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Research Note

Length-weight relationships and relative condition factor in razor surgeonfish, *Prionurus laticlavius* (Teleostei: Acanthuridae) from the southwestern coast of the Gulf of California, Mexico

Relación peso-longitud y factor de condición relativo del navajón barbero *Prionurus laticlavius* (Teleostei: Acanthuridae) de la costa sudoccidental del Golfo de California, México

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Abstract.- The razor surgeonfish, *Prionurus laticlavius*, listed on the IUCN Red List of Threatened Species under the Least Concern category, plays an important ecological role as energy regulator in reef communities, but it is sought by the aquarium and aquaculture industry, and also is consumed by people. This study estimated the length-weight relationship (LWR) and relative condition factor (K_{rel}) in *P. laticlavius*. The equation for length-weight relationship was $TW = 0.02\ TL^{3.01}$ for the Overall category, and the relative condition factor was 1.28. A total of 379 fish (3-45.6 cm total length) were collected in the southwestern coast of the Gulf of California using harpoon (for large fishes) and hand net (for small fishes), of which 181 were females (20.2-45.6 cm), 137 males (20.6-43.4 cm), and 61 juveniles (3-19.5 cm). Allometric coefficient *b* of LWR for the Overall category suggested isometric growth (*b* = 3.01), positive allometric growth for juveniles (*b* = 3.14), and negative allometric growth for adults (2.75). Results of K_{rel} showed higher values for females during the warm season. The population showed a good nutritional condition, mainly in the warm season. This work is the first to estimate LWR and K_{rel} for *P. laticlavius*, which will inform stock assessment and the management of this species in the Gulf of California.

Key words: Razor surgeonfish, growth, LWR, Gulf of California

Introduction

Many marine fish populations are declining due to overfishing or from the direct effects of fishing on the ecosystem, disrupting its function and structure and causing adverse effects not only on the target species but also across the entire food web involved (Coll *et al*. 2008, Sumaila & Tai 2020). Another cause of the decline of fish populations is the aquarium industry that has been expanding worldwide, causing an imbalance in marine communities from the use of juvenile organisms. The main species captured to sustain ornamental market are reef fish, given their diversity of colors and shapes (Lango-Reynoso *et al.* 2012). Fishes most traded worldwide belong to the families Pomacentridae, Pomacanthidae, Acanthuridae, Labridae, Gobiidae, and Chaetodontidae from tropical and subtropical countries (Lango-Reynoso *et al*. 2012).

Length-weight relationship (LWR) is a useful tool in biology, physiology, and ecology, as well as in the assessment of fishery resources (Khatun *et al*. 2019) because it provides important information for the management of marine populations, considering their economic and ecological importance (Irigoyen-Arredondo *et al*. 2016). These relationships allow estimating the biomass of species from length data, evaluate the condition and well-being of organisms, and derive somatic growth models (Duarte *et al*. 2015, Rahman *et al.* 2021). In addition, this quantitative expression measures the degree of body development of an organism by means of the relative condition factor (K_{rel}), that represents variation in the nutritional condition of the organism (Cifuentes *et al*. 2012, Hossain *et al*. 2021). Altogether, these tools are indirect indicators of population growth, maturity, reproduction, nutrition, and health status (Froese 2006, Cifuentes *et al*. 2012, Sabbir *et al*. 2021).

Razor surgeonfish, *Prionurus laticlavius* (Valenciennes, 1846), listed as Least Concern in the IUCN's Red List of Threatened Species (Abesamis 2012), is distributed across the tropical Eastern Pacific from the northern Gulf of California to Ecuador, including Revillagigedo and Galapagos islands (Robertson & Allen 2016). *P. laticlavius* plays an important ecological role in energy regulation of reef communities (Montgomery *et al*. 1980) and is one of the most efficient and important herbivore fish in the region because of its broad diet (Moreno-Sánchez *et al.* 2014). It has a high demand in aquariums and aquaculture industry and is also occasionally used for local human consumption (Piña-Espallargas 2005, Ulloa-Ramírez *et al.* 2008). Despite its importance, no study has described its length-weight relationship (LWR) and body condition (K_{rel}) in FishBase (Froese & Pauly 2021). Thus, the aim of this study was to estimate LWR and K_{rel} in *P. laticlavius* from the southern coast of the Gulf of California, Mexico.

