Length-weight relationships and relative condition factor in razor surgeonsfish, *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 surgeonsfish, *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, and 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*<sub>rel</sub>) in *P. laticlavius*. The equation for length-weight relationship was *TW* = 0.02 *TL<sup>3.11</sup> 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* = 3.0), positive allometric growth for juveniles (*b* = 3.1), and negative allometric growth for adults (2.75). Results of *K*<sub>rel</sub> 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*<sub>rel</sub> for *P. laticlavius*, which will inform stock assessment and the management of this species in the Gulf of California.

**Key words**: Razor surgeonsfish, 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*<sub>rel</sub>), 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...
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):

$$K_{rel} = \frac{TW}{aTL^3}$$

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

$$GSI = \left(\frac{GW}{EW}\right) \times 100$$

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](image-url)
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).

Table 1. LWR, relative condition factor (K_rel), and gonadosomatic index (GSI) in P. laticlavius from the southwestern coast of the Gulf of California

| Category   | n  | Total length (cm) | Total weight (g) | K_rel | GSI | Confidence Interval | Confidence Interval | R² |
|------------|----|-------------------|------------------|-------|-----|---------------------|---------------------|----|
| Overall    | 379| 29.2 ± 9.56       | 618.3 ± 440.5    | 2.12 ± 0.27 | 0.97 ± 0.08 | 0.02 | 0.01-0.02 | 3.01 | 2.98 | 3.03 | 0.99 |
| Adults     | 318| 32.5 ± 5.71       | 807.2 ± 377.8    | 5.21 ± 0.60 | 1.01 ± 0.07 | 0.05 | 0.04-0.06 | 2.75 | 2.68 | 2.82 | 0.96 |
| Juveniles  | 61 | 11.8 ± 6.15       | 68.6 ± 56.8      | 1.60 ± 0.17 | 0.53 ± 0.50 | 0.01 | 0.01-0.02 | 3.14 | 3.11 | 3.18 | 0.99 |
| Cold       | 137| 32.3 ± 5.76       | 790.9 ± 376.5    | 4.68 ± 0.74 | 0.50 ± 0.44 | 0.04 | 0.03-0.06 | 2.78 | 2.69 | 2.87 | 0.97 |
| Warm       | 181| 32.7 ± 5.69       | 819.6 ± 379.3    | 5.08 ± 0.45 | 1.56 ± 1.01 | 0.05 | 0.04-0.08 | 2.72 | 2.62 | 2.82 | 0.96 |

n: Number of fish, x̄: mean, SD: standard deviation, a: intercept, b: regression slope, R²: determination coefficient, Lower: lower limit, Upper: upper limit
*Indicate isometric growth; Bold value indicate positive allometry

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...
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* > 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* 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).

**ACKNOWLEDGMENTS**

This research was made possible through funding from projects 20195375 and 20200525 of the Mexican Secretaría de Investigación y Posgrado (SIP). Fernando Aguilar Santana is a fellow student of BEIFI and CONACyT; the results presented herein are part of his M. Sc. thesis. We thank María Elena Sánchez-Salazar for her editorial contribution to the English manuscript.

**LITERATURE CITED**

Abesamis R, JH Choat, KD Clements, J McIwain, R Myers, C Nanola, LA Rocha, B Russell & B Stockwell. 2012. *Prionurus laticlavius*. The IUCN Red List of Threatened Species 2012: e.T183310A17253060. <https://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T183310A17253060.en>

Barnham C & A Baxter. 1998. Condition factor, K, for salmonid fish. Fisheries Notes Vol. 57(1): 61-66, 2022

Choat JH & LM Axe. 1996. Growth and longevity in acanthid fishes: An analysis of otolith increments. Marine Ecology Progress Series 134(1/3): 15-26.

Cifuentes R, J González, G Montoya, A Jara, N Ortiz, P Piedra & E Habit. 2012. Relación longitud-peso y factor de condición de los peces nativos del río San Pedro (cueva del río Valdivia, Chile). Gayana 76(Supl. 1): 101-110.

