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Research Article

Length–Weight and Length–Length Relationships of 12 Fish Species Caught as Bycatch in the Artisanal Whiteleg Shrimp (*Litopenaeus vannamei*) Fishery in the Biosphere Reserve Marismas Nacionales, Nayarit, Mexico

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Length–weight relationship (LWR) and its parameters can be used for the development of models for the rational exploitation of fishery resources. In this study, we estimated the parameters of the LWRs and length–length relationships (LLRs) of 12 fish species caught incidentally by the artisanal whiteleg shrimp fishery in the Biosphere Reserve Marismas Nacionales (BRMN), Nayarit, Mexico. Fishes were sampled during the 2022–2024 fishing seasons (September–March) using cast nets of different mesh sizes recording total length (TL), standard length (SL), and total weight (W) for each. All LWRs and LLRs were significant ($p < 0.05$) with high coefficient of determination ($R^2 > 0.89$) and b-values of LWRs ranging from 2.59 (*Diapterus brevirostris*) to 3.14 (*Elops affinis*). These findings will serve as a basis for understanding the status of fish species in BRMN, an area impacted by human activity (e.g., artisanal fishing and aquaculture).

1. Introduction

The Nayarit whiteleg shrimp fishery within the Biosphere Reserve Marismas Nacionales (BRMN, Figure 1) represents an important economic activity in this protected natural area because it is one of the main sources of food and livelihoods for settled communities to the surroundings. Approximately between 12 and 14 thousand fishermen are directly involved with the fishery in the BRMN, generating between 4 and 6 thousand average tons of whiteleg shrimp, which represented close to 55% of the region's annual fishing production, with a value close to 9 million US dollars [1, 2].

The BRMN is located on the western coastal plain of Mexico between the south of the State of Sinaloa and the north of the State of Nayarit within the coast of the Gulf of California and is one of the largest mangrove forests on the northern Pacific coast in America [3]. Although the BRMN is one of the most important mangrove forests ecosystems in Mexico, with a size greater than 133,000 Ha, there are several factors that have generated harmful impacts on this reserve. Among the main problems identified are the construction of protective walls causing physical changes in drainage patterns, the dynamics of aquaculture, overfishing, unauthorized and harmful fishing practices, and absence of adequate fisheries management, which contribute to these negative impacts [3, 4].

In BRMN, whiteleg shrimp is caught by smaller vessels, and in addition to the authorized gear (cast nets of different mesh

