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Length-Weight Relationship of Demersal Fish from the Eastern Coast of the Mouth of the Gulf of California

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Abstract: The present study was performed with the purpose of describing the length-weight relationships for 64 species from 36 fish families of ecological and commercial importance, found at the soft bottom of the continental shelf on the Eastern coast of the mouth of the Gulf of California. The knowing the LWR is important because it provides information on the life history of species and may be an input to the assessment of fishery resources in the region. In this study, the demersal fish were collected during eight surveys aboard a commercial shrimp-trawling boat that operated at depths of 10 to 60 m during the 2005/06 and 2006/07 shrimp fishing seasons. Parameter b of the model $W = aL^b$ varied from 1.801 to 3.916, with a mean value of 2.9511 (SD = 0.3574) and fits a normal distribution. We reported 38 new records of the LWR and 10 of larger total length than those reported in FishBase.

Key words: Gulf of California, length-weight relationship, growth type, shrimp fishery, demersal fish

INTRODUCTION

The shrimp fishery is one of the most important to Mexico's foreign trade. In particular, the area located on the Eastern coast of the mouth of the Gulf of California provides 90% of shrimp catches in the country (García-Caudillo and Gómez-Palafox, 2005). This area is characterized by soft bottoms (mainly sand and mud) (Rodríguez-de la Cruz, 1981a, b) and be a transition zone with the open sea, of high productivity and biodiversity by the influence of lagoons, estuaries (Ortiz-Pérez *et al*., 2006), the dynamics of water masses from the Gulf of California (Sánchez *et al*., 1978) and by the confluence of the California Current (Southward), the North Equatorial (Northward) (Wyrtki, 1967; Kessler, 2006). Most of the work undertaken within the study area describes catch composition by species as well as the spatial and temporal distribution of the relative abundance of the demersal fish community as a part of by-catch monitoring (Chávez and Arvizu, 1972; Mellado and Findley, 1985; Linares, 1987, 1996; Van der Heiden *et al*., 1986).

The Length-Weight Relationship (LWR) is an important element in population dynamics and stock assessment (Pauly, 1993; Oniye *et al*., 2006). This relationship is described by the

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model W = aL^b, where W is weight, L is the length (Froese, 1998), a is the logarithm of the intercept and b is the slope; both are linear regression parameters of LWR (İlhan *et al*., 2008). In biological terms, a is the factor of condition of the fish (Mortuza and Rahman, 2006) b is the growth type, which in the case of fish when growth is isometric b = 3 (Csirke, 1993). Although, these parameters would be relevant in the fishery resource management, at the Gulf of California, there are few studies about the fish fauna found with the shrimp by-catch, even when artisanal fisheries exploit some species. Some of these are carried in particular habitats like mangrove systems (González Acosta *et al*., 2004), reefs associated (Balart *et al*., 2006), deep-sea habitats (De La Cruz-Agüero and Gómez, 2006) and coastal lagoons (Aguirre *et al*., 2008). Campos *et al*. (2006) described the LWR for fishes inhabiting continental shelf on this region, but in the North part of the Baja California Peninsula. The most closed study by Rodríguez-Romero *et al*. (2009), calculated some LWRs for fish species but on the Western coast of the mouth of the Gulf of California, which is typically characterized by rocky-type bottoms. Despite those studies, the LWR of fishes in a given geographic zone is not only basic in fisheries biology but can also be used as indices of fish condition for life-history comparisons of different regions (Petrakis and Stergiou, 1995; Thomas *et al*., 2003).

This study discusses the LWR parameters for 64 demersal fish species found on the soft bottoms of the Northwest Mexican Pacific; of these, 38 species do not have records in the FishBase database (Froese and Pauly, 2009).

MATERIALS AND METHODS

Samples were collected over eight surveys carried out during the 2005/06 and 2006/07 shrimp fishing seasons and were based on 139 commercial trawl hauls during 2005/06 and 38 during 2006/07 on the continental shelf of Southern Sinaloa and Northern Nayarit coasts (Fig. 1). In both seasons, we used commercial shrimp trawl nets (headrop length of 28.96 m, mesh size of 5.08 cm and 3.17 cm in the body and cod end) at depths ranging between 10 to 60 m.

