various values of K (Figure 2), showing different strategies of the occupation of the "available growth space" by species. These patterns are similar to those observed for fish species in other latitudes and ecosystems (Pauly 1998b).

K values decreased among the sedentary species in the floodplain, probably because these populations are affected by an irregular flood regime (Agostinho et al. 1999, 2001) due to many upstream dams (26 reservoirs covering about 100 km²), while reservoir populations live in an environment with more stability.

The relationship assumed by some authors that Trophic Level increases with fish size (Pauly et al. 1998) is not clear for the Paraná species. The correlation (r = 0.36) was disproportionately influenced by the longest species (*P. corruscans* and *P. luetkeni*).

The compilation also indicated that Q/B varies inversely with L_∞ and Trophic Level (see Table 1). García and Duarte (2002) showed similar trends for Caribbean fishes. Natural Mortality has a high correlation with L_∞ and K, but since M is calculated by equation 2, these relationships have no biological significance.

Estimates presented here should be useful for construction of Ecopath models, since in tropical regions like Brazil, ecological modeling is at a development stage (Angelini and Petrere 1996; Wolff et al. 2000; Angelini and Agostinho 2005).

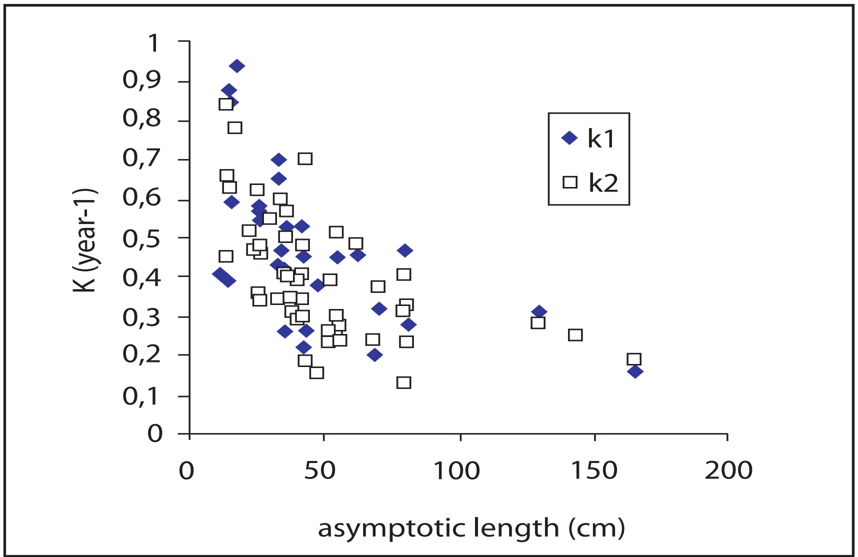

Figure 2. Plot of K and asymptotic length (L∞) (n=87). K1: 1983-1988; K2: 1992-1995 for the Itaipu reservoir and Upper Paraná River floodplain (Brazil).

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References

Agostinho, A.A. and M. Zalewski. 1995. The dependence of fish community structure and dynamics on floodplain and riparian ecotone zone in the Paraná river, Brazil. Hydrobiologia (303):141-148.

Agostinho, A.A., N.S. Hahn, L.C. Gomes and L.M. Bini. 1997. Estrutura trófica, p. 229-248. *In* A.E.M. Vazzoler, A.A. Agostinho and N.S. Hahn (eds.) A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e sócio-econômicos. EdUEM - Maringá/PR – Brazil.

Agostinho, A.A., L.E. Miranda, L.M. Bini, L.C. Gomes, S.M. Thomaz and H.I. Suzuki. 1999. Patterns of colonization in neotropical reservoirs and prognoses on aging, p. 227-265. *In* J.G. Tundisi and M. Straskraba (eds.) Theoretical reservoir ecology and its applications. Backhuys Publishers.

Agostinho, A.A., L.C. Gomes and M. Zalewski. 2001. The importance of floodplains for the dynamics of fish communities of the upper Paraná River. Ecohydrology and Hydrobiology 1(1-2):209-217.

Allen, K.R. 1971. Relation between production and biomass. Journal Fisheries Research 28:1573-1581.