Materials and methods

From January to December 2003 and from August 2018 to July 2019, 5 to 25 individuals of *Prionurus laticlavius* were collected (at 3-10 m depth) each month with harpoon (for large fish) and hand net (for small fish) at three nearby sites named Barco Hundido (24°06'N, 109°83'W), Cueva de León (24°02'N, 109°49'W), and Ensenada de Muertos (23°59'N, 109°49'W), in the southwestern coast of the Gulf of California (Fig. 1). In order to establish warm and cold seasons (used below as the Season category), sea surface temperature was recorded with a mercury thermometer at the time of capture. In the laboratory, morphometric data of each sampled fish were recorded, including total length (TL, in cm, to the nearest 0.1 mm), total weight (TW, in g), eviscerated weight (EW, in g), and gonad weight (GW, in g, to the nearest 0.01 g). LWR estimates were based on the potential model $TW = aTL^b$ (Le Cren 1951), adjusting the parameters for maximum likelihood from logarithmic transformation:

$$Ln(TW) = Ln(a) + b \cdot Ln(TL)$$

where *a* is the intercept (initial growth coefficient) and *b* is the slope (allometric coefficient) (Froese 1998, De La Hoz *et al.* 2016). One of the reasons for using logarithmic transformation was to avoid trends in residuals from the adjustment, which would invalidate the estimate (Duarte *et al*. 2015). A TL-TW graph was constructed to detect and eliminate outliers from causal errors (De La Hoz *et al.* 2009). A Student's *t*-test was used to determine whether the allometric coefficient (*b)* was significantly different from the isometric growth hypothesis (H_0: $b = 3$, H_1: $b \neq 3$) (Zar 2010). 95% confidence intervals (95% CI) were estimated for *a* and *b* (De La Hoz *et al*. 2016).

LWR was estimated for each of the following categories: Overall (adults and juveniles combined), Adults (females and males combined), Sex, Juveniles, and Season (cold, warm). Statistical differences in the allometric coefficient between

