Length-weight relationship of marine fishes from Palawan, Philippines

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ABSTRACT

The parameters of the length-weight relationships (LWR) of fishes are the primary variables applied to estimate the biomass of reef fishes in situ. Estimates of reef fish biomass using fish visual census survey in the Philippines still utilized the values of LWR parameters derived from the results of studies conducted abroad due to paucity of local information. This paper presents the first comprehensive records of the LWR of marine fishes from the West Philippine Sea and the Sulu Sea, western Philippines. Data were collected between 1998 and 2014 using various artisanal and commercial fishing gears. A total of 11,539 specimens covering 33 families, 59 genera and 87 species were investigated. The allometric coefficient b varied between 2.140 (*Gnathanodon speciosus*) and 3.410 (*Taeniura lymma*) with the mean of 2.840±0.25. The values of r^2 ranged from 0.521 to 0.996. This paper provides the first comprehensive information on the LWR of marine fishes from the western Philippines consisting of 15 new LWR values and 12 higher maximum lengths for online database.

Keywords: Sulu Sea, West Philippine Sea, reef fish, Honda Bay

INTRODUCTION

The parameters of the length-weight relationships (LWR) of fishes are of primary importance in fishery assessment and management (Garcia et al. 1998). It provides estimates of total fish biomass even when length is only known and weight is practically not available. For instance, to evaluate the fish biomass in a coral reef as requirement in the establishment of marine protected area, the fish visual census (FCV) is the popular method being used. This method requires the length and number of individual fish in situ while the total biomass is determined empirically by applying the established parameters of the LWR. Length and weight measurements in conjunction with age data can give information on the stock composition, age at maturity, life span, mortality, growth and production (King 1996; Diaz et al. 2000).

The LWR of fishes is useful in assessing the relative well-being of the fish population. It is important in estimating the standing stock biomass, and comparing the ontogeny of fish population from different regions (Petrakis and Stergiou 1995). Length-weight relationship parameters are often used as an indicator of fatness and general well-being or of gonad development of fish and are useful for between region comparisons of life histories of a specific species (Le Cren 1951; Wotton 1990).

Palawan is one of the major fish producing provinces in the Philippines. It supplies fresh and processed fish to Metro Manila and other neighboring provinces. At present, it is also the top exporter of live reef fish products to mainland China and Hong Kong (PSA 2016). Nevertheless, basic information on the biology and ecology of many commercially important marine fishes are poorly documented.

In the Philippines, estimates of coral reef fish biomass mainly utilize the results of studies conducted in New Caledonia (Kulbicki et al. 1993) due to paucity of locally available information. Only limited number of studies have been reported so far in the country (De la Peña 1998; Gonzales et al. 2000; Palla and Wolff 2007). The most comprehensive study was recently reported from the southern Philippines comprising 139 fish species (Gumanao et al. 2016). In this study, the standard length-total length, standard length-fork length relationships and 15 new records of maximum fish length and weight were reported. Further, it has been established that growth of fish is largely influenced by its environmental conditions. Thus, information derived from other geographical regions may give inaccurate estimate. Hence, it is essential to establish the LWR of fishes in the locality. The objective of this study was to provide information on the LWR parameters (a, b, r^2) of 87 marine fish species from Palawan, Philippines.

METHODS

The province of Palawan is located within the coordinates of 7.951°N-12.428 °N and 115.904°E-120.704 °E (Figure 1). The data were obtained from the results of series of fish stock assessment studies conducted from 1998 until 2014. These include the studies in Aborlan coastal waters, Arreceffi Island in Honda Bay, Puerto Princesa Bay, Ulugan Bay, Green Island Bay and Taytay Bay. Specimens were derived from landing sites, fish markets and actual fishing surveys caught using artisanal and commercial fishing gears such as;

the hook and line, gillnet, trammel net, fish corral, spear gun, otter trawl, ring net, fish pot and beach seine. To reduce bias in sizes, specimens were bought unsorted with prior agreement from fish vendors. Specimens were identified following Schroeder (1980), Carpenter and Niem (1999, 2001a,b), Gonzales (2013), and Motomura et al. (2017).

