RESEARCH NOTE

Length-weight relationships for 30 fish species caught in coastal waters of Veracruz, western Gulf of Mexico

Relaciones de longitud-peso para 30 especies de peces capturadas en aguas costeras de Veracruz, Oeste del Golfo de México

Gabriela Galindo-Cortes[1], César Meiners[1] and Lourdes Jiménez-Badillo[1]

[1]Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana, Hidalgo 617, Col. Río Jamapa, 94290, Boca del Rio, Veracruz, México. gagalindo@uv.mx

Abstract.- Length-weight relationships were calculated for 30 fish species belonging to 14 families using 2562 specimens caught in coastal waters of the western Gulf of Mexico. The number of fish measured varied by species, ranging from 32 individuals for *Polydactylus octonemus* to 177 for *Anchoa hepsetus*. Most of the values of the parameter *b* are within expected range of 2.5-3.5. The effects of sex for some of these species were taken into account; however, none of them had significantly different. The results of this study provide useful basic biological information about the most conspicuous species of fish caught in the study area.

Key words: Coastal fishes, fish assemblages, length-weight relationship

INTRODUCTION

The relationship between body length and weight is relevant for fishery biology in several topics related with stock and population assessments such as biomass estimates obtained from age- and length-structured models (Pope 1972, Methot 1989), which require the calculation of mean weight of individuals per age or length class through the length-weight relationship (LWR). Furthermore, LWR is useful to calculate fish condition and provides information about life history and morphological comparisons between different fish species or between different fish populations from different habitats (Petrakis & Stergiou 1995, Koutrakis & Tsikliras 2003, Froese 2006).

This contribution takes importance because the study area, known as Las Barrancas, is neighbor to the south of Veracruz Coral Reef System National Park, which was decreed as a marine protected area in 1992, and it could be impacted in the short-term by human activities related to port expansion in order to increase capabilities for commercial activities. Despite its importance, basic biological information about fish species and its interactions with other living resources in the area of influence of the Park is still scarce or unpublished. This study, therefore, aims to present fish diversity, size ranges, and provides the first LWR reference for 30 fish species in coastal waters of Veracruz, western Gulf of Mexico.

MATERIALS AND METHODS

The specimens of fish species were collected from 16 fishing samplings carried out during September 2009 to October 2012 in a shallow sandy beach called 'Las Barrancas' and located at 18°59'43.83''N, 95°57'53.78''W (8 km southward of the Veracruz Reef System) (Fig. 1). Each sampling consisted of a single fishing haul with a beach seine net of 750 m long, 3 m high, mesh size 31/2'' at lateral wings and 3/4'' at the cod-end. Once each fishing haul was concluded, the total catch was separated and identified at the species level, a subsample was used for biometrics. The scientific name for each species was checked according to Froese & Pauly (2013).

