Length-Weight and Length-Length Relationships and Fulton Condition Factor of Philippine Mullets (Family Mugilidae: Teleostei)

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The present study describes the length-weight (*LW*), length-length (*LL*) relationships and Fulton condition factor (*K*) for 10 mullets collected from 14 sampling sites in the Philippines. Comparisons of *LW, LL,* and *K* are confined to five mullet species with sample size between 11 and 438. The other five mullet species are excluded in the comparison due to the limited sample size (n = 3 - 6). Among these mullets *Liza* sp. from Ilocos Sur is the longest at 21 cm and the heaviest at 89 g. It is followed by the bluespot mullet *Crenimugil seheli* with a mean total length of 18 cm and a mean weight of 72 g. The greenback mullet *Chelon subviridis* (Negros Oriental) ranked third in mean total length at 17 cm and a mean weight of 62 g. The shortest (12 cm) and lightest (19 g) is the dwarf mullet *Osteomugil engeli*. The relationships between total length (*TL*) and weight (*W*) for the 10 mullets show high coefficients of determination (r^2 = 0.88 - 0.98). All mullet species show negative allometric growth as indicated by the regression coefficient b < 3. The relationships among *TL, FL,* and *SL* for Philippine mullets are all linear (r^2 > 0.96). The average Fulton condition factor is highest for the longfinned mullet *Osteomugil perusii* (2.12) and lowest for the dwarf mullet *Osteomugil engeli* (1.71). The results of this study are important for the management and conservation of mullet species in the Philippines.

KEYWORDS: Philippine mullets, length-weight and length-length relationships, Fulton Condition Factor (*K*)

INTRODUCTION

The establishments of length-weight and length-length relationships are important tools in fisheries biology because they provide information on the external morphology, growth pattern and general condition of the fish that can be used in population structures analysis (Le Cren, 1951; Strauss & Bond, 1990). Most noted studies on length-weight and length-length relationships among the Philippine fishes include milkfish, grouper, silver perch and wetland fishes (Grover & Juliano, 1976; Gonzales et al., 2000; Quilang et al., 2007; Garcia 2010). There are no extensive data, to the best of one's knowledge, on length-weight and length-length relationships on any of the Philippine mullet species.

Previous studies on the length-weight relationships of mullets were often based from singular collection of fish species from commercial and artisanal fisheries. Of the 80 mullet species, 12 species have been studied for length-weight relationships which included *Chelon labrosus, Liza aurata, Liza ramado, Liza saliens, Liza falcipinnis, Liza grandisquamis, Liza carinata, Liza subviridis, Liza melinoptera, Liza parsia, Mugil cephalus,* and *Valamugil cunnesius* (Borges et al., 2003, Ecoutin et al., 2005; Verdiell-Cubedo et al., 2005; Andrea-Soler et al., 2006; Garcia, 2010; Hussain et al., 2010). The sample sizes of these studies ranged from less than 10 to more than 1,000 individuals.

In the Philippines, there are 20 recorded mullet species (Froese & Pauly, 2011) but only one study on length-weight relationships was conducted on the greenback mullet *Chelon subviridis* collected from Candaba wetland on the island of Luzon. However, the linear regression parameters of this study were derived from three individuals (Garcia, 2010).

This study aims to determine the length-weight and length-length relationships and condition factor for 10 mullet species in the Philippines. These species are economically important food fish all over the country and are caught throughout the year regardless of their sizes. This paper reports for the first time the occurrence of the longfinned mullet *Osteomugil perusii* and the dwarf mullet *Osteomugil engeli* in Philippine waters.