After each trawl, random samples between 12 to 20 kg were collected and frozen on the boat before being transferred to laboratory, where the species of the fish were identified using taxonomic keys of Bussing and Lopez (1993), Fischer *et al*. (1995), Roberson and Allen (2006) and specific keys for *Diplectrum* (Bortone, 1997) and *Umbrina* (Walker and Radford, 1992). The Total Length (TL) was measured to the nearest 0.1 cm and Total Weight (TW) to nearest 0.01 g by an electronic balance. In this analysis, we did not consider fish with an incomplete caudal fin.

Parameters a and b were estimated by a least-squares regression with the linear expression Log (TW) = log (a) + (b) log (LT), which was obtained from the logarithmic transformation of the relationship between total weight and total length (TW = aTL^b) (Stergiou and Politou, 1995; Sivasahanthini *et al*., 2009). The value of exponent b provides information on the fish growth type. The LWR reflects isometric growth when b = 3. Hence, the hypothesis of b = 3 was tested for difference based on the t-test at a 0.05 significance level (Zar, 1999). Additionally, we explored the frequency distribution of b values for all species and then test the normality using the Kolmogorov-Smirnov test, for determine the incompatible of observed distribution of frequencies ($p<0.05$), with a normal distribution (Daniel, 2005). The species list was grouped into families according the systematic order proposed by Nelson (2006).

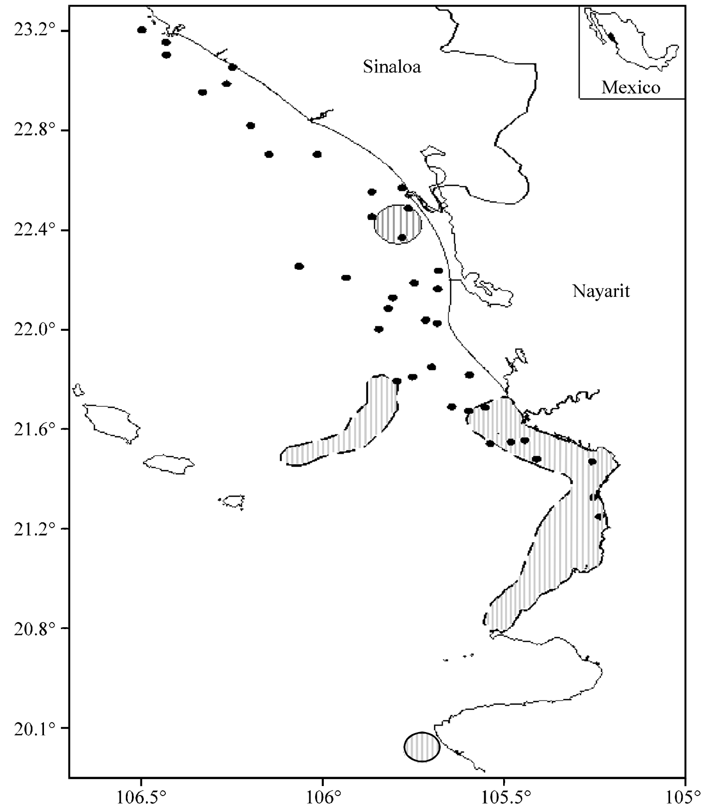

Fig. 1: Study area along the Eastern coast of the mouth of the Gulf of California (South coast of Sinaloa and Nayarit). Sampling stations are shown as black dots; the gray spots indicate the area where commercial shrimp hauls were made

RESULTS

In total, 37,350 specimens of 64 species of fish belonging to 55 genera and 36 families were sampled. The families with the most species were Sciaenidae (7) and Carangidae (6), followed by Achiridae, Haemulidae, Paralichthyidae, Serranidae and Tetraodontidae, which had 3 species each. The species, number of specimens, length, weight, LWR parameters a and b, determination coefficient (R^2) and growth type (allometric or isometric) are shown in Table 1. The sample size for species varies from 17 fish for *Narcine vermiculatus* (Narcinidae) to 5,460 fish for *Selene peruviana* (Carangidae).