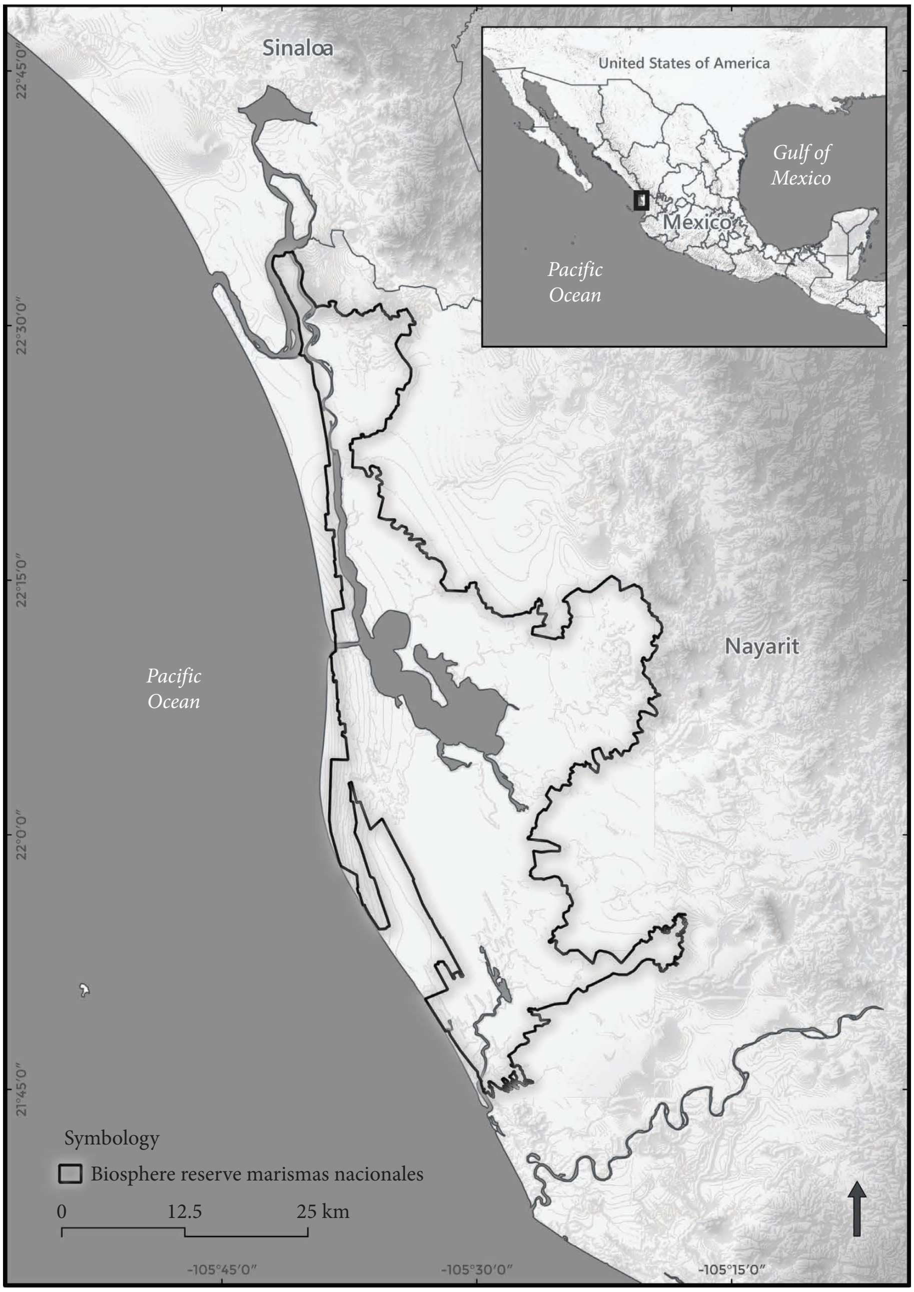

Figure 1: Location of biosphere reserve in Nayarit, Mexico.

sizes), local fishermen use a traditional system of wooden piles (mostly mangrove) that are placed at the sea bottom across the estuary channels, known as tapos, to retain shrimp. This type of fishing can have significant impacts on the marine environment, such as habitat alteration and the bycatch of other species such as fish, crustaceans, and mollusks, which in turn can cause net loss of biodiversity and low abundance of macrofauna species [5, 6]. In this context, few bycatch species have been studied, so there is a need to develop scientific studies to generate indicators of their abundance and distribution of sizes and weights.

Length and weight are two basic components at individual and population levels, which can be used to estimate growth rates, and with the length–weight relationship (LWR), the condition factor and the type of growth (somatic growth) can be known, information necessary for the development of models for the rational exploitation of fishery resources [7–9]. Therefore, this study provides LWR parameters of fish species caught incidentally by the artisanal whiteleg shrimp fishery in the BRMN, which will allow to evaluate the impact of artisanal fishing on these species.

2. Materials and Methods

As a part of the implementation of the Fishery Improvement Project (FIP) of the whiteleg shrimp (*Litopenaeus vannamei* Boone, 1931) fishery in BRMN, monthly monitoring of incidentally caught fish species was carried out during the

Table 1: Length-weight relationships (LWRs) for 12 fish species caught as bycatch in the artisanal whiteleg shrimp (*Litopenaeus vannamei*) fishery in the biosphere reserve marismas nacionales, Nayarit, Mexico.