Angelini, R. and M. Petrere. 1996. The ecosystem of the Broa Reservoir (Brazil), modeled using the ECOPATH II. NAGA, WorldFish Center Q. 19(2):36-41.

Angelini, R. and A.A. Agostinho. 2005. Food web model of the upper Paraná river floodplain: description and aggregation effects. Ecological Modelling 181:109-121.

Christensen, V. and D. Pauly (eds.) 1993. Trophic models of aquatic ecosystems. ICLARM. Conf. Proc. 26.

FAO-ICLARM. 1996. Stock Assessment Tools. User's Manual. Ed: FAO-ICLARM, Roma.

Garcia, C.B. and L.O. Duarte. 2002. Consumption to biomass (Q/B) ratio estimates of Q/B-predictor parameters for Caribbean fishes. NAGA, WorldFish Center Q. 25(2):19-22.

Gomes, L.C. and L.E. Miranda. 2001. Hydrologic and climatic regimes limit phytoplankton biomass in reservoirs of the upper Paraná river basin, Brazil. Hydrobiologia 457:205-214.

Hahn, N.S., I.F. Andrian, R. Fugi and V.L.L. Almeida. 1997. Ecologia trófica, p. 209-228. *In* A.E.M. Vazzoler, A.A. Agostinho and N.S. Hahn (eds.) A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e sócio-econômicos. EdUEM - Maringá/PR – Brazil.

Ivlev, V.S. 1945. The biological productivity of waters. Biol. 19:98-120. Uspekhi Sovrem.

Lizama, M.L.A.P. and A.E.A.M. Vazzoler. 1993. Crescimento em Peixes do Brasil: Uma síntese comentada. Rev. Unimar. 15 (supl.):141-173.

Palomares, M.L. and D. Pauly. 1998. Predicting food consumption of

Table 1. Estimated parameters for species at the Itaipu reservoir and upper Paraná river floodplain (Brazil) in two periods.