Accounting for all of the species, the values of b ranged from 1.801 for *Narcine vermiculatus* (Narcinidae) to 3.916 for *Citharichthys platophys* (Paralichthydae). All values of parameter b in the model were significant ($p<0.05$) and their frequencies fit a normal distribution ($p = 0.15$). The median value of b was 2.97, while 67.19% of the species were found in the range (2.5974 to 3.1190) defined by the average value of b (2.9546) ±standard deviation (SD = 0.3572) (Fig. 2). The R^2 values ranged from 0.693 for *Fistularia corneta* (102 ind.; Fistulariidae) to 0.995 for*Lutjanus guttatus* (1,359 ind.; Lutjanidae), whereas 71.87% of species had R^2 values greater than 0.95 and for eight species $R^2<0.9$.

Table 1: LWRs for 64 demersal species from the continental shelf of the Eastern coast of the mouth of the Gulf of California (Southern Sinaloa and Nayarit)

Species	Sample size, n	Length (cm) Min.	Length (cm) Max.	Weight (g) Min.	Weight (g) Max.	Parameters of the relationship a	b	Gt	S.E.(b)	R^2
Muraenesocidae										
Cynoponticus coniceps (Jordan and Gilbert, 1882)[1]	42	11.20	74.50	1.90	425.40	0.004	2.686	-A	0.00435	0.980
Ophichthidae										
Ophichthus triserialis (Kaup, 1856)[1]	94	9.20	72.20	7.82	373.25	0.011	2.417	-A	0.01154	0.878
Synodontidae										
Synodus scituliceps (Jordan and Gilbert, 1882)[1]	541	9.40	41.20	1.60	440.00	0.008	2.858	-A	0.02194	0.969
Synodus sechurae (Hildebrand, 1946)[2]	1011	2.30	47.60	0.13	515.54	0.012	2.749	-A	0.01326	0.977
Batrachoididae										
Porichthys analis (Hubbs and Schultz, 1939)[1]	716	4.50	23.40	0.94	135.40	0.022	2.901	-A	0.00091	0.932
Clupeidae										
Opisthonema libertate (Günther, 1867)	229	3.70	24.30	0.42	145.80	0.007	3.039	+A	0.00027	0.998
Engraulidae										
Anchovia macrolepidota (Kner, 1863)[1]	295	11.00	22.20	7.30	57.24	0.007	3.292	+A	0.00171	0.952
Pristigasteridae										
Opisthopterus dovii (Günther, 1868)[1,2]	189	6.50	21.00	1.90	55.60	0.009	2.865	I	0.00670	0.875
Fistulariidae										
Fistularia corneta (Gilbert and Starks, 1904)[1]	102	6.90	50.50	1.60	30.83	0.017	1.855	-A	0.02017	0.693
Lophiidae										
Lophiodes caulinaris (Garman, 1899)[1]	90	3.80	19.30	0.90	136.92	0.022	2.950	I	0.00418	0.976
Urolophidae										