Species	*N*	TL range (mm) (mean)	*W* range (g) (mean)	LWR parameters					Student's *t*-test	
				a	*b*	95% CI *a*	95% CI *b*	R^2	*t*	*p*
Anchoa analis (Miller, 1945)	131	4.0–12.0 (7.745)	0.3–11.0 (3.37)	−2.09	2.89	−2.24 | −1.94	2.72 | 3.06	0.89	1.21	0.22
Anchoa curta (Jordan & Gilbert, 1882)	119	3.0–12.0 (6.83)*	0.1–12 (2.57)	−2.27	3.12	−2.41 | −2.12	2.95 | 3.29	0.91	1.42	0.15
Ariopsis guatemalensis (Günther, 1864)	74	7.8–41.0 (17.51)	3.0–730.0 (90.45)	−2.22	3.11	−2.28 | −2.16	3.06 | 3.16	0.99	4.45	3E − 05
Achirus mazatlanus (Steindachner, 1869)	18	4.5–19.0 (11.88)	2.0–135.0 (54.88)	−1.67	3.00	−1.91 | −1.44	2.78 | 3.22	0.97	0.06	0.95
Centropomus robalito (Jordan & Gilbert, 1882)	119	4.6–24.8 (10.98)	0.7–202.0 (18.65)	−2.12	3.05	−2.21 | −2.03	2.96 | 3.13	0.97	1.26	0.2092
Diapterus brevirostris (Sauvage, 1879)	150	4.5–11.7 (9.08)	1.3–21.0 (9.55)	−1.53	2.59	−1.69 | −1.36	2.43 | 2.76	0.86	4.69	6E − 05
Dormitator latifrons (Richardson, 1844)	148	7.0–16.9 (10.69)	4.0–81.0 (24.81)	−1.74	2.97	−1.83 | −1.65	2.88 | 3.06	0.96	0.51	0.6
Elops affinis (Regan, 1909)	66	6.0–40.7 (27.56)	1.0–344.0 (115.18)	−2.54	3.14	−2.63 | −2.44	3.07 | 3.20	0.99	2.15	8E − 05
Eucinostomus currani (Zahuranec, 1980)	17	5.5–26.8 (14.5)*	5.0–191.0 (51.47)	−1.48	2.62	−1.87 | −1.10	2.28 | 2.96	0.94	2.37	0.03
Mugil setosus (Gilbert, 1892)	19	15.8–32.0 (22.83)	37.0–279.0 (135.15)	−2.09	3.06	−2.27 | −1.91	2.92 | 3.19	0.99	0.95	0.35
Oligoplites altus (Günther, 1868)	29	14.4–23.2 (18.32)	27.0–110.0 (55.03)	−1.98	2.93	−2.30 | −1.67	2.68 | 3.18	0.95	0.53	0.6
Oreochromis niloticus (Linnaeus, 1758)	49	6.3–28.6 (14.57)	6.0–459.0 (89.91)	−1.71	3.03	−1.90 | −1.52	2.87 | 3.19	0.96	0.42	0.67

Note: N, sample size; TL, total length; *W*, total weight; *a*, intercept of LWR; *b*, slope of LWR; R^2, coefficient of determination; *t*, Student's *t*-test value; *p*, *p*-value of the Student's *t*-test.
Abbreviation: CI = confidence intervals.
*New record of the maximum total length.

Table 2: Length-length relationships (LLRs) for 11 fish species caught as bycatch in the artisanal whiteleg shrimp (*Litopenaeus vannamei*) fishery in the biosphere reserve marismas nacionales, Nayarit, Mexico.

Species	LLR parameters				
	a	***b***	**95% CI *a***	**95% CI *b***	R^2
Anchoa analis	0.4401	1.1388	0.2351 | 0.6452	1.1075 | 1.1702	0.97
Anchoa curta	0.5780	1.1206	0.3190 | 0.8371	1.0756 | 1.1657	0.95
Ariopsis guatemalensis	0.2050	1.2254	−0.0931 | 0.5033	1.2065 | 1.2442	0.99
Achirus mazatlanus	0.2545	1.3057	−0.3858 | 0.8950	1.2396 | 1.3719	0.99
Centropomus robalito	0.4329	1.2364	0.2654 | 0.6005	1.2182 | 1.2546	0.99
Dormitator latifrons	0.3645	1.2432	0.0752 | 0.6538	1.2094 | 1.2771	0.97
Elops affinis	−1.040	1.3188	−1.9317 | −0.1614	1.2790 | 1.3586	0.98
Eucinostomus currani	−0.1436	1.3376	−0.5702 | −0.2828	1.3013 | 1.3740	0.99
Mugil setosus	0.5852	1.2343	0.3839 | 1.5545	1.1821 | 1.2866	0.99
Oligoplites altus	1.5599	1.1986	0.4902 | 2.6296	1.1228 | 1.2744	0.97
Oreochromis niloticus	0.2547	1.3057	−0.3858 | 0.8950	1.2396 | 1.3719	0.99

Note: a, intercept of LLR; *b*, slope of LLR; R^2, coefficient of determination.
Abbreviation: CI = confidence intervals.