Total length (L) of each fish was measured to nearest 0.1 cm, and the individual total weight (W) recorded to nearest 0.1 g. Sex was determined in some cases by macroscopic analysis of the gonads, otherwise it was registered as indeterminate sex. We applied a power function (Huxley 1932, Le Cren 1951), $W = aL^b$, where a, is the intercept (initial growth coefficient or condition factor) and b the slope (growth coefficient, *i.e.,* fish relative growth rate). W and L were log transformed and the resulting linear relationship fitted by the least squares regression using W as the dependent variable (Le Cren 1951, Ricker 1975). The degree of association between the variables was computed by the determination coefficient (r^2). The Cook's distance was helpful to identify
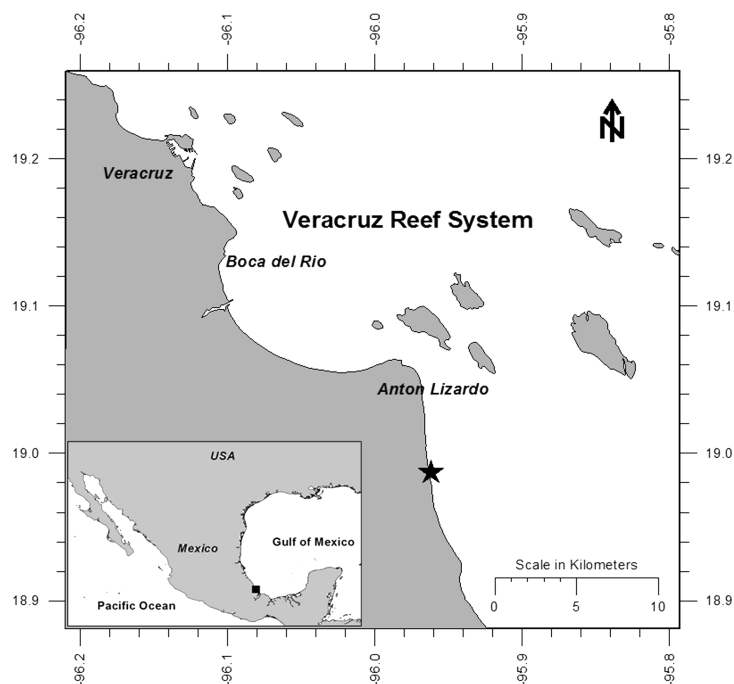
Figure 1. Study area sandy beach Las Barrancas showing sampling area at western of Gulf of Mexico (★), and the Veracruz Coral Reef System inside the National Park / Área de estudio en playa arenosa Las Barrancas indicando el sitio de muestreo en el oeste del Golfo de México (★) y el Sistema Arrecifal Veracruzano dentro del Parque Nacional

the most influential observation in data sets (Cook 1977). When the sample size by sex was sufficient (n ≥ 30 for each sex), length-weight relationships were calculated separately; and data from juveniles of indeterminate sex were added in both length-weight relationship regressions for females and males. To test the hypothesis of isometric growth, H_o: $b = 3$ *vs* H_1: $b \neq 3$, a special case of the Wald (F-distribution) test was used (Seber & Wild 1989). This is based on an F test with 1 degree of freedom of the numerator and *n-k* parameter degrees of freedom of the denominator. The test is rejected with a significance level (α) of 0.05 if $\hat{F} > F_{k,n-k}^{\alpha}$. In the same manner, to determine if there are significant differences between the male and female values of *b* was tested if H_o: $b_{males} - b_{females} = 0$, which indicates that there is no difference between slopes, vs. H_1: $b_{males} - b_{females} \neq 0$, indicating differences in the value of *b*. In all cases, Ho is rejected if $P < 0.05$. Statistics were performed using the STATA software version 13.0.

RESULTS AND DISCUSSION

A total of 2562 individuals from 30 fish species belonging to 14 families were examined. The taxa examined in this study included species covering a wide array of body shapes and life history strategies. Carangidae was the most important family in terms of abundance and species richness. The number of fish measured varied by species, ranging from 32 individuals for *Polydactylus octonemus* to 177 for *Anchoa hepsetus*.

Table 1 shows the sample size, length range, LWR parameters (*a* and *b*) for each fish species and its statistical values. Linear regressions fitted to estimate the LWR were significant for all species. Values of parameters *b* vary from 2.525 for *Hyporhamphus unifasciatus* to 3.597 for *Cetengraulis edentulus*. Most of the *b* values ranged for 2.5 < b < 3.5 as suggested Carlander (1969), except to *C. edentulus*. For 11 species the *b* values showed an isometric growth. A positive allometry growth was detected for 14 fish species (b > 3), while only for 5 species had negative allometry growth (*b* < 3). Seven species had a sample size enough to applied length-weight regressions by sex (n ≥ 30 for each sex); however no significant differences in slopes were observed.

