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RESEARCH NOTE

Length-weight relationship of four batoid species from the Pacific coast of Ecuador

Relación longitud-peso de cuatro especies de batoideos de la costa del Pacífico de Ecuador

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Abstract.- Length-weight relationships (LWR) were estimated for four species of batoids, *Zapteryx xyster*, *Rostroraja equatorialis*, *Pseudobatos leucorhynchus* and *Gymnura crebripunctata*, collected in Ecuadorian waters. Values of the allometric growth parameter (*b*) oscillated from 2.41 to 3.15. *Pseudobatos leucorhynchus* and *G. crebripunctata* exhibited isometric type growth, while *Z. xyster* and *R. equatorialis* showed negative and positive allometric growth, respectively. New records of minimum sizes were obtained for free-swimming *R. equatorialis* (7.8 cm TL) and *G. crebripunctata* (20.0 cm DW). Data obtained constitute a baseline for future management and conservation studies.

Key words: Length-weight, batoids, Ecuadorian waters

INTRODUCTION

Length-weight relationship (LWR) is a useful approach that provides basic data on population dynamics of the species, which facilitates their management and conservation through the formulation of fisheries management measures (Froese 2006, Koushlesh *et al*. 2017, Correia *et al*. 2018, Wei *et al*. 2019). LWR analysis is used to assess weight of an organism from a determined length (Froese 2006); understanding changes in fish weight as a function of size is essential information to deduce age structure, calculate growth rates or quantify some other aspect of fish population dynamics (Jellyman *et al*. 2013, Wang *et al*. 2013, Liu *et al*. 2018). Recently, a number of LWR of batoids have been reported (Romero-Caicedo *et al*. 2015, Rastgoo *et al*. 2016, Ehemann *et al*. 2017, Gladston *et al*. 2018, González-González & Ehemann 2019); however, life history of many batoids are still unknown or have been little studied (Dulvy *et al*. 2014).

In Ecuador, batoids are caught as part of bycatch of fishing fleets that operate with shrimp trawls and bottom gill nets. Most of these organisms are discarded and some are destined for local consumption or converted into fishmeal (Martínez-Ortiz & García-Domínguez 2013). Information of this biological group is scarce. Thus, the current work aim to determine LWR parameters of four batoid species catched in Ecuadorian waters, being one of the first reports about life cycle of *Gymnura crebripunctata* (Peters, 1869) and *Rostroraja equatorialis* (Jordan & Bollman, 1890), and an increase in the biological knowledge of *Pseudobatos leucorhynchus* (Günther, 1867) and *Zapteryx xyster* Jordan & Evermann, 1896. This information is important for subsequent population assessment, allowing the proposal of management measures for these resources.

MATERIALS AND METHODS

Specimens of the four batoid species were collected from shrimp trawlers as bycatch along the Ecuadorian coast (1°363´N and 79°122´W to 03°019´S and 80°444´W), between 20 and 80 m depth, from October 2016 through August 2017. A total of 12 fishing trips were monitored, information on four batoid species was registered randomly of 49 shrimp trawl spears. Trawl nets had a dimension between 30 and 35 m long and a mesh size of 3.8-5.0 cm. Trawl lasted between 3 and 4 h, with speeds of 1.8 to 2 kt.

All specimens were identified using the identification guide of Last *et al*. (2016). Sex was identified by the presence (males) or absence (females) of claspers. Size was recorded by means of a measuring tape with a precision of 0.1 cm; for each specimen, the total length (TL, ± 0.1 cm) was recorded from tip of rostral to distal point of caudal; in the case of *Gymnura crebripunctata*, the disc width (DW, ± 0.1 cm) was registered measured as the straight-line distance between the two outermost points of pectoral fins (Romero-Caicedo *et al*. 2015). Total weight (TW) was measured to the nearest gram (g) using a digital balance (W, ± 0.1 g).