Urotrygon aspidura (Jordan and Gilbert, 1882)[1,2]	191	7.60	48.40	3.37	789.82	0.006	3.040	I	0.00195	0.988
Urotrygon nana (Miyake and McEachran, 1988)[1,2]	22	9.00	32.00	3.50	365.70	0.004	3.180	I	0.01481	0.969
Ophidiidae										
Brotula clarkae (Hubbs, 1944)[1]	75	10.50	29.20	3.19	106.59	0.003	3.091	I	0.01305	0.872
Lepophidium prorates (Jordan and Bollman, 1890)[1]	95	11.00	27.50	5.40	109.50	0.003	3.045	I	0.00368	0.963
Carangidae										
Alectis ciliaris (Bloch, 1787)	52	4.40	21.50	1.00	155.20	0.019	2.894	I	0.00350	0.984
Chloroscombrus orqueta (Jordan and Gilbert,1883)[1]	1935	12.00	22.70	13.86	112.70	0.004	3.229	+A	0.02327	0.909
Hemicaranx leucurus (Günther, 1864)[1]	51	7.90	9.30	4.50	179.20	0.017	2.759	+A	0.00192	0.982
Selar crumenophthalmus (Bloch, 1793)	31	11.50	22.80	14.10	142.50	0.005	3.280	I	0.00885	0.962
Selene brevoortii (Gill, 1863)[1]	67	4.90	27.00	1.15	209.02	0.027	2.715	-A	0.00356	0.949
Selene peruviana (Guichenot, 1866)[1]	5460	4.50	29.00	1.00	217.75	0.021	2.749	-A	0.00017	0.986
Centropomidae										
Centropomus robalito (Jordan and Gilbert, 1882)[1]	850	9.00	30.00	8.00	274.40	0.008	3.063	+A	0.01531	0.976
Chaetodontidae										
Chaetodon humeralis (Günther, 1860)[1]	92	3.80	20.70	1.70	298.40	0.029	3.048	I	0.00149	0.991
Johnrandallia nigrirostris (Gill, 1862)[1]	29	4.20	20.70	2.47	327.17	0.021	3.215	+A	0.00245	0.993
Ephippidae										
Chaetodipterus zonatus (Girard, 1858)[1]	83	6.20	16.80	8.50	170.50	0.017	2.684	-A	0.00405	0.929
Gerreidae										
Diapterus brevirostris (Sauvage, 1879)	1284	6.30	29.20	3.76	295.15	0.019	2.853	-A	0.00050	0.976
Eucinostomus currani (Zahuranec, 1980)	1391	7.50	20.30	3.23	123.68	0.007	3.254	+A	0.00125	0.944
Haemulidae										
Conodon serrifer (Jordan and Gilbert, 1882)[1]	45	16.20	24.10	49.87	138.00	0.071	2.372	-A	0.00201	0.940
Orthopristis chalceus (Günther, 1864)	410	4.20	44.10	1.04	332.90	0.015	2.956	I	0.02068	0.974
Pomadasys panamensis (Steindachner, 1876)[1]	2987	4.00	38.00	0.80	888.68	0.015	3.011	+A	0.00596	0.988
Lutjanidae										
Lutjanus guttatus (Steindachner, 1869)	1359	1.80	36.30	0.10	607.75	0.018	2.895	-A	0.00541	0.995
Mullidae										
Pseudupeneus grandisquamis (Gill, 1863)	954	6.00	21.30	2.00	146.73	0.006	3.331	+A	0.01579	0.979