Table 1. Descriptive statistics and estimated parameters of length-weight relationships (W= aLᵇ) for the 30 fish species in coastal waters of Veracruz, western Gulf of Mexico. N: sample size; L: total length (cm); W: total weight (g); CI: confidence interval; a: intercept; b: slope; *new maximum length compared with those reported in FishBase.org / Estadísticos descriptivos y parámetros estimados de las relaciones longitud-peso (W= aLᵇ) para 30 especies de peces capturadas en aguas costeras de Veracruz, Oeste del Golfo de México. N: tamaño de muestra; L: longitud total (cm); W: peso entero (g); CI: intervalo de confianza; a: intercepto; b: pendiente; *nueva longitud máxima en comparación con las reportadas en FishBase.org

Families/Species	N	Sampling dates (month-year)	L, mean ± SD (range)	W, mean ± SD (range)	a	95% CI of a	b	95% CI of b	Determination coefficient (r^2)	Relationship (Wald test)
Belonidae										
Tylosurus acus	45	Sep-09; Jan, Mar, Jun, Sep-10; Apr, Aug-11; Jul, Oct-12	48.2 ± 14.4 (22.5-94.0)	178.5 ± 223.9 (9.1-1160)	0.0024	0.00087-0.00659	2.827	2.563-3.090	0.91 ($P < 0.01$)	Isometric
Carangidae										
Caranx crysos	111	Sep, Nov-09; Jan, May, Sep, Nov-10; Feb, Aug-11; Jul, Oct-12	17.9 ± 3.8 (11.2-29.5)	74.3 ± 57.58 (15.7-354.2)	0.0121	0.00946-0.01555	2.973	2.886-3.059	0.98 ($P < 0.01$)	Isometric
Caranx latus	88	Sep, Nov-09; Sep, Nov-10; Aug-11; Jul, Oct-12	11.7 ± 3.6 (4.5-22.6)	28 ± 27.9 (1.4-163)	0.0131	0.01004-0.01723	3.015	2.903-3.127	0.97 ($P < 0.01$)	Isometric
Caranx hippos	69	Sep, Nov-09; Jun, Aug, Nov-11; Jul, Oct-12	15.01 ± 5.63 (4.4-25.5)	62 ± 44.9 (1-217.2)	0.0126	0.01106-0.01444	3.016	2.966-3.066	0.99 ($P < 0.01$)	Isometric
Oligoplites saurus	73	Sep, Nov-09; Jun, Mar, Nov-10; Feb, Apr, Aug-11; Mar, Jul, Oct-12	20 ± 4.1 (12.1-28.8)	58.2 ± 35.2 (9.2-164.9)	0.0027	0.00219-0.00347	3.279	3.201-3.356	0.99 ($P < 0.01$)	(+)Allometry
Hemicaranx amblyrhynchus	44	Nov-09; Jan, Nov-10; Feb, Apr, Jun, Aug-11; Mar-12	20.8 ± 5.9 (8.6-30.3)	85.5 ± 53.2 (6.4-223.3)	0.01	0.00786-0.01279	2.917	2.836-2.998	0.99 ($P < 0.01$)	Isometric
Decapterus punctatus	39	Sep-10; Feb, Apr, Aug-11	15.5 ± 2 (11.4-18.7)	34.6 ± 13.1 (12.7-57.8)	0.0067	0.00486-0.00939	3.098	2.977-3.218	0.98 ($P < 0.01$)	Isometric
Chloroscombrus chrysurus	94	Jan, Sep, Nov-10; Feb, Apr, Jun, Aug-11; Mar, Jul-12	13.1 ± 4.5 (3-20.9)	22.9 ± 15.6 (0.3-66.1)	0.0145	0.01242-0.01704	2.765	2.702-2.828	0.99 ($P < 0.01$)	(-)Allometry
Selene brownii	127	Sep, Nov-09; Sep, Nov-10; Feb, Apr, Nov-11; Mar, Jul-12	9.7 ± 4.4 (2.7-22.)	17.3 ± 20.4 (0.3-97.6)	0.0171	0.01553-0.01885	2.837	2.794-2.881	0.99 ($P < 0.01$)	(-)Allometry
Clupeidae										
Harengula jaguana All	159	Sep, Nov-09; May, Sep, Nov-10; Feb, Apr-11; Mar, Jul, Oct-12	12.2 ± 3.2 (4.2-16.8*)	22.4 ± 13.8 (0.6-50.5)	0.009	0.00782-0.01030	3.058	3.003-3.113	0.99 ($P < 0.01$)	(+)Allometry