MATERIALS AND METHODS

The collection sites and their geographic coordinates are the following:

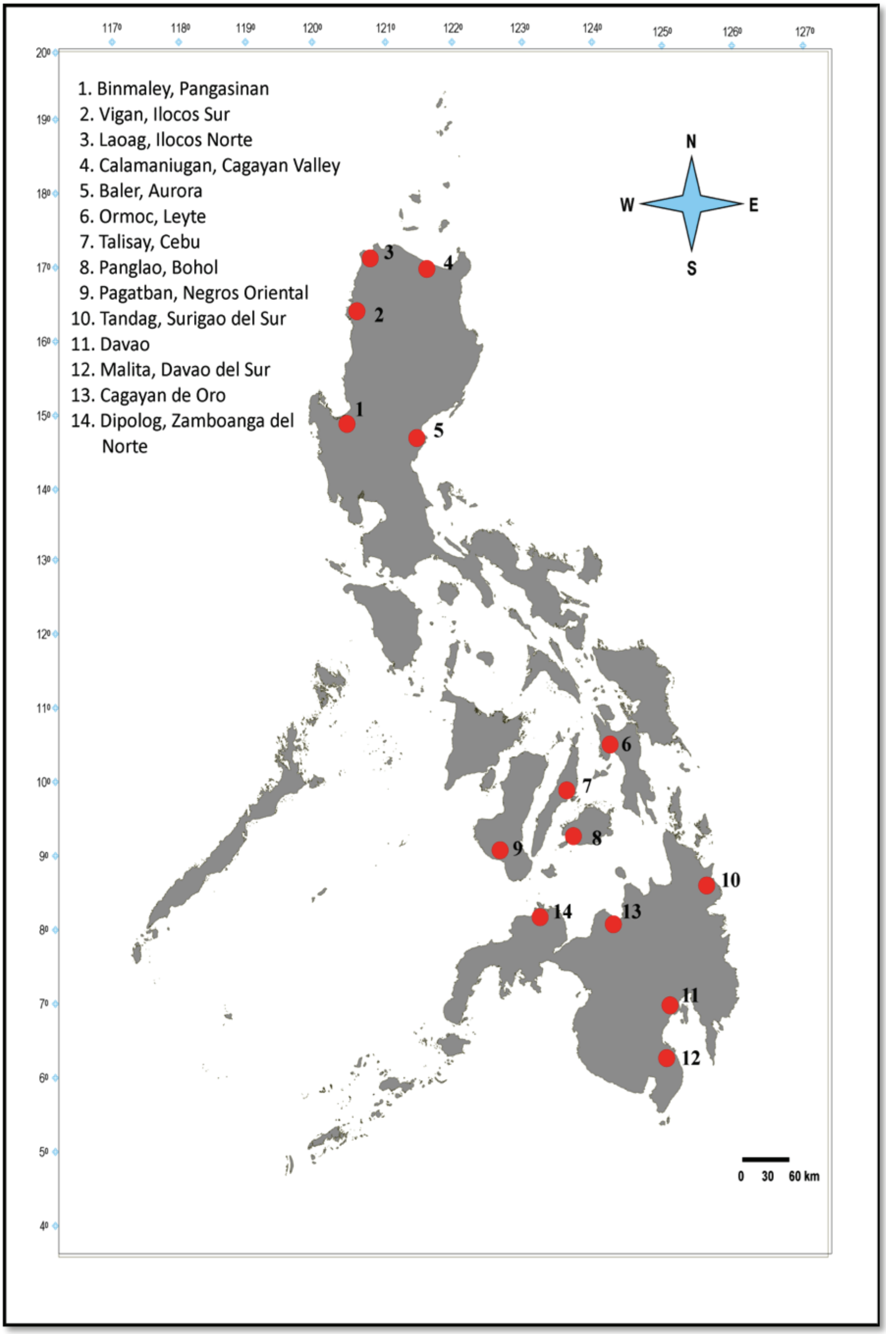

Figure 1. Collection sites of mullets in the Philippines are shown in the dots.