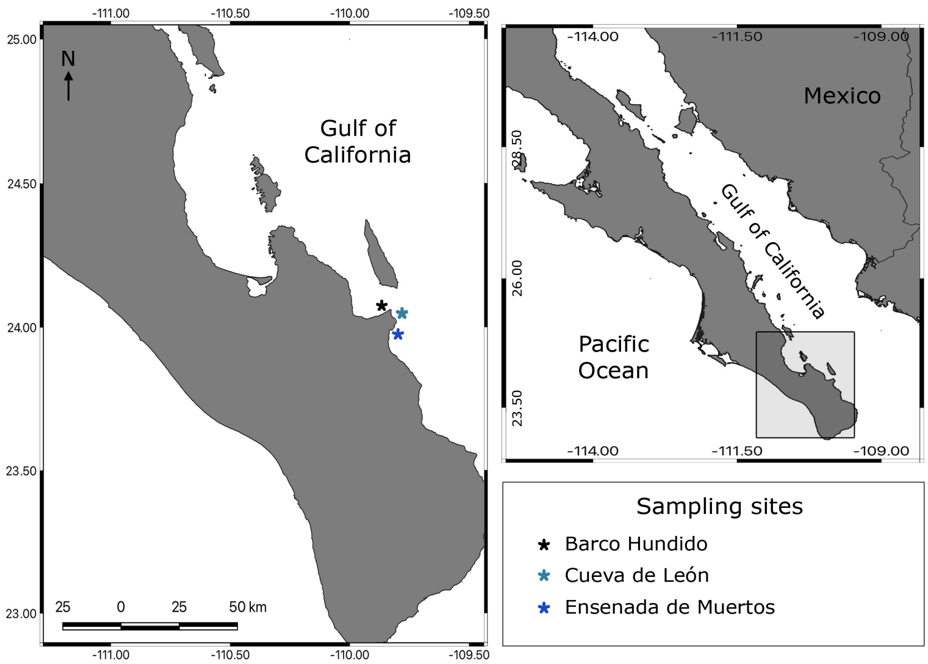

Figure 1. Geographic location of the study area. The box indicates the southwestern coast of the Gulf of California; asterisks denote sampled localities / Ubicación geográfica de la zona de estudio. El recuadro indica la costa sudoccidental del Golfo de California, y los asteriscos las localidades muestreadas

categories were tested using ANCOVA, with *P* significant at <0.05. Specimens were sexed based on direct observation of gonads (Muriel-Hoyos & Carmona-Guerra 2020). In the Sex and Season categories, only adult organisms were considered because the use of both growth stages combined (juvenile plus adult) in the same analysis may lead to estimation errors (Froese 2006). An adult organism was considered when any fish individual reached 20 cm TL and showed a developed gonad (vascularization and increasing firmness, yellow color with spots, firm connective tissue, gonad weight >0.18 g). A juvenile stage was considered when any fish individual was less than 20 cm TL and showed an incipient, non-active gonad. Season category was defined based on the annual average SST (25 °C), where months with lower values were considered the cold season (December to May) and those with higher temperatures, the warm season (June to November).

Degree of fish well-being, or relative robustness of individuals, was determined through relative condition factor (K_{rel}) according to the following equation (Le Cren 1951):

$$K_{rel} = \frac{TW}{aTL^b}$$

Additionally, gonadosomatic index (GSI) was calculated following the equation:

$$GSI = \left({}^{GW}\!/_{EW} \right) \cdot 100$$

GSI values were compared across all categories using an analysis of variance for non-parametric data (Kruskal-Wallis test). For all the analyses, coefficient of determination (R^2) of LWR values were used as a measure of goodness of fit, and 95% CIs were estimated using bootstrap method, accelerated with bias correction and 1000 resamples (Efron 1987, Zar 2010). All statistical tests were performed in R (R Core Team 2019), considering a *P*-value < 0.05.

Results and discussion

A total of 379 fish were obtained (3-45.6 cm TL, mean= 29.2 cm ± 9.56 SD; 0.58-1904.8 g TW, 688.3 ± 440.5 g), of which 181 were females (20.2-45.6 cm TL, mean= 32.8 cm ± 6.09 SD; 173.1-1861.8 g TW, 831.2 ± 399.2 g), 137 males (20.6-43.4 cm TL, 32.1 ± 5.30; 225.5-1904.8 TW, 775.6 ± 346.4), and 61 juveniles (3-19.5 cm TL, 11.8 ± 6.15; 0.5-202 g TW, 68.6 ± 56.8). Frequencies of sizes of all fish analyzed are shown in Figure 2.