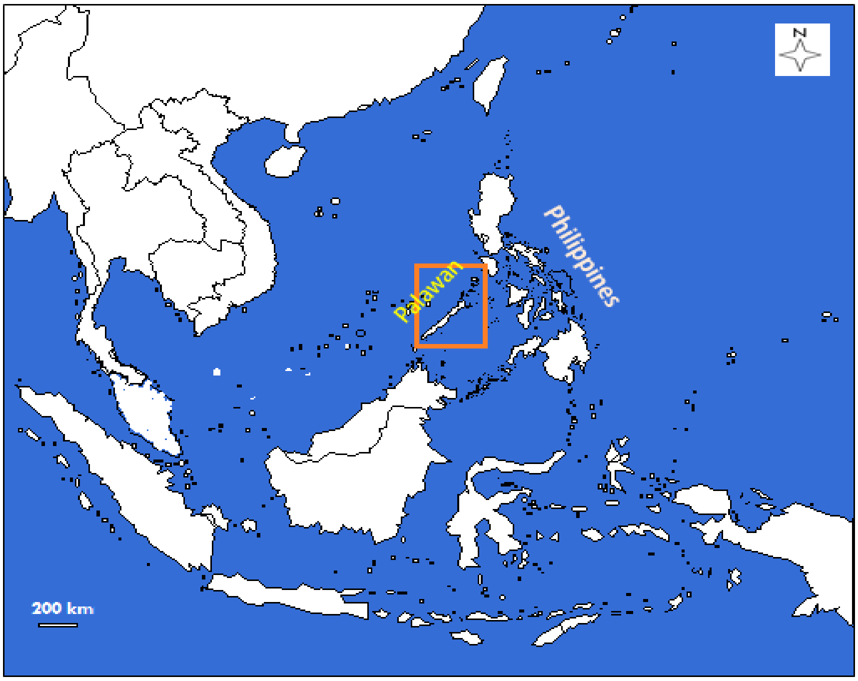

Figure. 1. Map of Southeast Asia, denoting the Philippines and the Island of Palawan (redrawn from www.google.com/search?q=outline+map+southeast +asia).

The total length (TL), fork length (FL) and standard length (SL) of individual fish were measured to the nearest 0.1 cm using measuring board and weighed to the nearest 0.5 g using top loading balance (500 g and 10 kg max). The length-weight relationship (LWR) of fishes was estimated using the equation:

$$W = a * L^b$$

where: W= weight (g), L= total length (cm), *a* = constant, *b*= growth exponent. A logarithmic transformation was used to make the relationship linear (Le Cren 1951):

$$\log W = \log a + b \log L$$

The LWR parameters *a* and *b* as well as the coefficient of determination (r^2) were derived from least squares regression (Ricker 1973). The slope (*b*) was used to describe the three dimensional growth of fish in length, width, and depth. If $b = 3$, growth is isometric, if $b < 3$, it is negative allometric and if $b > 3$, it is positive allometric (Froese 2006). The systematic arrangement of families followed Nelson (2006), while the species were arranged alphabetically in each family.

RESULTS

A total of 11,539 individuals belonging to 33 families, 59 genera and 87 species were examined (Table 1). The allometric coefficient (*b)* varied between 2.140 (*Gnathanodon speciosus*) and 3.410 (*Taeniura lymma*) with the mean of 2.840±0.250. Four species showed isometric growth, 55 species with negative allometric and 28 species with positive allometric growth. The coefficient of determination (r^2) ranged from 0.521 (*Paramonacanthus japonicus*) to 0.996 (*Lutjanus argentimaculatus*). In addition, studies reported 11 species earlier from the province were also cited (De la Peña 1998; Gonzales et al. 2000; Palla and Wolff 2007) (Table 1).

DISCUSSION

The record of 87 species (3 cartilaginous, 84 bony) reported in this study represents the first comprehensive information on the LWR of marine fishes from the western Philippines. Among these species, 82 comprised the first record in the area in addition to the four (*Cephalopholis argus, C. boenak, C. miniata* and *C. sonnerati*) presented earlier by Gonzales et al. (2000) and one (*Pentaprion longimanus*) Palla and Wollf (2007), respectively (Table 1). In a recent study, 139 species were reported from the southern Philippines (Gumanao et al. 2016). In this paper, only 26 species recorded in the present study were listed, making an overall number of 200 species reported for the LWR parameters in the Philippines.