Species	Common name	Ecosystem	Reproductive behavior	TL	L_∞	K1	K2	M1	M2	QB	Ar	n1	n2
Acestrorhyncus lacustris (Lütken, 1875)	Peixe Cachorro	Floodplain Reservoir	Sedentary	3.6 3.6	38 38	 0.40	0.40 0.31	 0.9	0.9 0.8	9.74 9.74	2.73 2.73	 1034	2371 478
Ageneiosus ucayalensis (Casteunal, 1855)	Mandubé	Reservoir	Sedentary	3.7	35	0.26	0.41	0.7	0.9	10.05	2.49	2162	512
Astyanax altiparanae (Garutti & Britski, 2000)	Tambiú	Reservoir Floodplain	Sedentary	2.7 2.7	15 14	0.39	0.66 0.45	1.1	1.6 1.3	12.17 12.17	1.24 1.24	1523	1205 919
Auchenipterus nuchalis (Spix & Agassiz, 1829)	Mandi Peruano	Reservoir Floodplain	Sedentary	3.1 3.1	33 33	0.65 0.7	0.35 0.34	1.3 1.3	0.8 0.8	8.96 8.96	1.85 1.85	5985 791	7306 572
Brycon orbignyanus (Valenciennes, 1850)	Piracanjuba	Floodplain	Migratory	2.8	40		0.29		0.7	6.99	1.6		170
Cyphocharax modestus (Fernández-Yapéz, 1948)	Saguiru	Floodplain	Sedentary	2.1	18	0.94	0.78	1.9	1.7	23.31	0.81	321	304
Hemisorubin platyrhynchos (Valenciennes, 1840)	Braço de moça	Floodplain	Migratory	3.8	52		0.23		0.6	5.81	1.04		211
Hoplias malabaricus (Bloch, 1794)	Traíra	Reservoir Floodplain	Sedentary	3.8 3.8	55 44	0.45	0.51 0.7	0.9	0.9 1.2	6.05 6.05	1.3 1.3	7527	18764 2303
Hoplosternum littorale (Hancock, 1828)	Tamboatá	Floodplain	Sedentary	2.6	23		0.52		1.2	9.10	1.68		1795
Hypophthalmus edentatus (Spix & Agassiz, 1829)	Mapará	Reservoir Floodplain	Sedentary	2.7 2.7	56 56	0.28	0.28 0.24	0.6	0.6 0.6	26.8 26.8	2.04 2.04	7522	18758 171
Hypostomus spp	Cascudo	Reservoir Floodplain	Sedentary	2.0 2.0	41 34	0.53 0.47	0.41 0.6	1 1	0.9 1.2	15.3 15.3	0.94 0.94	465 545	899 553
Iheringichthys labrosus (Lütken, 1874)	Mandi	Reservoir Floodplain	Sedentary	2.7 2.7	33 30	0.43	0.56 0.55	1	1.2 1.2	23.2 23.2	1.63 1.63	1506	3389 1536
Leporinus friderici (Bloch, 1794)	Cabeça Gorda	Reservoir Floodplain	Migratory	2.6 2.6	42 42	0.22	0.48 0.34	0.6	1 0.8	6.38 6.38	1.37 1.37	712	524 864
Leporinus obtusidens (Valenciennes, 1836)	piapara	Reservoir Floodplain	Migratory	2.6 2.6	44 42	0.26	0.18 0.3	0.6	0.5 0.7	6.24 6.24	1.37 1.37	165	207 1297
Loricaria sp	Acari	Reservoir	Sedentary	2.3	36	0.56	0.5	1.1	1	20.9	1.16	115	111
Loricariichthys platymetopon (Isbrücker & Nijssen, 1979)	Acari	Floodplain	Sedentary	2.3	36	0.53	0.57	1.1	1.1	20.9	1.16	7056	5894
Megalancistrus parananus (Peters, 1881)	Cascudo abacaxi	Reservoir	Sedentary	2.0	52		0.26		0.6	10.0			1590
Moenkhausia intermedia (Eigenmann, 1908)	Lambari	Reservoir	Sedentary	3.0	11	0.41		1.3		13.2	0.726	431	
Pimelodus maculatus (Lacepède, 1803)	Mandi	Reservoir Floodplain	Migratory	3.1 3.1	43 40	0.45 0.29	0.41 0.39	0.9 0.7	0.9 0.9	17.8 17.8	1.64 1.64	1223 1057	2710 1213
Pinirampus pirinampu (Spix & Agassiz, 1829)	Pinarambu	Reservoir	Migratory	3.4	68	0.2	0.24	0.5	0.5	6.4	2.48	461	834
Plagioscion squamosissimus (Heckel, 1840)	Pescada branca	Reservoir Floodplain	Sedentary	3.7 3.7	62 48	0.46 0.38	0.48 0.15	0.9 0.8	0.9 0.4	6.0 6.0	1.43 1.43	6623 699	16089 339
Prochilodus lineatus (Valenciennes, 1836)	Curimba	Reservoir Floodplain	Migratory	2.2 2.2	81 81	0.28	0.33 0.23	0.6	0.6 0.5	12.8 16.3	2.16 2.16	2093	2326 6250