Table 1 Continued / Continuación Tabla 1

	n	Months	Length mean ± SD (range)	Weight mean ± SD (range)	a	a range	b	b range	R^2 (P)	
Female	91		11.9 ± 3.4 (4.2-16.8)	21.7 ± 14.4 (0.6-50.5)	0.0082	0.00701-0.00949	3.101	3.038-3.163	0.99 ($P < 0.01$)	(+)Allometry
Male	60		11.1 ± 3.3 (4.2-16)	17.4 ± 12.7 (0.6-44.2)	0.0073	0.00599-0.00894	3.154	3.066-3.243	0.99 ($P < 0.01$)	(+)Allometry
Opisthonema oglinum	90	Sep-09; Mar, Sep-10; Feb, Apr, Aug, Nov-11; Mar, Jul-12	13.3 ± 4.1 (5.1-24.5)	29 ± 33.7 (1.4-144.9)	0.006	0.00504-0.00706	3.153	3.087-3.219	0.99 ($P < 0.01$)	(+)Allometry
Sardinella aurita	41	Sep-10; Feb, Nov-11; Jul-12	14.1 ± 4.9 (6.3-21.3)	30.1 ± 26.5 (2.3-79.5)	0.0052	0.00434-0.00614	3.149	3.006-3.169	0.99 ($P < 0.01$)	(+)Allometry
Elopidae										
Elops saurus	65	Sep, Nov-09; Nov-10; Apr, Nov-11; Jul-12	35.2 ± 6.6 (25.4-51.2)	234.1 ± 148.5 (71.6-740.5)	0.002	0.00144-0.00291	3.236	3.137-3.335	0.98 ($P < 0.01$)	(+)Allometry
Engraulidae										
Anchoa hepsetus										
All	177	Nov-09; Jan, Sep, Nov-10; Feb, Apr, Jun, Nov-11; Mar, Jul, Oct-12	11.5 ± 2 (6.3-15.1*)	12 ± 5.9 (1.6-25.7)	0.0042	0.00347-0.00499	3.220	3.146-3.295	0.98 ($P < 0.01$)	(+)Allometry
Female	87		11.4 ± 2.1 (6.3-15.1)	11.7 ± 6 (1.6-25.7)	0.00406	0.00335-0.00493	3.230	3.151-3.309	0.98 ($P < 0.01$)	(+)Allometry
Male	52		10.7 ± 1.8 (6.3-14.4)	9.5 ± 4.8 (1.6-24.3)	0.004	0.00317-0.00505	3.236	3.138-3.335	0.97 ($P < 0.01$)	(+)Allometry
Cetengraulis edentulus	52	Nov-09; Nov-10; Feb, Apr-11; Mar, Jul, Oct-12	12.1 ± 2.9 (7.7-17.3)	18 ± 13.8 (3-44.4)	0.0018	0.00144-0.00227	3.597	3.505-3.688	0.99 ($P < 0.01$)	(+)Allometry
Gerreidae										
Eucinostomus melanopterus										
All	125	Sep, Nov-09; Sep, Nov-10; Apr, Jun, Aug, Nov-11; Mar, Jul-12	12.7 ± 2.6 (7.2-17.9*)	25.2 ± 15.8 (3.4-69.5)	0.004	0.00310-0.00522	3.386	3.283-3.488	0.97 ($P < 0.01$)	(+)Allometry
Female	45		12.6 ± 2.7 (7.2-17.9)	24.9 ± 16.8 (3.4-69.5)	0.00413	0.003312-0.00547	3.373	3.262-3.484	0.97 ($P < 0.01$)	(+)Allometry
Male	40		11.8 ± 2.2 (7.2-15.9)	19.9 ± 12.3 (3.4-49.4)	0.0035	0.00245-0.00492	3.444	3.303-3.585	0.96 ($P < 0.01$)	(+)Allometry
Diapterus auratus	120	Sep, Nov-09; May, Sep, Nov-10; Feb, Apr-11; Mar, Jul, Oct-12	14.6 ± 2.3 (9.5-20.7)	40.1 ± 18.6 (11.3-113.3)	0.0067	0.00486-0.00939	3.032	2.906-3.159	0.95 ($P < 0.01$)	Isometric
Haemulidae										
Conodon nobilis	51	Sep-09; May-10; Feb, Apr, Nov-11; Jul, Oct-12	11.3 ± 5.1 (5.4-21.2)	33.5 ± 38.7 (1.9-135.3)	0.0103	0.00717-0.01478	3.105	2.953-3.258	0.97 ($P < 0.01$)	Isometric
Hemiramphidae										
Hemiramphus brasiliensis										