Total length was used for the length-weight relationship (LWR), except for *G. crebripunctata* where it was replaced by DW. LWR was described using a power model $W= a{\cdot}TL^b$ or $W= a{\cdot}DW^b$, where *a* and *b* are parameters of the model estimated as the linear regression between log (W) and log (TL) or log (WD), meaning *log W= loga + b·logTL* or *log W= loga + b·logDW* (Froese 2006). 95% confidence limits were calculated for parameters *a* and *b*, as well as coefficient of determination (r^2) to quantify variation of model explained by length-weight relationship. LWR was evaluated for males and females of each species and sexual differences were tested by a covariance analysis (ANCOVA), using size as a covariant (Zar 1999), with a significance level of 0.05. Type of growth for all species was determined by the slope *b*, when *b*= 3, the species presents an isometric growth, whereas allometric growth is negative or positive when *b* is <3 or >3, respectively (Froese 2006), and it was evaluated using a Student's *t* test for slopes (H_0: *b*= 3). All analyse were done using R (R Core Team 2013) and the package FSA (Ogle *et al*. 2018).

Results and discussion

A total of 1,424 organisms of all species were analyzed. Results of the model for species and sex, sample size, minimum and maximum value of length and weight, estimates of parameters *a* and *b* with their confidence intervals ($CI_{95\%}$), coefficient of determination (r^2), Student's *t* test for slopes with their level of significance, and growth type are shown in Table 1.

Minimum total lengths herein reported were the smallest values for free-living organisms of *R. equatorialis* and *G. crebripunctata*, with 7.8 cm TL and 20.0 cm DW, respectively. Other studies carried out in the Eastern Pacific coasts record minimum sizes of 25.0 cm TL for *R. equatorialis* (Martínez-Ortiz & García-Domínguez 2013) and 29.0 cm DW for *G. crebripunctata* (Smith *et al*. 2009). The current study provides new minimum lengths for these species along the Ecuadorian coast; these new registers can be a result of fishing effort, combining two factors: catches in areas near the coast (20-80 m of depth) and a small mesh size (3.8-5.0 cm), as smaller organisms can be entangled in fishing gears. Thus, elasmobranchs, during the first stages of their life cycle, prefer shallow waters where they can easily find preys and havens (Simpfendorfer & Milward 1993, Salomón-Aguilar *et al*. 2009).

A minimum size of 14.3 cm TL was recorded for *Z. xyster*. The smallest size recorded worldwide for this species was found in Costa Rican waters with 14.0 cm TL (Espinoza *et al*. 2015). Present results represent the smallest size in Ecuadorian waters, where there were records of a minimum size of 38 cm TL (Martínez-Ortiz & García-Domínguez 2013). Minimum and maximum total lengths of 21.0 and 118.0 cm, respectively, have been reported for *P. leucorhynchus* in Ecuadorian waters by Romero-Caicedo *et al*. (2015), which differs from reported in the current study, with a maximum total length of 76.1 cm, also reported in Colombian waters (76.0 cm LT) (Payán *et al*. 2011).

Length-weight relationships for the species showed r^2 values ranging from 0.92 to 0.98, therefore, these estimations can be considered near to adequate. Analysis by sex also showed high values of r^2 (0.97 to 0.99), except for males of *G. crebripunctata* (r^2= 0.66), which may be due to low sample number or the range of limited sizes for males. According to Froese *et al*. (2011), when determination coefficient (r^2) is minor than 0.95 it may indicate outliers, due to the inclusion of extreme individuals such as juveniles (minor size) or adults (major size), abrupt change of shape during development, sex-differences, seasonal differences, among others.

First records of growth type are provided for *R. equatorialis* and *G. crebripunctata* (Table 1). Allometric growth parameter *b* for *R. equatorialis* was 3.11 (positive allometric growth) and *G. crebripunctata* showed isometric growth (2.94). For *Zapteryx xyster* values showed negative allometric growth (*b*= 2.92), this type of growth is similar as the one reported in the Southwest Atlantic Ocean for *Z. brevirostris*, a congener species (Pasquino *et al*. 2016), but differs from the value reported in a previous work in the Colombian Pacific of *b*= 2.85, interpreted by the authors as isometric growth (Mejía-Falla *et al*. 2006). Isometric growth herein reported for *P. leucorhynchus* differs from other studies in Colombian and Ecuadorian Pacific, where allometric growth rates were reported by Payán *et al*. (2011) and Romero-Caicedo *et al*. (2015). Male and female presented the same type of growth, except for *G. crebripunctata*, where an isometric growth was observed for females (*b*= 3.12), and negative allometric growth for males (*b*= 2.41) (Table 1), however, as proposed by Froese *et al*. (2011), a re-evaluation of these type of cases is suggested.