>Table I - *Continued*

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Species	Common name	Ecosystem	Reproductive behavior	TL	L_∞	K1	K2	M1	M2	QB	Ar	n1	n2
Pseudoplatystoma corruscans (Spix & Agassiz, 1829)	Pintado	Reservoir Floodplain	Migratory	4.0 4.0	165 143	0.16	0.19 0.25	0.3	0.4 0.5	3.7 3.7	1.86 1.86	250	181 310
Pterodoras granulosus (Valenciennes)	Abotoado	Reservoir Floodplain	Migratory	2.3 2.3	70 55	0.32	0.37 0.3	0.7	0.7 0.7	5.4 5.4	1.35 1.35	1603	10868 224
Rhaphiodon vulpinus (Spix & Agassiz, 1829)	Peixe-cachorro	Reservoir Floodplain	Sedentary	3.8 3.8	80 80	0.47	0.31 0.4	0.8	0.6 0.7	5.84 5.84	1.76 1.76	1098	806 1618
Rhinelepis aspera (Spix & Agassiz, 1829)	Cascudo preto	Reservoir	Migratory	2.1	53		0.39		0.8				1962
Salminus brasiliensis (Cuvier, 1816)	Dourado	Floodplain	Migratory	3.6	80		0.13		0.4	4.4	1.43		187
Schizodon altoparanae (Garavello & Britski, 1990)	Piava	Floodplain	Sedentary	2.0	27		0.48		1.1	33.8	2.06		560
Schizodon borellii (Boulenger, 1900)	Piava	Reservoir Floodplain	Sedentary	2.0 2.0	38 36	0.5 0.53	0.35 0.4	1 1.1	0.8 0.9	19.8 19.8	2.03 2.03	543 832	462 2869
Serrasalmus marginatus (Valenciennes, 1836)	Piranha	Reservoir Floodplain	Sedentary	3.8 3.8	26 26	0.58 0.57	0.62 0.36	1.3 1.2	1.3 0.9	11.5 11.5	3.33 3.33	2244 1503	1363 6723
Serrasalmus spilopleura (Kner, 1858)	Piranha	Floodplain	Sedentary	3.8	27	0.55	0.34	1.2	0.9	9.12	2.35	3547	379
Steindachnerina insculpta (Fernández & Yépez, 1948)		Floodplain	Sedentary	3.8	14	0.88	0.84	1.9	2	23.7		519	1690
Trachelyopterus galeatus (Linnaeus, 1766)	Cangati	Reservoir Floodplain	Sedentary Sedentary	2.6 2.6	27 24	0.54	0.46 0.47	1.2	1.1 1.1	8.92 8.92	1.44 1.44	2634	387 2629
Trachydoras paraguayensis (Eigenmann & Ward, 1907)	Rique-rique	Reservoir Floodplain	Sedentary	2.5 2.5	16 15.5	0.59 0.85	 0.63	1.5 1.9	 1.5	8.5 8.5		2019 638	 1126
Zungaro jahu (Ihering, 1898)	Jaú	Reservoir	Migratory	4.0	130	0.31	0.28	0.5	0.5	2.5		352	122

TL- Trophic Level; L_∞- Asymptotic Length (cm); K- Growth Rate (year^{-1}); M- Natural Mortality (year^{-1}); QB- Consumption/Biomass (t km^{-2}year^{-1}); Ar- Aspect Ratio of the caudal fin; n – sample size. Number 1:1983-1987 for reservoir and 1986-1988 for floodplain; Number 2: 1988-1992 for reservoir and 1992-1995 for floodplain.

fish populations as functions of mortality, food type, morphometrics, temperature and salinity. Marine and Freshwater Research 49(5):447-453.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil International pour l'Exploration de la Mer 39(3):175-192.

Pauly, D. 1998a. Tropical fishes: patterns and propensities. Journal of Fish Biology 53 (Supplement A):1-17.

Pauly, D. 1998b. Beyond our original horizons: the tropicalization of Beverton and Holt. Reviews in Fish Biology and Fisheries 8:307-334.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F.C. Torres, Jr. 1998. Fishing down marine food webs. Science 279:860-863.

Peres-Neto, P.R. 1999. How many statistical tests are too many? The problem of conducting multiple ecological inferences revisited. Marine Ecology Progress Series 176:303-306.

Petrere, M. Jr., A.A. Agostinho, E.K. Okada and H.F. Júlio, Jr. 2002. Review of the fisheries in the Brazilian portion of the Paraná/Pantanal basin, p. 123-143. *In* L.G. Cowx (ed.) Management and ecology of lake and reservoir fisheries. Fishing New Books, Oxford.

Sparre, P., E. Ursin and S.C. Venema. 1989. Introduction to tropical fish stock assessment. Part 1. Manual. FAO, Fisheries Technical Paper, Rome.

Wolff, M., V. Koch and V. Isaac. 2000. A trophic model of Caeté Mangrove Estuary (North Brazil) with considerations for the sustainable use of its resources. Estuarine, Coastal and Shelf Science 50:789-803.

Zar, J.H. 1996. Biostatistical analysis. 3ª ed. Ed: Prentice Hall.

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