Table 1 Continued / Continuación Tabla 1

	n	Months	Length mean ± SD (range)	Weight mean ± SD (range)	a	a range	b	b range	r²	Allometry
All	145	Sep, Nov-09; Jan, May-10; Feb, Apr, Jun, Aug, Nov-11; Jul-12	30.7 ± 6.2 (13.8-40*)	90.7 ± 43.5 (6.4-178)	0.0013	0.00108-0.00158	3.213	3.158-3.269	0.99 ($P < 0.01$)	(+)Allometry
Female	36		30.5 ± 6.8 (13.8-38)	90.9 ± 47.4 (6.4-178)	0.0015	0.00123-0.00181	3.175	3.118-3.232	0.99 ($P < 0.01$)	(+)Allometry
Male	49		29.7 ± 6.5 (6.8-36.8)	83.2 ± 44.4 (6.4-144)	0.00127	0.00104-0.00156	3.223	3.163-3.283	0.99 ($P < 0.01$)	(+)Allometry
Hyporhamphus unifasciatus	63	Jan, May, Sep, Nov-10; Nov-11; Jul, Oct-12	20.8 ± 3.2 (14.6-29*)	25.2 ± 11.3 (5-63.6)	0.0111	0.00617-0.02011	2.525	2.331-2.720	0.92 ($P < 0.01$)	(-)Allometry
Mugilidae										
Mugil curema	38	Sep, Nov-09; May, Sep, Nov-10; Apr, Nov-11; Mar, Jul, Oct-12	26.5 ± 4.8 (14.4-42.8)	172.4 ± 104.9 (28.3-629.4)	0.0121	0.00576-0.02553	2.887	2.659-3.115	0.94 ($P < 0.01$)	Isometric
Polynemidae										
Polydactylus octonemus	32	Sep-09; May, Sep-10; Nov-11; Jul, Oct-12	12.4 ± 3.4 (7.1-19.6)	21.5 ± 21.8 (6.8-74.5)	0.0083	0.00455-0.01514	3.020	2.779-3.261	0.95 ($P < 0.01$)	Isometric
Sciaenidae										
Menticirrhus americanus										
All	158	Sep, Nov-09; May, Sep, Nov-10; Feb, Apr, Jun, Aug, Nov-11; Mar, Jul, Oct-12	19.7 ± 5.9 (3.2-31.4)	92.3 ± 62.7 (0.2-263)	0.0051	0.00442-0.00582	3.203	3.156-3.250	0.99 ($P < 0.01$)	(+)Allometry
Female	67		23.5 ± 3.2 (12.6-31.4)	94.4 ± 42.7 (31.1-263)	0.005	0.00436-0.00580	3.205	3.155-3.254	0.99 ($P < 0.01$)	(+)Allometry
Male	49		21 ± 3.2 (14.8-26.7)	94.4 ± 42.7 (31.1-220.7)	0.005	0.00434-0.00578	3.206	3.155-3.258	0.99 ($P < 0.01$)	(+)Allometry
Umbrina coroides	104	Sep-09; May, Sep-10; Feb, Apr-11; Jul, Oct-12	13.9 ± 5.1 (4-22.8)	43.8 ± 38.1 (0.4-134.4)	0.0087	0.00736-0.01019	3.108	3.045-3.171	0.99 ($P < 0.01$)	(+)Allometry
Cynoscion arenarius	72	Sep, Nov-10; Feb, Apr, Nov-11; Mar, Oct-12	19.1 ± 2.9 (10.5-26.9)	73.5 ± 30.3 (8.7-180.1)	0.0053	0.00389-0.00729	3.206	3.099-3.313	0.98 ($P < 0.01$)	(+)Allometry
Bairdiella ronchus	41	Nov-09; Nov-10; Feb, Apr, Nov-11; Mar, Jul-12	15.5 ± 1.5 (12.9-19.3)	44.9 ± 14.4 (23.1-83.5)	0.0042	0.00239-0.00751	3.363	3.154-3.572	0.96 ($P < 0.01$)	(+)Allometry
Scombridae										
Scomberomorus cavalla	60	Sep, Nov-10; Feb, Apr, Jun, Nov-11; Jul, Oct-12	26.6 ± 9.4 (13-46.5)	146.7 ± 139 (11.8-679.6)	0.0092	0.00706-0.01213	2.859	2.775-2.942	0.99 ($P < 0.01$)	(-)Allometry
Scomberomorus maculatus	56	Sep, Nov-09; Jan, May, Sep-10; Apr, Nov-11; Mar, Jul, Oct-12	32 ± 9.9 (9.5-48.5)	240.7 ± 182 (4.5-760.7)	0.0076	0.00580-0.01003	2.920	2.840-3.000	0.99 ($P < 0.01$)	Isometric
Sphyraenidae										
Sphyraena guachancho										
All	151	Sep, Nov-09;	24.1 ± 8.6 (7.5-41.5)	86.5 ± 67.9 (1.6-335)	0.0084	0.00633-0.01122	2.815	2.723-2.906	0.96 ($P < 0.01$)	(-)Allometry

