



Length-weight relationship of fish from high mountain freshwater environments of the central Andes, Argentina

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Abstract. This study provides the length-weight relationship in four nonnative and one native fish species of the central Andes, Argentina. The only species showing positive allometric growth was the native torrent catfish *Hatcheria macraei*.

Keywords: Freshwater environments, Andean fish, growth type

Resumen. Relación largo-peso de peces de ambientes de agua dulce de alta montaña de los Andes centrales, Argentina. Este estudio proporciona las relaciones largo-peso para cuatro especies de peces exóticas y una nativa de los Andes centrales, Argentina. La única especie que mostró un crecimiento alométrico positivo fue la especie nativa bagre torrente *Hatcheria macraei*.

Palabras clave: ambientes de agua dulce, peces Andinos, tipo de crecimiento

The central Andes (South America) has the highest peaks of the Andes range (e.g., Mount Aconcagua, 6962 m) and represents the second most important glacier area in Argentina, after the Patagonian Andes. Due to the existence of more than 8076 glaciers in the central Andes (IANIGLA-ING 2018), it is considered the main fresh water reservoir of the region. The rivers and streams provide the main source of drinking water supply to the population and for the irrigation of the agricultural areas (Civit *et al.* 2018). Management plans (Argentinian law 26.639, enacted in 2010 for the preservation of glaciers and the periglacial environment) have been implemented to control water reservoirs for human uses as well as

biodiversity protection (IANIGLA-ING 2018). In this sense, there is an increasing interest to know the diversity and biological traits of the fish community inhabiting central Andes freshwater environments to build biomonitoring plans for water quality assessments. This region is an arid environment with extreme climates, whose freshwater environments have low biodiversity as well as a poor abundance of fish. However, surprisingly in this region the number of nonnative fish species is greater than the number of native species (Villanueva & Roig 1995). This could plausibly be due to a negative impact of nonnative on native Andean species; however, currently no studies have been conducted to support this hypothesis.

Length–weight relationship (LWR) is a key tool to assess physical condition indices of fish inhabiting ecosystems with different human impact or to track changes in food availability (Petraakis & Stergiou 1995, Froese 2006, Teixeira de Mello *et al.* 2011). Length and weight information is usually fitted using a potential equation ($W_T = a L_S^b$) whose parameter a represents fish nutritional condition (Anderson & Neuman 1996) and b represents the type of growth, usually taking values between 2.5 and 4 (Haimovici & Velasco 2000, Froese 2006). The aim of this study was to provide empirical information on the length–weight relationships of commonly found fish species from freshwater ecosystems of the central Andes region.

Fish used for the construction of LWR were captured in successive sampling campaigns conducted in the central Andes region between 2013 and 2016. Four species of nonnative fish were captured: rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), brown trout *Salmo trutta* (Linnaeus, 1758), brook trout *Salvelinus fontinalis* (Mitchill, 1814), silverside fish *Odontesthes bonariensis* (Valenciennes, 1835), and one native species, the torrent catfish *Hatcheria macraei* (Girard, 1855). The nonnative species have been introduced in the Andean freshwater systems of the province of Mendoza since the year 1957 (trout species) and 1960 (silverside fish) for gastronomy and sport fishing (Ríos *et al.* 2019). All fish specimens were adults and caught within the non-reproductive season (austral winter corresponds to the breeding season in the Andean region of Argentina) by using conventional fishing with artificial lures according to our research authorization. The catch dates, the number of individuals and the fishing methodology, were in

accordance with the Direction of Renewable Natural Resources permit (Government of Mendoza, Argentina, research permit #659). None of the mentioned species is threatened according to the IUCN Red List of Threatened Species™ (status: ongoing).

Fish were measured [Standard length (SL); to the nearest 0.1 cm] and weighed [fresh total weight (WT); to the nearest 0.01g]. The parameters for the equation $W_T = a L_S^b$ (Ricker 1973) were estimated by a linear regression, after a logarithmic (Log 10) transformation of the variables. In the particular case of rainbow trout, linear regressions were calculated by pooling together specimens belonging to three different sampling points (**Table I**). This was made with the purpose of increasing robustness of regression by increasing the number of individuals. Since none of the species of this study present sexual dimorphism, specimens were not separated by sex. In order to check if fish growth was statistically different from isometric growth (regression coefficient b), a t -test ($H_0: b = 3$), with $\alpha = 0.05$ was performed (Ricker, 1973, 1975). Statistical analysis was carried out using the InfoStat 2011 software (Di Rienzo *et al.* 2011).

The georeferenced sampling sites, the species and the number of individuals captured per site are shown in Table I. Fish length and weight means, standard error and range (maximum and minimum), as well as sample size, parameters a and b , coefficient of determination (r^2), and growth type, of the studied species are provided in Table II. All performed regressions were highly significant ($p < 0.0001$). The lowest r^2 value registered was 0.879 for silverside fish, while for the remainder species the value was higher than 0.9.