Baler in Aurora (15°44′51″N, 121°34′41″), Binmaley in Pangasinan (16°03′55″N, 120°19′42″), Vigan in Ilocos Sur (17°33′38″N, 120°29′54″), Laoag in Ilocos Norte (18°27′11″N, 120°47′45″), Camalaniugan in Cagayan Valley (18°17′38″N, 121°40′59″), Pagatban River in Negros Oriental (9°21′52″ N, 122°48′3″ E), Talisay in Cebu (10°15′38″N, 123°56′26″), Panglao in Bohol (9°36′46″N, 123°51′01″), Ormoc City in Leyte (10°58′54″ N,124°34′51″E), Cagayan de Oro City in Misamis Oriental (8°29′15″N, 124°41′46″E), Davao City in Davao del Norte (7°03′47″N, 125°37′57″E), Malita in Davao del Sur (6°24′58″N, 125°35′48″E), Dipolog City in Zamboanga del Norte (8°33′24″N, 123°20′52″E), and Tandag in Surigao del Sur (9°07′15″N, 126°11′43″E).

Monthly sampling was done in Pagatban River in Negros Oriental from January 2011 to December 2011. Mullet samplings outside Negros Oriental were conducted on the following months: December 2011 (Cagayan Valley), February 2012 (Baler in Aurora), May 2012 (Ilocos Sur, Ilocos Norte, Leyte, Davao, Cagayan de Oro and Zamboanga) and June to August 2012 (Bohol, Pangasinan and Surigao).

Monthly fish samples were collected in Pagatban River on Negros Island, Central Philippines using a non-selective seine net (mesh size = 1 cm^2). The salinity of the river where the fish were collected ranged from 0–0.2 ppt. The river depth was between 1.5 and 2.5 m and a width between 110 and 120 m. The monthly sample size consisted of more than 30 fishes per species which were sorted, labeled and examined in the laboratory. Other mullet species outside Negros Island were collected by small-scale fishermen within three to five days during the author's site visit to the designated sampling sites.

At least twenty (20) fish specimens per mullet species were used for taxonomic identification based on the following diagnostic features: shape of teeth and tails, pattern of the hind margin of scales, shape of premaxilla, position of the maxilla when the mouth is closed, color of the pectoral fin, length of the pectoral fin in relation to the origin of the first dorsal fin and standard morphometric and meristic counts (Strauss & Bond, 1990). These data were compared to the mullet taxonomic guides by Thompson (1997), Harrison and Senou (1999) and Durand et al., (2012). Fish were measured for total length (*TL*), fork length (*FL*), standard length (*SL*), body depth (*BD*), body depth/ standard length percentage ratio (*BDSLR*), head length (*HL*) and eye diameter (*ED*) to the nearest 0.01 mm (Quilang et al., 2007). Each fish specimen was photographed before proceeding to standard fish measurements and meristic counts using ImageJ software program which enlarges the image to a desired size and converts standard length measurements into their equivalent pixels. Furthermore, the use of ImageJ software enables the fish specimens to be preserved longer because of the shorter exposure time of the latter to ambient temperature, thus giving more time to examine the specimens closely without the irritating smell of the fixative solution. Each specimen was weighed to the nearest 0.01 gram using a digital weighing scale and later fixed in 10% formalin solution and stored in 70% ethanol solution for long-term preservation.

The length-weight relationship was determined using the regression equation $W = a{\times}L^b$ where L is the total length in cm, W is the weight in g, a is the regression intercept, and b is the regression coefficient or slope. The b value was used to determine the type of somatic growth of a fish either isometric or allometric (Zhu et al., 2008). Isometric growth as indicated by $b = 3$ means that the fish has an "unchanging body shape" regardless of its size while allometric type (b is < 3 or > 3) indicates that the fish has a "changing body shape" in relation to its size. Length-length relationships of *SL* against *TL*, *SL* against *FL*, and *FL* against *TL* were determined using linear regression equation $SL = a + b{\times}TL$. The Fulton's condition factor (K) indicates a measure of the well-being of a fish or determined using the equation $K = (W/SL^3) \times 100$ where L is the standard length in cm and W is the weight in g. A I value of > 1 indicates good condition while $K < 1$ indicates poor condition (Hall & Van Avylle, 1986); in general the higher the K value, the better is the physical condition of the fish (Froese, 2006).