Table 1 Continued / Continuación Tabla 1

	n	Months	Length	Weight	a	a CI	b	b CI	R² (P)	Allometry
Female	32	May, Sep, Nov-10; Feb, Apr, Nov-11; Mar, Jul, Oct-12	21.6 ± 8.8 (7.5-41.5)	68.8 ± 67.9 (1.6-335)	0.0086	0.00594-0.01239	2.807	2.685-2.929	0.95 ($P < 0.01$)	(-)Allometry
Male	45		22.1 ± 8.4 (7.5-37.2)	71.6 ± 62.6 (1.6-243.9)	0.0078	0.00557-0.01095	2.842	2.731-2.953	0.96 ($P < 0.01$)	(-)Allometry
Trichiuridae										
Trichiurus lepturus	72	Nov-09; Jan, Nov-10; Nov-11; Mar, Jul-12	45.8 ± 14.4 (20.4-93.1)	78.7 ± 102 (3-680)	0.0001	0.00007-0.00018	3.399	3.265-3.533	0.97 ($P < 0.01$)	(+)Allometry

No information on LWR of the selected fish species was available for the study area. However, it is possible comparing our findings against estimations from other areas reported in FishBase (Froese & Pauly 2013). Taking this into account, the LWR parameters of this study were within the ranges reported in the literature for the most fish species but lower for *Tylosurus acus* and *H. unifasciatus*, and higher for *Cynoscion arenarius*, *Eucinostomus melanopterus*, *Oligoplites saurus* and *P. octonemus*.

It is well known that the functional regression *b*, value varies according to the body shape of fish and some life history parameters such as maturity, maximum size, growth rate, and others factors like habitat, stomach fullness, health, sex, age, etc., (Ricker 1975, Froese 2006).

According to Froese *et al.* (2011) an adequate sample size of about 100 specimens per species, *i.e.*, there is no need to kill thousands of specimens only for WLR estimates with exception of rare and endangered species as well as specimens that were caught from opportunity sampling.

The results of this study provide useful basic biological information about the most conspicuous species of fish caught in the study area that can also be compared to surrounding areas, like the Veracruz Coral Reef System National Park.

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