Table I. Georeferenced study sites in the central Andes region. m. a. s. l.: Meters above the sea level; dd: decimal degrees; n: number of individuals collected.

Sites	Latitude [dd]	Longitude [dd]	Altitude [m.a.s.l.]	Species	n
Mendoza River	-32.9943	69.1454	1359	brown trout <i>Salmo trutta</i>	3
Mendoza River	-32.9943	69.1454	1359	rainbow trout <i>Oncorhynchus mykiss</i>	9
Mendoza River	-33.0519	68.9396	1009	torrent catfish <i>Hatcheria macraei</i>	12
Yaucha River	-34.2458	69.3260	1873	rainbow trout <i>Oncorhynchus mykiss</i>	6
Pircas Stream	-33.6033	69.3829	1730	brook trout <i>Salvelinus fontinalis</i>	6
Carrizal Dam	-33.3402	68.7321	788	silverside fish <i>Odontesthes bonariensis</i>	29
Vaina Stream	-35.9329	70.0419	1689	rainbow trout <i>Oncorhynchus mykiss</i>	7

Table II. Morphometry, Length-Weight parameters and growth type of nonnative (N-n) and native fish species collected in freshwater environments of the central Andes (Mendoza, Argentina). Morphometric values for size and weight are mean \pm standard error, and range (line below); n represents the number of individuals analyzed for estimation of parameters a and b, and r^2 is the determination coefficient. Growth type indicates if b was lower (N: negative), higher (P: positive) or equal (isometry) to 3. No regression analysis was performed (nd) for *Salmo trutta* since only 3 specimens were caught.

Order (Family)	Species	Status	Total length (cm)	Total weight (g)	n	Length – Weight parameters			Growth type
						a	b \pm SE	r^2	
Salmoniformes	<i>Oncorhynchus</i>	N-n	30.2 \pm 1.16	354 \pm 39.8	22	0.0407	2.639 \pm 0.152	0.93	N
Salmonidae	<i>mykiss</i>		24.5–42.0	168–800					
	<i>Salvelinus fontinalis</i>	N-n	11.8 \pm 1.63	23.7 \pm 8.23	6	0.0176	2.820 \pm 0.138	0.98	N
			7.20–16.5	4.40–53.7					
	<i>Salmo trutta</i>	N-n	44.0 \pm 2.00	981 \pm 101	3	nd	nd	nd	N
			40.0–46.0	800–1150					
Atheriniformes	<i>Odontesthes</i>	N-n	21.6 \pm 0.32	64.3 \pm 2.68	29	0.0285	2.505 \pm 0.182	0.88	N
Atherinopsidae	<i>bonariensis</i>		18.5–26.5	41.3–102					
Siluriformes	<i>Hatcheria macraei</i>	native	11.14 \pm 0.46	8.43 \pm 1.23	12	0.0026	3.323 \pm 0.330	0.92	P
Trichomycteridae			8.50–14.5	3.26–19.3					

Results showed that according to the *b* values registered, the native torrent catfish showed a positive allometric growth while all the remaining species, which were nonnative, showed a negative allometric growth (Table II). To the best of our knowledge, this study represents the first analysis of LWR for the torrent catfish *Hatcheria macraei*.

The negative allometric growth of silverside fish found in the Carrizal dam (Table II), showed a clear difference with the LWR analyses in its original lagoon habitat (Pampa region, Argentina) where silverside fish ($b = 3.34$) showed a positive growth (Grosman *et al.* 2013). In this study, the negative growth type found for silverside fish from the Carrizal dam could plausibly be due to the occurrence of organochlorine compounds (Ríos *et al.* 2019) and low food availability. The negative allometric growth of the rainbow trout in this study ($b = 2.64$) is the same found for this species ($b = 2.64$) inhabiting the Patagonian river Pichi Leufú, in the southern Andes region (Alonso *et al.* 2003). However, rainbow trout specimens collected from Patagonian lakes and lagoons showed a higher value ($b = 3.07$) suggesting an isometric growth for lentic environments of the southern Andes region (Lafarga & Guerrero 1991, Alonso *et al.* 2003). An isometric type of growth in fish determines that the morphological characteristics of weight and length grow in the same proportion with time (Froese 2006). This growth type could be attributed to an adequate individual nutrition and energy balance (Karasov & Martínez del Río 2007).

It is important to consider the complexity to obtain samples from these high mountain environments with low fish densities. In addition, we note a significant lack of information on fish communities in the central Andes range, where there are currently no peer-reviewed publications on this issue for the region. Therefore, it is necessary to generate information on the fish communities of the central Andes region in order to develop management plans for the protection of these fragile ecosystems dependent on glaciers.

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