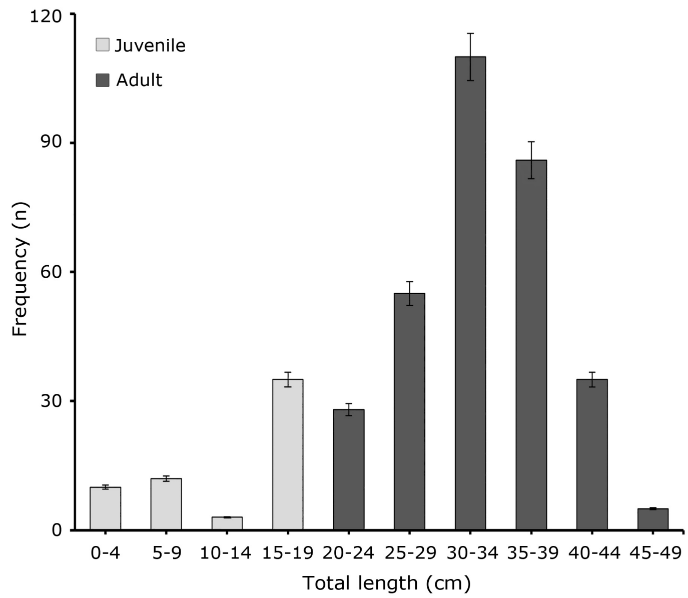

Figure 2. Length frequency distribution of juveniles and adults of *Prionurus laticlavius* in the southwestern coast of the Gulf of California. Bars indicate standard error / Distribución de frecuencia de tallas de *Prionurus laticlavius* en el Golfo de California. Las barras indican el error estándar

For estimating LWR, Sex category was excluded because a non-significant difference was found between females and males (ANCOVA: $F_{(1,316)}$= 0.001; P > 0.05). By contrast, statistical differences in LWR were observed between all other categories (P < 0.05). Analyses explained over 96% of the variance, and a strong correlation between TW and TL was observed in every category (Table 1). LWR for Overall category showed isometric growth (b = 3, t-test, P > 0.05), suggesting that organisms have proportional growth in weight and length. However, LWR per life cycle stage showed positive allometric growth (b = 3.14) in juveniles, meaning that fish tend to be elongated rather than thicker, and negative allometric growth (b < 3, t-test, P < 0.05) in adults, with fish being thicker rather than elongated. For Season category, LWR showed negative allometric growth (b < 3, t-test, P < 0.05).

K_{rel} and GSI were higher in females (5.77 ± 0.60 and 1.07 ± 0.88, respectively) than in males (4.54 ± 0.58 and 0.95 ± 0.75, respectively). Likewise, warm season registered the higher values (5.08 ± 0.45 and 1.56 ± 1.01) (Table 1).

All categories evaluated (Overall, Adult, Juvenile, and Season) for *P. laticlavius* showed the expected range for b (2.5 < b < 3.5), demonstrating that the sample did not have narrow size ranges (Carlander 1977, Froese 2006). In general, *P. laticlavius* showed isometric growth; however, when analyzed separately by category, it depicted different growth types. A similar case has been reported in sardine *Clupea harengus*, for which growth variation has been explained by abrupt changes or "growth stanzas" (Renán *et al.* 2015) during the juvenile stage, while growth in the adult stage may vary depending on aspects related to sexual maturity (Renán *et al*. 2015). Findings suggest that these development stages should be recognized and that growth estimates be conducted for the stages separately (*e.g.,* Juvenile, Adult, Sex) to avoid under- or overestimation of growth (Froese 2006).

During Juvenile stage, *P. laticlavius* showed positive allometric growth (b = 3.14), similar to reports for juveniles of other acanthurids, such as *Zebrasoma flavescens* (3.16) (Froese 1998), *Naso minor* (b = 3.25) (Gumanao *et al.* 2016), *Acanthurus triostegus* (b = 3.13), and *A. nigrofuscus* (b = 3.36) (Peyton *et al*. 2016). These findings corroborate that during early development stages (from settlement to juvenile), fish growth takes place mainly as somatic growth (Lloret *et al.* 2013). On the other hand, adults of *P. laticlavius* showed negative allometric growth (b < 3), which was consistent with reports for 19 acanthurid species (Choat & Axe 1996, Kamikawa *et al*. 2015, Gumanao *et al*. 2016). Negative allometric growth occurs at the onset of sexual maturation, so fish start allocating large portions of energy reserves to reproduction, with body growth assuming a secondary role (Lloret *et al*. 2013). In the genus *Prionurus*, LWR has been estimated only for *P. maculatus* in the eastern Australian coral reefs, showing negative allometric growth (Choat & Axe 1996), which coincides with the growth type estimated