Table 1. Parameters of the length-weight relationships of 87 marine fishes in Palawan, Philippines. 11 species cited from published literatures and 7 species recorded both in Puerto Princesa Bay and Honda Bay.

Family	Species	n	LWR			Length			Source
			a	b	r^2	min.	max.	type	
Carcharhinidae	*Carcharhinus melanopterus* (Quoy and Gaimard 1824)	55	0.015	2.750	0.832	44.3	60.3	TL	This study
Dasyatidae	*Neotrygon orientalis* (Last, White and Séret 2016)	44	0.022	3.100	0.930	17.0	34.0	DW	This study
	Taeniura lymma (Forrskål 1775)	54	0.023	3.410	0.965	14.5	31.5	DW	This study [fr]
Plotosidae	*Plotosus lineatus* (Thunberg 1787)	62	0.024	2.680	0.781	16.5	25.0	TL	This study
Synodontidae	*Saurida longimanus* Norman 1839	37	0.004	3.110	0.927	12.7	25.5	TL	This study [fr]
Mugilidae	*Crenimugil buchanani* (Bleeker 1853)	86	0.011	3.010	0.977	19.2	53.5	TL	This study
	Moolgarda seheli (Forrskål 1775)	31	0.025	2.760	0.988	14.8	46.7	TL	This study
Hemiramphidae	*Hemiramphus far* (Forrskål 1775)	177	0.018	2.690	0.917	21.2	35.6	TL	This study
	Hyporhamphus neglectus (Bleeker 1866)	41	0.007	2.860	0.824	26.7	38.7	TL	This study [fr]
Belonidae	*Tylosorus punctulatus* (Günther 1872)	15	0.002	2.900	0.867	44.0	59.5	TL [hm]	This study [fr]
Platycephalidae	*Cymbacephalus nematophthalmus* (Günther 1860)	35	0.021	2.780	0.944	9.2	42.0	TL	This study [fr]
Ambassidae	*Ambassis gymnocephalus* (Lacepède 1802)	303	0.130	2.200	0.563	4.5	11.0	TL	This study
Serranidae	*Anyperodon leucogrammicus* (Valenciennes 1828)	67	0.040	2.650	0.956	14.2	42.5	TL	This study
	Cephalopholis argus Schneider 1801	51	0.013	3.060	0.958	7.1	27.0	TL	This study
	Cephalopholis boenak (Bloch 1790)	30	0.027	2.840	0.969	11.0	22.5	TL	This study
	Cephalopholis cyanostigma (Valenciennes 1828)	184	0.019	2.960	0.938	14.0	55.0	TL [hm]	This study
	Cephalopholis miniata (Forsskål 1775)	110	0.028	2.850	0.933	17.0	35.0	TL	This study
	Cephalopholis sonnerati (Valenciennes 1828)	72	0.012	3.120	0.966	9.8	44.0	TL	This study
	Epinephelus fasciatus (Forsskål 1775)	182	0.027	2.840	0.887	5.8	32.0	TL	This study
	Epinephelus merra Bloch 1793	61	0.008	3.240	0.954	13.5	28.0	TL	This study