Statistics such as mean, minimum and maximum were used to describe lengths and weights of the specimens. Statistical differences of the lengths, weights and condition factors (K) of the mullet species were tested using Kruskal-Wallis as the data did not conform to the normality test.

RESULTS

Ten mullet species with a total of 753 individuals were collected from 14 sampling sites all over the Philippines. Total length and body weight of the fish are shown in Table 1.

Of the total 438 greenback mullet *Chelon subviridis* fish samples measured in this study, 344 or 78% were within the mean total length (*TL*) range between 9 cm and 19 cm, 90 or 21% were between 20 and 29 cm and four or 1% between 30 and 36 cm. The mean total length was 17 cm (SD + 4). Whereas 374 or 85% of *C. subviridis* samples weighed between 6 g and 99 g, 52 or 12% between 100 g and 199 g and 12 or 3% between 200 g and 392 g. The mean weight was 62 g (SD + 51.1). Meanwhile, of the190 longfinned mullet *Osteomugil perusii* samples, 121 or 64% had total lengths (*TL*) between 9 cm and 14 cm, 66 or 34.7% between 14 cm and 20 cm and 3 or 1.6% between 21 cm and 23 cm. The mean length of *O. perusii* was 15 cm (SD + 2.7). In terms of weight, 123 or 64.7% weighed between 11 g and 39 g, 53 or 27.9% between 40 g and 79 g and 14 or 7.3% between 80 g and 130 g. The mean weight of *Osteomugil perusii* was 40 g (SD + 23). Of the eleven *Liza* sp. samples, two or 18.2% had total lengths (*TL*) between 18 cm and 19 cm, 8 or 72.7% between 20 cm and 22 cm, and one or 9% at 23 cm. The mean length of *Liza* sp. was 21 cm (SD+1.58). In terms of weight, two or 18.2% had weights between 63 g and 79 g, 7 or 63.6% between 80 g and 99 g, and two or 18.2% between 100 g and 122 g. Of the 59 bluespot mullet *Crenimugil seheli*, 11 or 18.6% had total lengths (*TL*) between 12 cm and 16 cm, 47 or 80 % between 17 cm, and 21 cm and one (1.7%) at 24 cm. Its mean length was 18 cm (SD+2.2). In terms of weight, two or 3.4% had weights between 19 g and 24 g, 16 or 27.1% between 25 g and 64 g, and 41 or 69.5% between 65g and 102 g. The mean weight of *C. seheli* was 72 g (SD+20.91). Of the 59 dwarf mullet *Osteomugil engeli*, 15 or 42.8% had total lengths (*TL*) between nine cm and 11 cm, 16 or 45.7% between 12 cm and 13 cm, and four or 11.4% between 14 cm and 15 cm. The mean length of *O. engeli* was 12.10 cm (SD +1.71). In terms of weight, two or 8.3% had weights between 7 g and 8 g, 9 or 37.5% between 8 g and 15 g, and 13 or 54.2% between 16 g and 29 g. The mean weight of *O. engeli* was 19 g (SD+6.9).

The regression parameters and the coefficient of determination for the length-weight relationships (LWR) of the 10 Philippine mullets are shown in Table 1. The sample sizes ranged from three to 498. The regression coefficient (*b*) ranged from 1.74 - 2.9. Nine out 10 of the *b* values were below 3; only the squaretail mullet *Ellochelon vaigiensis* had a slope value (*b*) of above 3. The regression intercept (*a*) ranged from 0.004 - 0.407 while the coefficient of determination (r^2) ranged from 0.88 - 1.0.

The regression parameters and coefficients of determination of the length-length relationships (*TL, SL,* and *FL*) of the 10 mullets are estimated in Table 2. The coefficient of determinations (r^2) for all the length-length relationships for the 10 species ranged from 0.80 to 1. The range of r^2 for *FL* vs. *TL* was 0.92 to1.00; the range of r^2 for *FL* vs.

Table 1.

Total Length (*TL*), Body Weight (*W*), and Length-Weight Relationship ($W=aTL^b$) for Ten Philippine Mullets.