2022-2023 (September–March) and 2023-2024 (September–March) fishing seasons. Cast nets of different mesh sizes (0.75, 1, and 1.5 inches) were used to capture the fish, and the total length (TL) and standard length (SL) were recorded for each of them to the nearest 1 mm and total weight (W) to the nearest 1 g.

The LWR parameters were estimated with length and weight data transformed logarithmically (base 10) using the following formula:

$$\log_{10} W = \log_{10} a + b(\log_{10}\mathrm{TL}), \quad (1)$$

where W is the total weight, TL is the total length, and a and b are the intercept and the slope (allometric coefficient) of the regression line, respectively [10]. To determine if the b-value of the LWR of each fish species was different from 3 (theoretical value for isometric growth), a Student's t-test was used [11]. In addition, the parameters of the length–length relationship (LLR) were estimated using simple linear regression using the following formula:

$$\mathrm{TL} = a + b(\mathrm{SL}), \quad (2)$$

where TL is the total length, SL is the standard length, and a and b are the intercept and the slope of the regression line, respectively. All statistical analysis was performed using R software [12].

3. Results

During the sampling period, 939 specimens of 12 fish species were measured and weighed. The parameters of LWR for each fish species are presented in Table 1. All LWRs were significant ($p < 0.05$) with high coefficient of determination ($R^2 > 0.89$) and b-values ranging from 2.59 (*Diapterus brevirostris* Sauvage, 1879) to 3.14 (*Elops affinis* Regan, 1909). The results of Student's t-test revealed that the b-value of 8 of the 12 species analyzed was not significantly different from 3 ($p > 0.05$; Table 1) (i.e., length and weight grow in the same proportion over time).

The parameter of the LLRs for each fish species are presented in Table 2. For *D. brevirostris*, the SL was not recorded, so the LLR parameters were not estimated. All LLRs were significant ($p < 0.05$) with high coefficient of determination ($R^2 > 0.95$).

4. Discussion

The estimated LWR b parameter for the analyzed fish species fall within the expected range (2.5–3.5) of values reported for fishes [10], since generally, b-values lower or higher than this range are considered inaccurate [13].

This study provides LWR and LLR parameters of fishes caught incidentally in the BRMN and will serve as a basis for understanding their status in an area impacted by human activity (e.g., artisanal fishing and aquaculture). The LWR and LLR parameters can be used for the conversion of TL into W and SL into TL and, therefore, to convert growth in length into growth in weight to obtain biomass measurements [10, 14]. In addition, this study reports novel LWR parameters for three species: *E. affinis*, *Anchoa analis* (Miller, 1945), and *A. curta* (Jordan and Gilbert, 1882), novel LLR parameters for *D. brevirostris*, and new maximum TL for two species: *A. curta* and *Eucinostomus currani* (Zahuranec, 1980) according to FishBase [15].

During sampling, it was not possible to record the sex of the specimens, so future studies are recommended to test for differences between sexes. If significant differences are found, LWR parameters should be presented separately for males, females, and both sexes [10].

Data Availability Statement

Data used in the analyses were generated by the Fishery Improvement Project (FIP) "Mexico Marismas Nacionales artisanal whiteleg shrimp - trap/cast-nets (FIP ID# 18740)" which is hosted on the website https://fisheryprogress.org/. As part of the progress report of said FIP, the manuscript was previously hosted on the website, but it was not peer-reviewed. The article is a result of the mentioned FIP. We confirm that the website does not hold copyright over the content, and we retain full rights to publish this work. All necessary permissions have been obtained, and no copyright conflicts exist.

Conflicts of Interest

The authors declare no conflicts of interest.

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