Family	Species	n	LWR			Length			Source
			a	b	r²	min.	max.	type	
	Epinephelus quoyanus (Valenciennes 1830)	15	0.014	3.040	0.977	4.5	31.5	TL	This study[fr]
	Variola louti (Forrskål 1775)	48	0.011	3.000	0.972	15.0	34.0	SL	This study
Priacanthidae	*Priacanthus macracanthus* Cuvier 1829	143	0.035	2.470	0.936	10.1	13.5	TL	This study
Apogonidae	*Apogonichthyoides melas* Bleeker 1848	168	0.020	3.000	0.620	7.8	12.1	TL[hm]	This study[fr]
	Cheilodipterus singapurensis Bleeker 1860	52	0.128	2.230	0.872	6.0	16.9	TL	This study
Centrogenyidae	*Centrogenys vaigiensis* (Quoy and Gaimard 1824)	143	0.034	2.910	0.890	6.0	17.9	TL	This study[fr]
Carangidae	*Atule mate* (Cuvier 1833)	560	0.009	3.066	0.988	11.4	29.9	TL	This study
	Carangoides ferdau (Forsskål 1775)	65	0.013	3.010	0.993	12.4	31.7	TL	This study
	Carangoides fulvoguttatus (Forsskål 1775)	68	0.012	2.820	0.990	9.0	71.0	SL	This study
	Caranx ignobilis (Forsskål 1775)	44	0.024	2.800	0.879	18.4	62.0	TL	This study
	Decapterus kurroides Bleeker 1855	24	0.056	2.350	0.903	13.9	21.4	TL	This study
	Decapterus macrosoma Bleeker 1851	132	0.010	2.950	0.772	14.4	22.2	TL	This study
	Decapterus russelli (Rüppell 1830)	52	0.008	3.070	0.960	13.1	23.2	TL	This study
	Gnathanodon speciosus (Forsskål 1775)	10	0.359	2.140	0.810	35.4	55.0	TL	This study
	Scomberoides tol (Cuvier 1832)	21	0.010	2.860	0.947	28.4	39.1	TL	This study
	Selaroides leptolepis (Cuvier 1833)	35	0.014	2.920	0.703	15.0	17.7	TL	This study
	Uraspis secunda (Poey 1860)	26	0.082	2.410	0.812	16.8	19.0	TL	This study
Leiognathidae	*Equulites oblongus* (Valenciennes 1835)	69	0.009	3.170	0.753	9.2	14.6	TL	This study[fr]
Lutjanidae	*Aphareus rutilans* Cuvier 1830	101	0.017	2.590	0.948	28.0	78.0	FL	This study
	Lutjanus argentimaculatus (Forsskål 1775)	13	0.029	2.810	0.996	16.5	42.6	TL	This study
	Lutjanus decussatus (Cuvier 1828)	12	0.014	3.040	0.948	13.7	20.6	TL	This study
	Lutjanus ehrenbergii (Peters 1869)	153	0.047	2.640	0.916	10.7	25.0	TL	This study
	Lutjanus fulviflamma (Forsskål 1775)	67	0.062	2.560	0.868	10.7	18.5	TL	This study

Family	Species	n	LWR			Length			Source
			a	b	r^2	min.	max.	type	
	Lutjanus vitta (Quoy and Gaimard 1824)	716	0.030	3.040	0.938	11.3	28.0	TL	This study
Caesionidae	*Caesio lunaris* Cuvier 1830	54	0.018	2.410	0.533	12.5	17.0	FL	This study
Gerreidae	*Gerres abbreviatus* Bleeker 1850	16	0.011	3.180	0.995	10.2	25.6	TL	This study
	Gerres abbreviatus Bleeker 1850	57	0.015	2.730	0.910	9.0	21.5	FL	This study
	**Gerres oyena* (Forsskål 1775)	169	0.016	2.990	0.950	7.0	16.7	TL	This study
	***Gerres oyena* (Forsskål 1775	257	0.017	2.960	0.958	7.0	23.0	TL	This study
	Pentaprion longimanus (Cantor 1849)	300	0.032	2.670	0.828	9.1	15.6	TL [hm]	This study
Haemulidae	*Plectorhinchus pictus* (Tortonese 1936)	45	0.012	2.830	0.985	10.0	41.5	SL	This study
Nemipteridae	*Nemipterus aurora* Russell 1993	26	0.030	2.710	0.896	13.8	27.8	TL [hm]	This study [fr]
	Nemipterus bathybius Snyder 1911	102	0.029	2.650	0.906	9.7	32.0	TL [hm]	This study
	Nemipterus furcosus (Valenciennes 1830)	310	0.016	2.890	0.963	12.0	25.2	TL [hm]	This study
	Nemipterus hexodon (Quoy and Gaimard 1824)	200	0.015	2.940	0.907	12.0	23.5	TL [hm]	This study
	Nemipterus peronii (Valenciennes 1830)	192	0.013	2.770	0.994	8.0	48.5	FL [hm]	This study
	**Pentapodus caninus* (Cuvier 1830)	173	0.051	2.640	0.900	7.2	27.2	TL	This study
	***Pentapodus caninus* (Cuvier 1830)	109	0.021	2.910	0.860	7.2	15.3	TL	This study
	Pentapodus emeryii (Richardson 1843)	81	0.015	3.010	0.786	7.0	15.6	TL	This study [fr]
	Scolopsis ciliatus (Lacepède 1802)	381	0.009	3.300	0.797	6.2	16.5	TL	This study
Lethrinidae	*Lethrinus chrysostomus* Richardson 1848	68	0.010	3.010	0.978	9.5	25.5	SL	This study
	Lethrinus genivittatus Valenciennes 1830	133	0.014	3.020	0.952	11.0	22.7	TL	This study
	Lethrinus harak (Forsskål 1775)	273	0.015	3.000	0.976	11.6	36.5	TL	This study
	**Lethrinus lentjan* (Lacepède 1802)	200	0.067	2.510	0.904	7.0	18.8	TL	This study
	***Lethrinus lentjan* (Lacepède 1802)	423	0.012	2.840	0.812	7.0	38.5	SL	This study
	Lethrinus miniatus (Forster 1801)	82	0.010	2.900	0.982	14.0	73.5	SL	This study