Coll M, S Libralato, S Tudela, I Palomera & F Pranovi. 2008. Ecosystem overfishing in the ocean. PLoS ONE 3(12): e3881. <http://doi:10.1371/journal.pone.0003881>

De la Hoz J, J Narváez & O Solano. 2009. Length-weight relationships for 36 fish populations from a disturbed tropical estuary in northern Colombia. Journal of Applied Ichthyology 25: 618-619.

De La Hoz MJ, J Motta & J Paramo. 2016. Length-weight relationships for 36 deep-sea fish in the Colombian Caribbean Sea. Journal of Applied Ichthyology 32(6): 1356-1359.

Duarte LO, H Castillo-Navarro, A Rojas & E Castro. 2015. Variabilidad temporal de relaciones biométricas y de la condición del bonito, *Thunnus atlanticus*. En: Rojas A, M Prada & M Jay (eds). Atlas biológico pesquero de la Reserva de Biosfera Seafloor, pp. 58-72. Gobernación del Departamento de San Andrés, Providencia y Santa Catalina, San Andrés Islas.

Efron B. 1987. Better bootstrap confidence intervals (with discussion). Journal of the American Statistical Association 82: 171-200.

Froese R. 1998. Length-weight relationships for 18 less-studied fish species. Journal of Applied Ichthyology 14(1/2): 117-118.

Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. Journal of Applied Ichthyology 22(4): 241-253.

Froese R & D Pauly. 2021. FishBase. World Wide Web electronic publication. <https://www.fishbase.org>

Gumanao GS, MM Saucedo-Cardoza, B Mueller & AR Bos. 2016. Length-weight and length-length relationships of 139 Indo-Pacific fish species (Teleostei) from the Davao Gulf, Philippines. Journal of Applied Ichthyology 32(2): 377-385.

Hayward A & JF Gillooly. 2011. The cost of sex: quantifying energetic investment in gamete production by males and females. PLoS ONE 6(1): e16557. <https://doi:10.1371/journal.pone.0016557>

Hossain MY, MA Hossen, Z Mawa, MA Rahman, MR Hasan, MA Islam, D Khatun, MA Rahman, S Tanjin, MS Sarmin & MA Bashar. 2021. Life-history traits of three Ambassid fishes (*Chanda nama, Parambassis lala* and *Parambassis ranga*) from the Mathabhanga River, southwestern Bangladesh. Lakes & Reservoirs: Research & Management 26(1): 59-69.

Ighwela KA, AB Ahmed & AB Abol-Munafi. 2011. Condition factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) feed on different levels of maltose. American-Eurasian Journal of Agriculture & Environmental Sciences 11(4): 559-563.

Irigoyn-Arredondo MS, F Marin-Enriquez, XG Moreno-Sánchez, LA Abitúa-Cárdenas & JS Ramirez-Pérez. 2016. Weight-length relationship and condition factor of leopard grouper *Mycteroperca rosacea* (Perciformes: Serranidae) from the Gulf of California. California Fish and Game 102(2): 50-54.
Kamikawa KT, E Cruz, TE Essington, J Hospital, JKT Brodziak & TA Branch. 2015. Length-weight relationships for 85 fish species from Guam. Journal of Applied Ichthyology 31(6): 1171-1174.

Khatun D, MY Hossain, FA Nawer, AA Mostafa & A Al-Askar. 2019. Reproduction of Eutropiichthys vacha (Schilbeidae) in the Ganges River (NW Bangladesh) with special reference to potential influence of climate variability. Environmental Science and Pollution Research 26: 10800-10815.

Lango-Reynoso F, M Castañeda-Chávez, JE Zamora-Castro, G Hernández-Zárate, MA Ramírez-Barragán & E Solís-Morán. 2012. La acuariofilia de especies ornamentales marinas: un mercado de retos y oportunidades. Latin American Journal of Aquatic Research 40(1): 12-21.

Le Cren ED. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). Journal of Animal Ecology 20(2): 201-219.