	TL (cm)			W (g)			W=aTLb		
Species	**n**	**Range**	**Mean ± SD**	**n**	**Range**	**Mean ± SD**	**a**	**b**	**r^2**
Chelon macrolepis	3	19.3 - 20.3	15.7 (1.5)	3	40.6 - 61.7	53.7 (11.4)	0.081	2.36	1.00
Ellochelon vaigiensis	3	16.0 - 21.4	19.1 (2.8)	3	50.0 - 130.2	96.1(41.4)	0.004	3.36	0.99
Chelon subviridis	438	9.1 - 35.5	16.6 (3.3)	438	12.6 - 115.9	50.1 (26.0)	0.014	2.90	0.95
Liza sp.	11	17.8 - 23.8	20.6 (1.5)	11	63.2 - 122.0	86.7 (16.0)	0.055	2.43	0.94
Osteomugil engeli	35	9.0 - 14.2	13.2 (1.2)	35	14.6 - 32.0	24.3 (4.6)	0.013	2.88	0.98
Osteomugil perusii	190	9.2 - 23.1	18.1 (1.3)	190	57.7 - 97.5	75.0 (10.7)	0.014	2.92	0.97
Crenimugil seheli	59	12.0 - 23.5	18.0 (2.8)	59	19.2 - 128.3	68.4 (27.5)	0.021	2.79	0.88
Mugil cephalus	3	18.0 - 24.5	21.5 (3.3)	3	59.7 – 99.2	84.9 (21.9)	0.407	1.74	0.92
Plicomugil labiosus	5	14.4 - 15.6	15.1 (0.5)	5	34.3 – 43.5	39.6 (3.5)	0.028	2.67	0.93
Valamugil sp.	6	19.1 - 20.5	20.0 (1.1)	6	19.2 – 128.3	68.4 (27.5)	0.054	2.43	0.89

n is sample size, *SD* is standard deviation, and r^2 is coefficient of determination, *a* is the regression intercept, *b* is the regression coefficient, and r^2 is the coefficient of determination.

Table 2.

Length-length relationships involving total length (TL), standard length (SL) and fork length (FL) for 10 Philippine mullets.

Species	n	SL = a + bTL	r^2	FL = a + bTL	r^2	FL = a + bSL	r^2
Chelon macrolepis	3	SL= -0.91 + 0.89TL	0.99	FL= -0.48 + 0.94TL	0.99	FL= 1.02 + 1.05SL	0.99
Chelon subviridis	438	SL= -0.09 + 0.83TL	0.99	FL= 0.08 + 0.93TL	0.99	FL= 0.32 + 1.11SL	0.99
Crenimugil seheli	59	SL= -0.07 + 0.84TL	0.96	FL= 0.16 + 0.93TL	0.98	FL= 0.42 + 1.09SL	0.99
Ellochelon vaigiensis	3	SL= 0.57 + 0.80TL	1.00	N.A.		N.A.	
Liza sp. (Ilocos Sur)	11	SL= -0.08 + 0.81TL	0.98	FL= 0.02 + 0.93TL	0.96	FL= 0.22 + 1.13SL	0.98
Mugil cephalus	3	SL= 2.47 + 0.725TL	1.00	FL= 3.02 + 0.80TL	1.00	FL= 0.33 + 1.10SL	1.00
Osteomugil engeli	35	SL= -0.19 + 0.85TL	0.98	FL= -0.23 + 0.97TL	1.00	FL= 0.14 + 1.12SL	0.99
Osteomugil perusii	190	SL= -0.42 + 0.85TL	0.99	FL= -0.18 + 0.95TL	0.99	FL= -0.21 + 0.90SL	0.99
Plicomugil labiosus	5	SL= -1.81 + 0.96TL	0.80	FL= -1.45 + 1.05TL	0.92	FL= 1.78 + 1.00SL	0.96
Valamugil sp. (Ilocos Norte)	6	SL= -3.28 + 0.96TL	0.96	FL= -1.44 + 1.05TL	0.92	FL= 1.78 + 1.00SL	0.96

n is the sample size; *SL* is the standard length in cm; *FL* is fork length in cm; *TL* is total length in cm; *a* is the regression intercept; *b* is the regression coefficient; and r^2 is the coefficient of determination; *N.A.* for not applicable.