Table 1. Descriptive statistics and estimated parameters of length-weight relationships for four species of batoids collected from Ecuadorian Pacific Ocean / Estadística descriptiva y parámetros estimados de las relaciones longitud-peso para cuatro especies de batoideos recolectadas del océano Pacífico Ecuatoriano

Species / Sex	n	Length (cm)		Weight (g)		Parameters							
		Min	Max	Min	Max	a	$CI_{95\%}$ (a)	b	$CI_{95\%}$ (b)	r^2	t-test	*P*	Growth type
Gymnuridae													
*Gymnura crebripunctata**	101	20.0	71.5	70.0	3665.0	0.0111	0.0058 - 0.0211	2.94	2.77 - 3.12	0.92	-0.65	>0.05	Isometric
Male*	49	20.0	46.0	70.0	900.0	0.0768	0.0123 - 0.4789	2.41	1.90 - 2.92	0.66	-2.34	<0.05	Allometric (-)
Female*	52	22.0	71.5	100.0	3665.0	0.0055	0.0030 - 0.0099	3.12	2.97 - 3.28	0.97	1.64	>0.05	Isometric
Rajidae													
Rostroraja equatorialis	519	7.8	61.0	4.6	1105.0	0.0036	0.0032 - 0.0041	3.11	3.08 - 3.15	0.98	6.61	<0.05	Allometric (+)
Male	230	10.1	58.2	5.2	1105.0	0.0033	0.0027 - 0.0040	3.15	3.10 - 3.20	0.98	5.53	<0.05	Allometric (+)
Female	289	7.8	61.0	4.6	1105.0	0.0039	0.0033 - 0.0045	3.09	3.05 - 3.14	0.99	4.13	<0.05	Allometric (+)
Rhinobatidae													
Pseudobatos leucorhynchus	297	22.3	76.1	30.0	1670.0	0.0029	0.0023 - 0.0035	3.05	3.00 - 3.10	0.97	1.78	>0.05	Isometric
Male	129	22.3	69.0	30.0	1550.0	0.0032	0.0022 - 0.0045	3.02	2.93 - 3.11	0.97	0.46	>0.05	Isometric
Female	168	23.1	76.1	30.0	1670.0	0.0027	0.0021 - 0.0035	3.06	3.00 - 3.13	0.98	1.94	>0.05	Isometric
Trygonorrhinidae													
Zapteryx xyster	507	14.3	66.0	17.3	1540.0	0.0079	0.0068 - 0.0092	2.92	2.88 - 2.96	0.98	-4.08	<0.05	Allometric (-)
Male	247	14.3	62.0	17.3	1205.0	0.0080	0.0062 - 0.0103	2.92	2.85 - 2.98	0.97	-2.47	<0.05	Allometric (-)
Female	260	16.0	66.0	24.5	1540.0	0.0079	0.0066 - 0.0095	2.92	2.87 - 2.96	0.98	-3.50	<0.05	Allometric (-)

n: sample size; a: intercept; b: slope; $CI_{95\%}$: confidence intervals; r^2: coefficient of determination; Student-t: test to evaluate growth
P: significance value of the Student-t test and growth type; Species/Sex*: disc width

According to ANCOVA analyse, significant differences were not found in LWR between sex for three species (*P. leucorhynchus*: *F*= 0.055, *P* > 0.05; *Z. xyster*: *F*= 2.498, *P* > 0.05; *R. equatorialis*: *F*= 0.088, *P* > 0.05), while *G. crebripunctata* did present differences (*F*= 9.706 *P* < 0.05), in which males had a negative allometric growth. Our results with other studies show that the values of *b* can be affected by several factors, such as differences in the number of examined organisms, area, season, or the use of different lengths (Froese *et al*. 2011, Pan *et al*. 2014, Ehemann *et al*. 2017).

This study represents the first contribution to knowledge of biological aspects for *G. crebripunctata* and *R. equatorialis*; as well as an increase in the life history information of *P. leucorhynchus* and *Z. xyster* in the Ecuadorian waters. The data obtained constitutes a baseline for future models used for fisheries resources management and conservation, however, it is suggested that the results of these relationships be used only with the presented length ranges.

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