Table 1: Continued

Species	Sample size, n	Length (cm) Min.	Length (cm) Max.	Weight (g) Min.	Weight (g) Max.	a	b	Gt	S.E.(b)	R^2
Polynemidae										
Polydactylus approximans (Lay and Bennett, 1839)	655	5.20	35.60	1.31	389.71	0.010	2.959	I	0.00111	0.965
Polydactylus opercularis (Gill, 1863)[1]	163	12.60	29.60	18.17	224.26	0.010	2.934	I	0.03547	0.964
Priacanthidae										
Pristigenys serrula (Gilbert, 1891)	60	4.00	28.60	1.90	663.67	0.042	2.880	-A	0.00132	0.995
Sciaenidae										
Cynoscion phoxocephalus (Jordan and Gilbert, 1882)[1]	72	8.5	27.50	5.30	172.60	0.007	*3.008*	I	*0.00329*	*0.963*
Cynoscion reticulatus (Günther, 1864)	60	7.50	39.50	3.00	519.20	0.014	2.875	I	0.00621	0.967
Isopisthus remifer (Jordan and Gilbert, 1882)	1852	4.50	28.00	0.77	192.00	0.008	3.003	I	0.00094	0.965
Ophioscion imiceps (Jordan and Gilbert, 1882)[1]	45	13.70	23.50	33.00	187.90	0.009	3.059	I	0.00297	0.960
Paralonchurus goodei (Gilbert, 1898)[1]	199	9.60	24.00	5.10	134.18	0.001	3.586	+A	0.03664	0.979
Stellifer illecebrosus (Gilbert, 1898)[1]	1055	1.50	22.80	0.03	162.96	0.008	3.165	+A	0.01165	0.986
Umbrina roncador (Jordan and Gilbert, 1882)	137	5.00	42.00	1.35	751.00	0.010	2.981	I	0.00064	0.994
Scombridae										
Scomberomorus sierra (Jordan and Starks, 1895)	47	3.35	43.60	0.20	381.50	0.005	2.983	I	0.02433	0.994
Sphyraenidae										
Sphyraena ensis (Jordan and Gilbert, 1882)	76	12.50	42.80	8.90	358.20	0.007	2.845	-A	0.00185	0.985
Stromateidae										
Peprilus medius (Peters, 1869)[1]	626	3.50	29.60	1.00	267.00	0.008	3.089	+A	0.01251	0.882
Serranidae										
Diplectrum labarum (Rosenblatt and Johnson, 1974)	2397	1.00	27.50	0.01	261.40	0.013	2.959	-A	0.00049	0.974
Epinephelus acanthistius (Gilbert, 1892)[1]	51	6.50	15.20	4.20	54.10	0.011	3.040	I	0.00293	0.975
Paralabrax loro (Walford, 1936)[1]	31	9.80	22.00	11.10	130.42	0.009	3.119	I	0.00206	0.989
Rypticus nigripinnis (Gill, 1861)[1,2]	25	9.40	21.80	11.40	153.50	0.011	3.043	I	0.00527	0.967
Trichiuridae										
Trichiurus nitens (Garman, 1899)	209	14.70	75.00	2.04	238.00	0.001	2.908	-A	0.00106	0.988
Achiridae										
Achirus mazatlanus (Steindachner, 1869)	418	5.00	20.60	1.38	193.41	0.005	3.494	+A	0.03631	0.956
Achirus sp.	44	5.3	17.40	2.00	84.77	0.011	3.169	+A	0.00435	0.974
Trinectes fonsecensis (Günther, 1862)[1]	52	5.60	14.00	1.52	51.99	0.002	3.867	+A	0.01230	0.943
Bothidae										
Bothus leopardinus (Günther, 1862)[1,2]	976	4.60	23.50	1.23	113.60	0.027	2.607	-A	0.00128	0.941
Cynoglossidae										
Symphurus fasciolaris (Gilbert, 1892)[1]	38	13.00	24.50	17.76	112.77	0.010	2.906	I	0.00391	0.958
Paralichthyidae										
Ancylopsetta dendritica (Gilbert, 1890)[1,2]	28	7.00	36.40	4.30	944.50	0.007	3.253	+A	0.00274	0.994
Citharichthys platophrys (Gilbert, 1891)[1,2]	345	6.2	20.60	1.05	114.20	0.001	3.916	+A	0.00300	0.963
Syacium ovale (Günther, 1864)[1,2]	4153	3.30	30.40	0.28	858.19	0.008	3.067	+A	0.00095	0.937
Scorpaenidae										
Scorpaena russula (Jordan and Bollman, 1890)	36	5.50	10.50	2.50	17.20	0.035	2.594	I	0.01086	0.868
Ariidae										
Bagre panamensis (Gill, 1863)[1]	250	8.5	23.60	3.00	90.50	0.003	3.279	+A	0.00220	0.976
Balistidae										
Balistes polylepis (Steindachner, 1876)	79	5.20	42.80	3.20	1365.00	0.043	2.710	-A	0.07021	0.989
Tetraodontidae										
Sphoeroides annulatus (Jenyns, 1842)[2]	34	23.70	44.50	302.80	1815.80	0.239	2.311	-A	0.01837	0.781
Sphoeroides lobatus (Steindachner, 1870)	2307	2.00	19.70	0.36	144.30	0.070	2.486	-A	0.00108	0.933
Sphoeroides sechurae (Hildebrand, 1946)	41	6.80	16.30	5.96	72.10	0.022	2.923	I	0.00313	0.975
Narcinidae										
Narcine vermiculatus (Breder, 1928)[1]	17	16.50	34.30	69.30	280.09	0.475	1.801	-A	0.01068	0.865