TL was 0.96 to 1.00 while that of *SL* vs. *TL* was 0.80 to 1.00.

The Fulton condition factor (*K*) value for the 10 Philippine mullet species are found in Table 3. The average *K* for these mullets ranged from 1.44 to 2.40. Among the mullets with sample greater than 10, *Chelon subviridis* (Negros Oriental) has the highest average *K* value (2.34). When all sample sizes were included, the largescale mullet *Chelon macrolepis* shows the highest *K* value (2.40) while the flathead grey mullet *Mugil cephalus* has the lowest average *K* value (1.44).

Table 3.

Fulton Condition Factor (K) for Ten Philippine Mullets.

Species	K	min	max
Chelon macrolepis	2.40	2.21	2.63
Chelon subviridis (Negros isolate)	1.93	1.05	2.88
Crenimugil seheli	2.03	1.24	2.72
Ellochelon vaigiensis	2.34	2.13	2.50
Liza sp. (Ilocos Sur isolate)	1.85	1.65	2.03
Mugil cephalus	1.44	1.20	1.60
Osteomugil engeli	1.71	1.50	1.93
Osteomugil perusii	2.12	1.46	2.87
Plicomugil labiosus	1.95	1.77	2.07
Valamugil sp. (Ilocos Norte isolate)	1.90	1.67	2.10

K is the average Fulton condition factor; *min* and *max* are minimum and maximum.

DISCUSSION

The length frequency distributions for *Chelon subviridis*, *Liza* sp., *Osteomugil engeli*, *Osteomugil perusii*, and *Crenimugil seheli* did not follow the bell-shaped configuration. Kruskal-Wallis test showed significant differences in length ($P<0.01$) and weight ($P<0.01$) among these mullet species where *Liza* sp. was the longest (20.8 cm) and heaviest (89.1 g) species while *O. engeli* was the shortest (12.1 cm) and lightest (18.6 g). The mean weights of the other three species ranged from 40 g to 72 g and mean total lengths ranged from 15 cm to 18 cm. The species *Chelon macrolepis*, *Ellochelon vaigiensis*, *Mugil cephalus*, *Plicomugil labiosus,* and *Valamugil* sp. were not included in the length-weight comparisons due to low sample size (n=3-6).

The length-weigh relationship equations for the 10 mullets generally indicated a negative allometric growth except for the species *Ellochelon vaigiensis* which showed positive allometric growth. By negative allometry ($b < 3$), the fish is said to be "lighter for its length" while positive allometry ($b > 3$), is when the fish is "heavier for its length" as it grows (Froese, 2006). Isometric growth ($b = 3$) is indicated by equal increment in terms of weight and length. Allometry values of the same species have been noted to vary in relation to place and time. Borges et al. (2003) reported that *Liza aurata* in Algarve, South of Portugal exhibited positive allometry with the parameter $b = 3.154$ (n=23) however, Andrea-Soler et al. (2006) reported isometric growth for the same species collected from Segura River, Southeastern Spain ($b = 3.006$, n=20). Similarly, the flathead mullet, *Mugil cephalus* in Spain showed positive allometric growth ($b = 3.357$, n=80) as reported by Verdiel-Cubedo et al. (2005), but the study of Andrea-Soler et al. (2006) showed negative allometric growth for *M. cephalus* in Portugal ($b = 2.96$, n=38). Variations in *b* in this study are attributed to sample size differences as there are species that are more commonly caught than others. Environmental parameters such as temperature, trophic level and food availability among others in the sampling sites vary as well which influence over-all fish growth. Regardless of the variation in *b* values, the significance of length and weight relationships is its usefulness in fish stock assessment where it is easier, faster, and more accurate to measure fish length than weighing it.