Family	Species	n	LWR			Length			Source
			a	b	r^2	min.	max.	type	
	Monotaxis grandoculis (Forsskål 1775)	69	0.013	2.800	0.986	14.0	57.0	FL	This study
Sciaenidae	*Otolithes ruber* (Bloch and Schneider 1801)	39	0.015	2.730	0.910	10.0	20.0	FL	This study
Mullidae	*Mulloidichthys vanicolensis* (Valenciennes 1831)	14	0.058	2.510	0.565	25.3	31.0	TL	This study
	Parupeneus indicus (Shaw 1803)	34	0.011	3.070	0.995	15.7	38.7	TL	This study
	Parupeneus macronema (Lacepède 1801)	33	0.010	3.110	0.885	14.3	21.3	TL	This study
	Upeneus tragula Richardson 1846	17	0.019	2.810	0.985	16.0	26.3	TL [hm]	This study
	Upeneus vittatus (Forsskål, 1775)	50	0.016	2.900	0.956	8.0	16.0	TL	This study
Ariommatidae	*Ariomma indicum* (Day, 1871)	33	0.042	2.660	0.808	16.2	20.2	TL	This study
Labridae	*Choerodon anchorago* (Bloch, 1791)	98	0.024	3.000	0.988	10.5	27.0	TL	This study
Gobiidae	*Amblygobius phalaena* (Valenciennes 1837)	68	0.022	2.900	0.526	7.0	11.2	TL	This study
Siganidae	**Siganus canaliculatus* (Park 1797)	290	0.022	2.950	0.978	6.7	33.6	TL [hm]	This study
	***Siganus canaliculatus* (Park 1797)	275	0.015	2.650	0.964	6.0	24.0	SL	This study
	Siganus fuscescens (Houttuyn 1782)	192	0.037	2.510	0.907	6.7	22.5	TL	This study
	**Siganus guttatus* (Bloch 1787)	32	0.022	3.050	0.985	7.8	26.2	TL	This study
	***Siganus guttatus* (Bloch 1787)	488	0.025	2.950	0.938	7.8	39.0	TL	This study
Sphyraenidae	**Sphyraena barracuda* (Edwards 1771)	74	0.006	3.030	0.956	10.0	50.5	TL	This study
	***Sphyraena barracuda* (Edwards 1771)	179	0.063	2.570	0.973	10.0	54.2	TL	This study
	Sphyraena obtusata Cuvier 1829	182	0.010	2.570	0.969	13.0	28.5	FL	This study
Emmelichthyidae	*Emmelichthys struhsakeri* Heemstra and Randall 1977	35	0.012	2.950	0.939	14.0	20.0	TL	This study [fr]
	Erythrocles schlegelii (Richardson 1846)	26	0.006	3.280	0.915	14.5	18.0	TL	This study [fr]
Scombridae	**Rastrelliger kanagurta* (Cuvier 1816)	114	0.005	3.270	0.940	20.7	31.5	TL	This study
	***Rastrelliger kanagurta* (Cuvier 1816)	43	0.021	2.160	0.888	10.0	16.0	FL	This study
Balistidae	*Rhinecanthus verrucosus* (Linnaeus 1758)	18	0.012	3.080	0.986	11.5	21.0	TL	This study [fr]