Gt: Growth type: I: Isometric, -A: Negative allometric, +A: Positive allometric. [1]Species without LWR in Fishbase. [2]Species with length larger than that reported in Fishbase

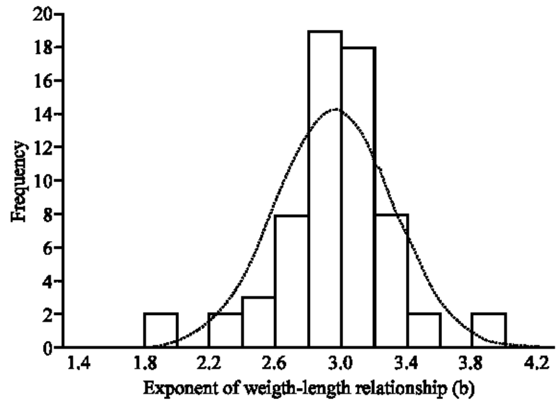

Fig. 2: Frequency distribution of parameter b of 64 demersal species, associated with the soft bottom of the continental shelf of the Eastern coast of the mouth of the Gulf of California. The line represents the trend of the data to a normal distribution

The t-test showed that 37.50% of species had isometric growth, 29.68% were positive allometric and 32.81% showed negative allometric growth.

DISCUSSION

A comparison of our results with information in the electronic database FishBase (www.fishbase.org, consulted in January 2010) shows that this study provided new records of total length for 10 species: *Synodus sechurae* (36.1 cm), *Opisthopterus dovii* (21.00 cm), *Urotrygon aspidura* (48.40 cm), *Urotrygon nana* (32.00 cm), *Rypticus nigripinnis* (21.80 cm), *Bothus leopardinus* (23.50 cm), *Ancylopsetta dendritica* (36.40 cm), *C. platophrys* (20.60 cm), *Syacium ovale* (30.40 cm), *Sphoeroides annulatus* (44.50 cm) with a minimum difference of 0.5 cm and a maximum of 10.6 cm.

The values of b for *B. leopardinus*, *C. platophrys*, *Lophiodes caulinaris*, *Peprilus medius*, *Porichthys analis*, *S. scituliceps* and *Sphoeroides lobatus* were different from those reported by Rodríguez-Romero *et al.* (2009) for the Western coast of the mouth of the Gulf of California. It is likely that this discrepancy is due to the influence of seasonal variability of the environment, food availability (Mommsen, 1998; Henderson, 2005), sampling size and the length interval within different areas (Morey *et al.*, 2003) or even habitat suitability. In contrast, the negative allometric growth type expressed by parameter b = 2.71 was similar to that reported by Soto *et al.* (2007) for *B. polylepis* collected from the artisanal fisheries off the coast of Mazatlan (within our study area), despite of the difference in sample size (443 specimens), fishing gear and habitat.

The trend in the frequency distribution of parameter b of this study coincides with the trend observed by Muto *et al.* (2000) in 57 marine fishes from Southeastern Brazil (Sample: Total = 14,344 ind., Average = 252 ind.), but differs from that observed by Morey *et al.* (2003) in 103 species from the west Mediterranean (Sample: Total = 13 719 ind., Average = 133 ind.).

CONCLUSIONS

An important contribution of this study is the new records of LWR for 38 fish species to those shown in FishBase. Also we reported, for 10 species, total lengths larger than those reported in FishBase. It is expected that if the b values follow a normal distribution then a large number of species have similar type of growth (Gt). We hope that the information provided in this study will be useful as a further reference for population dynamics studies, or even better, to assess the impact of perturbation in ecosystems.

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