The high coefficient of determinations (r^2) for all of the 10 mullet species indicate that length-length relationships are highly correlated with each other. The total lengths (*TL*) of the mullets in this study were notably different from the recorded *TL* of the same species in the mullet species guide by FAO (1984; 1974). For instance, the average *TL* of *Chelon subviridis* in this study was 17 cm but the mean *TL* for this species was 25 cm. Similarly, the mean *TL* of *Crenimugil seheli* in this study was 18 cm while the standard mean *TL* for this species was 20 cm according to Rau and Rau (1980) who studied the economically important fishes in Central Visayas of the Philippines 33 years ago.

Of the 10 mullets, only two species *Mugil cephalus* and *Osteomugil perusii* had average total length (TL) that were within the commonly reported *TL,* but *M. cephalus* sample size was small (n = 3) due to its seasonal rarity during the sampling period. Other mullets in this study whose average *TL* were below the commonly reported *TL* were: *Chelon macrolepis, Ellochelon. vaigiensis, Osteomugil engeli,* and *Plicomugil labiosus*. The species *Chelon subviridis* which was sampled on a monthly basis for an entire one year period was observed to have a wider distribution that includes the upper midstream section of the river whereas *Osteomugil perusii* and *Crenimugil seheli* were exclusively found in the downstream part of the estuary. For this reason, *C. subviridis* may find itself an easy target for overexploitation by human residents in the upstream portion of the river and the downstream estuary who depend on fish as their source of protein. Fishing pressure may play an important role for the observed *TL* disparities between the caught mullets and the commonly reported *TL*.

The Fulton Condition Factor (*K*) values for the 10 mullet species significantly vary from each other (p=<0.01). These values generally indicate that the fish species were in the "slimmer" side of the condition factor scale. The differences in *K* values could be attributed to differences in habitats, food availability, gonad development, gender of the fish (Quilang et al., 2007; Zhu et al, 2008; Hussain et al, 2010; Ndome & Eteng, 2010). The same factors are attributed to the variations in the regression coefficient (*b*) which indicates growth type of fish. Other factors that influence the condition factor of a fish include the number of specimens examined, season and area, spawning, degree of stomach fullness, healthy or diseased condition, differences of fishing gear and/or mesh size sizes, preservation techniques employed, and differences in the observed length ranges of the specimens (Borges et al., 2003; Andreu-Soler et al., 2006; Verdiell-Cubedo et al., 2006). Previous studies on the water quality of the Pagatban River in Negros Oriental where *Chelon subviridis*, *Crenimugil seheli,* and *Osteomugil perusii* thrive indicated environmental perturbations brought by mining activities 25 years ago (Rosario, 1999; Guino-o et al., 2011).

In summary, this study shows that *Liza* sp. was the longest (21 cm) and the heaviest (89 g) among the Philippine mullets. The bluespot mullet *Crenimugil seheli* ranked second in terms of length (18 cm) and weight (72 g). The species greenback mullet *Chelon subviridis* ranked third in total length (17 cm) and weight (62 g). The shortest (12 cm) and lightest (19 g) was the dwarf mullet *Osteomugil engeli*. All mullet species showed negative allometry while the Fulton Condition Factor was highest for *Osteomugil perusii* (2.12) and lowest in *Osteomugil engeli* (1.71). The parameters of the length-length relationships were highly correlated with each other (r^2 = 0.96 to1.0).

All mullet species in this study are commercially exploited by coastal residents. A regulatory framework is necessary to regulate their fishing activities to promote conservation and sustainable utilization of these species. A fishery regulation that limits fishing activity to the minimum legal total length will help these species from being overexploited as this will give them a chance to grow to maturity. Fish below and beyond the minimum legal total length should be returned to its habitat. A healthy mullet fishery can be expected in the estuaries when fishery regulations are coupled with a fishing ban during their reproductive season. Lastly, validating the levels of heavy metals in the tissues of the fishes collected at estuaries with history of mining and pollution is suggested in order to safeguard the health of the consumers.

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