Family	Species	n	LWR			Length			Source
			a	b	r^2	min.	max.	type	
Monacanthidae	*Monacanthus chinensis* (Osbeck 1765)	400	0.027	2.920	0.778	6.6	16.6	TL	This study
	Pseodomonacanthus macrurus (Bleeker 1856)	111	0.012	2.830	0.968	8.5	25.5	SL [hm]	This study [fr]
	Paramonacanthus japonicus (Tilesius 1809)	158	0.032	2.840	0.521	6.1	12.3	TL	This study
Tetraodontidae	*Arothron immaculatus* (Bloch and Schneider 1801)	39	0.085	2.550	0.913	6.2	19.9	TL	This study
	Chelonodon patoca (Hamilton 1822)	200	0.019	3.180	0.842	6.0	19.7	TL	This study
Clupeidae	*Amblygaster sirm* (Walbaum 1792)	450	0.005	3.200	-	11.0	24.0	TL	De la Peña 1998
	Sardinella gibbosa (Bleeker 1849)	50	0.009	3.030	-	10.0	13.5	TL	De la Peña 1998
	Sardinella longiceps Valenciennes 1847	200	0.024	2.640	-	7.6	10.0	TL	De la Peña 1998
Serranidae	*Cephalopholis argus* Schneider, 1801	504	0.012	3.100	-	12.7	36.0	TL	Gonzales et al. 2000
	Cephalopholis boenak (Bloch, 1790)	456	0.011	3.100	-	9.6	26.0	TL	Gonzales et al. 2000
	Cephalopholis microprion (Bleeker, 1852)	213	0.011	3.160	-	10.2	19.5	TL	Gonzales et al. 2000
	Cephalopholis miniata (Forsskål, 1775)	275	0.017	2.990	-	13.9	39.0	TL	Gonzales et al. 2000
	Cephalopholis sonnerati (Valenciennes, 1828)	305	0.012	3.100	-	14.0	51.0	TL	Gonzales et al. 2000
Leiognathidae	*Photopectoralis bindus* (Valenciennes 1835)	943	0.032	2.740	-	7.5	9.1	TL	Palla and Wolff 2007
	Equulites elongatus (Günther, 1874)	1000	0.015	3.420	-	8.0	17.0	TL	Palla and Wolff 2007
Gerreidae	*Pentaprion longimanus* (Cantor, 1849)	956	0.021	3.160	-	10.0	16.5	TL	Palla and Wolff 2007

n = sample size; TL- total length; FL – fork length; SL – standard length; DW- disc width ; a, b – regression coefficients; r^2 – coefficient of determination, *Puerto Princesa Bay, **Honda Bay , fr- first record, hm – higher maximum length

Temporally, the slopes (*b*) varied slightly for a span of 14 years among four groupers (*Cephalopholis* spp.). However, *P. longimanus* has considerably decreased in slope over the past decade which can be attributed to difference in sample size. In the context of growth type with reference to slope, 63% exhibited negative allometry, 32 % positive allometry and only 5% displayed isometric growth. This suggests that majority of fishes in Palawan exhibited low well-being.

Carlander (1969) pointed out that the coefficient *b* in the LWR of fishes usually ranged from 2.5 to 3.5. In this study only 8% of all species evaluated had the values beyond this range. The lowest value of *b* for *Gnathanodon speciosus* was due to low sample size and narrow size range which was only represented by medium size individuals. Whereas the highest *b* in *Taeniura lymma* remains unclear since the other species *N. orientalis* displayed *b* value close to 3.0 despite both species had relatively sufficient sample size and were measured in disc width. These species of ray have been landed without tail as common practice due to the danger posed by their venomous tail spine.

In terms of the coefficient of determination (r^2), majority (67%) of the total species examined attained the values of over 0.90. This indicates highly significant relationships of length to weight of fishes under study.

The LWR parameters of 87 species recorded in this study supplements the recently reported 139 species from southern Philippines making up a total of 200 species all over Philippines. Accordingly, this paper provides the first LWR values for 15 species and higher maximum length for 12 species (Table 1) to the online database of FishBase (Froese and Pauly 2017). Further studies of similar nature and involving some biological aspects of commercially important species are necessary to support the formulation of policies for sustainable utilization and appropriate management of fisheries resources in the country.

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