Table 1. LWR, relative condition factor (K_{rel}), and gonadosomatic index (GSI) in *P. laticlavius* from the southwestern coast of the Gulf of California / Variables biométricas y análisis de regresión de la relación peso-longitud, factor de condición (K_{rel}) e índice gonadosomático (GSI) de *P. laticlavius* que habita en la costa suroeste del Golfo de California

Category	n	Total length (cm)	Total weight (g)	K_{rel}	GSI		Confidence Interval			Confidence Interval		R^2
		$\bar{x}$ ± SD (Min-Max)	$\bar{x}$ ± SD (Min-Max)	$\bar{x}$ ± SD (Min-Max)	$\bar{x}$ ± SD (Min-Max)	a	Lower	Upper	b	Lower	Upper	
Overall	379	29.2 ± 9.56 (3.0 - 45.6)	638.3 ± 440.5 (0.5 - 1904.8)	2.12 ± 0.27 (1.28-7.32)	0.97 ±0.85 (0.00-4.46)	0.02	0.01	0.02	3.01*	2.98	3.03	0.99
Adults	318	32.5 ± 5.71 (20.2-45.6)	807.2 ± 377.8 (173.1-1904.8)	5.21 ± 0.60 (3.15-7.32)	1.01 ±0.87 (0.05-4.46)	0.05	0.04	0.06	2.75	2.68	2.82	0.96
Juveniles	61	11.8 ± 6.15 (3.0 - 19.5)	68.6 ± 56.8 (0.5-202.0)	1.60 ± 0.17 (1.28-2.17)	0.53 ± 0.50 (0.00-2.57)	0.01	0.01	0.02	**3.14**	3.11	3.18	0.99
Cold	137	32.3 ± 5.76 (20.2-45.6)	790.9 ± 376.5 (173.1-1861.8)	4.68 ± 0.74 (3.08-5.92)	0.50 ± 0.44 (0.21-0.85)	0.04	0.03	0.06	2.78	2.69	2.87	0.97
Warm	181	32.7 ± 5.69 (20.6-45.5)	819.6 ± 379.3 (213.5-1904.8)	5.08 ± 0.45 (4.07-10.72)	1.56 ± 1.01 (0.54-4.46)	0.05	0.04	0.08	2.72	2.62	2.82	0.96

n: Number of fish, $\bar{x}$: mean, SD: standard deviation, a: intercept, b: regression slope, R^2: determination coefficient, Lower: lower limit, Upper: Upper limit
*Indicate isometric growth; Bold value indicate positive allometry

for *P. laticlavius* in this study. Therefore, the present work is the first to estimate LWR in *P. laticlavius* because to date it has not been reported in FishBase database (Froese & Pauly 2021). All six fish species of the genus (Froese & Pauly 2019) are likely to show this same growth type, as also reported for species of the genera *Acanthurus* and *Naso* (Choat & Axe 1996, Kamikawa *et al*. 2015). Values of *b* may change depending on multiple biotic and abiotic factors, in addition to metabolic processes of each species (Nazek *et al.* 2018).

In the present work, condition factor estimated in *P. laticlavius* was high across all categories, with values above average ($K_{rel} > 1$, *t*-test, $P > 0.05$) (Ighwela *et al.* 2011), indicating that fish have sufficient energy reserves and a good nutritional condition, probably because of adequate food availability in the area and broad diversity of consumed food items (Moreno-Sánchez *et al.* 2014).

The nutritional condition of *P. laticlavius* was better during the warm season, as reflected in high GSI values. This is likely associated with an energetic strategy for reproduction (Le Cren 1951), supported by the presence of visceral fat during the warm season. Females showed the highest K_{rel} values because energy allocation to reproduction is higher in females than in males (Hayward & Gillooly 2011). Similar to other tropical fishes, *P. laticlavius* continues consuming food over the reproductive period (Volpato & Trajano 2005), contrary to temperate- and cold-water fish species (Barnham & Baxter 1998). Therefore, its condition is likely to depend primarily on food availability and its physiological reproductive processes (Nash *et al.* 2006).

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