Lloret J, G Shulman & RM Love. 2013. Condition and health indicators of exploited marine fishes, 262 pp. John Wiley & Sons, New York.

Montgomery WL, T Gerrodette & LD Marshall. 1980. Effects of grazing by the yellowtail surgeonfish, Prionurus punctatus, on algal communities in the Gulf of California, Mexico. Bulletin of Marine Sciences 30(4): 901-908.

Moreno-Sánchez X, L Abitia-Cárdenas, R Riosmena-Rodríguez, M Cabrera-Huerta & F Gutiérrez-Sánchez. 2014. Trophic spectrum of the yellowtail surgeonfish Prionurus punctatus (Gill, 1862) on the rocky reef of Los Frailes, Baja California Sur, Mexico. Cahiers de Biologie Marine 55: 1-8.

Muriel-Hoyos F & AF Carmona-Guerra. 2020. Crecimiento, reproducción y hábitos alimentarios de Stellifer melanochir (Sciaenidae) en el Golfo de Tortugas, Pacífico colombiano. Acta Biológica Colombiana 25(2): 210-218.

Nash RDM, AH Valencia & AJ Geffen. 2006. The origin of Fulton’s condition factor, setting the record straight. Fisheries 31(5): 236-238.

Nazeek J, G Younes, C Sukhn & MH El-Dakdouki. 2018. Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. Egyptian Journal of Aquatic Research 44: 299-305.

Peyton KA, TS Sakihara, LK Nishiura, TT Shindo, TE Shimoda, S Hau, A Akiona & K Lorance. 2016. Length-weight relationships for common juvenile fishes and prey species in Hawaiian estuaries. Journal of Applied Ichthyology 32(3): 499-502.

Piña-Espallargas R. 2005. La pesquería de especies marinas con fines de ornato en México. El parque marino de Loreto, BCS, como estudio de caso. Tesis de Maestría, Centro Interdisciplinario de Ciencias Marinas - IPN, La Paz, 86 pp.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. <http://www.R-project.org/>

Rahman MA, MY Hossain, S Tanjin, Z Mawa, MR Hasan, KA Habib & J Ohtomi. 2021. Length weight relationships of five marine fishes from the Bay of Bengal. Journal of Applied Ichthyology 37(2): 364-366.

Renán X, J Trejo-Martínez, D Caballero-Arango & T Brulé. 2015. Growth stanzas in an Epinephelidae-Lutjanidae complex: considerations to length-weight relationships. Revista de Biología Tropical 63(1): 175-188.

Robertson DR & GR Allen. 2016. Fishes: East Pacific. A guide to the shorefishes of the Tropical Eastern Pacific. Version 3.0 Smithsonian Tropical Research Institute, Balboa, Republic of Panama. <https://biogeodb.stri.si.edu/sftep/es/pages>

Sabbir W, MY Hossain, MA Rahman, MR Hasan, Z Mawa, S Tanjin & J Ohtomi. 2021. First report on reproductive features of the Hooghly croaker Panna Heterolepis trewavas, 1977 from the Bay of Bengal in relation to environmental factors. Environmental Science and Pollution Research 28(18): 23152-23159.

Sumaila UR & TC Tai. 2020. End overfishing and increase the resilience of the ocean to climate change. Frontiers of Marine Science 7:523. <doi: 10.3389/fmars.2020.00523>

Ulloa-Ramírez PA, JL Patiño-Valencia, ML Guevara-Rascado, S Hernández-Ventura, R Sánchez-Regalado & A Pérez-Velázquez. 2008. Pesces marinos de valor comercial del estado de Nayarit, México, 88 pp. Repositorio de la RNIIPA, Instituto Nacional de Pesca, Ciudad de México.

Volpato GL & E Trajano. 2005. Biological rhythms. In: Val AL, EMF de Almeida-Val & D Randall (eds). The physiology of tropical fishes, pp. 101-153. Academic Press, London.

Zar JH. 2010. Biostatistical analysis, 944 pp. Prentice Hall, Upper Saddle River.

Received 31 August 2020
Accepted 20 January 2022