California Fish and Game 102(2):50-54; 2016

Weight-length relationship and condition factor of leopard grouper *Mycteroperca rosacea* (Perciformes: Serranidae) from the Gulf of California

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Key words: Weight-length, Serranidae, leopard grouper, Gulf of California.

The weight-length (*W-L*) relationship and condition factor (*K*) are descriptors that provide fundamental information to evaluate the condition of fish and to determine possible differences among populations (Froese 2006). Fulton´s condition factor has been widely used as a proxy for the health status of organisms, relating size and weight of recently caught individuals (Nash et al. 2006). These relationships (*W-L* and *K*) are biologically relevant and provide fundamental information for the management of populations with high ecological and economic importance.

The leopard grouper (*Mycteroperca rosacea)* is a serranid of importance within the Gulf of California (GC). This species is endemic to the northwestern Mexican Pacific (Thomson et al. 2000), and is included in the Red List of Threatened Species as vulnerable (Craig and Sadovy 2008). However, despite its ecological importance, there are no studies on the weight-length relationship and condition factor for this species, and this study was carried out to provide information on this topic.

Monthly sampling was carried out from March, 2014 to May, 2015 by free diving using a polespear at depths of 6 to 10 m in the mining port of Santa Rosalía, Baja California Sur, in the central region of the GC (27 °20.353 'N, 112 °15.797' W). Total length (*TL*, ±0.5 cm precision) was measured using an ichtyometer, and total fresh weight was measured using an Explorer Pro electronic analytical balance (*W*, ±1g precision). Sex was determined by the direct observation of gonads.

Data were analyzed by sex (male or female). No juveniles were caught; sizes were therefore categorized as small (<360 mm), medium (>360 mm and <510 mm), or large

(>510 mm). Seasonality was defined according to temperature records obtained during the study period from MODIS-AQUA satellite images with 1.1 km resolution. Anomalies were calculated from the annual average of 23ºC. The months with positive anomalies were assigned to the warm season (June, July, August, September, October and November, 2014) and months with negative anomalies were assigned to the cold season (March, April, May, December 2014 and January, February, March, April and May, 2015).

The weight-length relationship was calculated using the equation (Froese, 2006), where W is the fish´s total weight (g), L is total length (mm), a is the point of intersection with the y axis, and b is the slope of the curve. The degree of association of the *W-L* relationship was calculated using the coefficient of determination (r^2). The 95% confidence interval of parameters a and b was also estimated.

The condition factor was obtained from Fulton´s equation (Ricker, 1975): ,where W is total weight (g) and L is length (cm) cubed, multiplied by 100 to represent values as percentages. The program R (R Core Team, 2015) was used for statistical analyses. Wald´s test was applied to all combinations using the wald.test function from the analysis of overdispersed data (aod) library (Lesnoff and Lancelot 2012) to verify the isometric growth hypothesis (H_o: b=3, H_1: b≠3). A chi squared test was used (Sokal and Rohlf 1981) to test whether there was a 1:1 sexual proportion.

A total of 332 leopard grouper organisms was analyzed. The *W-L* parameters and their different combinations are presented in Table 1. Of all analyzed specimens, 210 were female (63.3%) and 122 were male (36.7%). The sexual proportion was 1.72F:1M, differing from the expected 1F:1M proportion ($X^2_{(1,332)} = 23.32$ $P < 0.05$). The *W-L* relationship fit a power function, and the coefficients of determination were high in all cases ($r^2 = 0.90$-0.99). Growth was allometric for most combinations ($b \neq 3$; $p<0.05$), except during the warm season ($b=3$; $p=0.20$). The categories of male, female, cold season, medium, and large-size fish had positive allometric growth (b>3), whereas small-size fish had negative allometric growth (b<3). The condition factor resulted in values over 1 ($K<1$) for all combinations (Table 1).

The sexual proportion obtained in the present study (1.72F:1M) was different from the expected 1F:1M proportion. This was reported for this species by Estrada-Godínez et al. (2011), who recorded an even higher proportion of females (3.6F:1M). It has also been reported for other members of the Serranidae family, for species such as red grouper (*Epinephelus morio)* (4.2F:1M), red hind (*E. guttatus)* (1.5F:1M), gag grouper (*Mycteroperca microlepis)* (3.3F:1M*)*, and tiger grouper *(M. tigris)* (1.3F:1M) (Renán et al. 2015). It has been noted that although the 1:1 sexual proportion is commonly found in nature, there can be great variability in a population, depending on environmental, physiological, genetic, and ethological factors, as well as on the effect of fisheries on commercially important species, due to size selectivity (Estrada-Godínez et al. 2011).

The b values obtained for most combinations (sex, season and size) were high ($b>3$), which is also similar to what has been reported for other species within the Serranidae family such as black grouper (*M. bonaci),* gag grouper (*M. microlepis)*, and red grouper (*Epinephelus morio)* (Renán et al. 2015); however, small specimens had b values <3. This difference could be due to differential growth rates, such that small-sized individuals grew more in size than in weight (negative allometric growth).

Growth is not constant and is indeterminate in fish during their first developmental stages (Froese 2006). It is therefore suggested that data should be worked independently to establish *W-L* relationships, separating sexes, sizes, and maturity stages, because these relationships could be under or overestimated and not result in real data. The type of growth

Table 1. Statistics on Length-weight (L-W) relationships and Fulton´s condition factor *K* for *Mycteroperca rosacea* from the mining port of Santa Rosalia, Baja California Sur, México sampled monthly from March, 2014 to May, 2015.

Categories	Length (mm)		Weight (g)	Parameters of *W-L*					Fulton´s condition factor (*K*)	
	n	Range (min-max)	Range (min-max)	a	b	a95%CL	b95%CL	R^2	Range (min-max)	Mean value
General	332	210-700	120-5554	$3.08x10^{-6}$	3.23	$1.94x10^{-6}$- $4.88x10^{-6}$	3.16-3.30	0.9543	0.94-2.17	1.27
Male	122	240-610	155-3205.2	$2.07x10^{-6}$	3.30	$8.57x10^{-7}$- $4.69x10^{-6}$	3.17-3.44	0.9508	0.96-2.17	1.27
Female	210	210-700	120-5554	$1.65x10^{-6}$	3.33	$9.01x10^{-7}$- $2.99x10^{-6}$	3.24-3.43	0.9595	0.94-1.97	1.26
Hermaphrodites	9	300-685	340-3775	$2.98x10^{-5}$	2.85	$7.75x10^{-6}$- $1.01x10^{-4}$	2.66-3.06	0.9953	1.14-1.48	1.27
Cold season	274	210-700	120-5554	$3.89x10^{-6}$	3.20	$2.35x10^{-6}$- $6.39x10^{-6}$	3.12-3.28	0.9585	0.94-2.17	1.29
Cold season *Male	97	235-610	155-3205	$2.92 x10^{-6}$	3.24	$1.06x10^{-6}$- $6.67x10^{-6}$	3.11-3.41	0.9541	0.94-2.17	1.26
Cold season * Female	138	210-700	120-5554	$1.88 x10^{-6}$	3.31	$1.05x10^{-6}$- $3.87x10^{-6}$	3.23-3.41	0.9652	0.94-2.17	1.27
Warm season	67	296-556	243-2582	$1.15x10^{-5}$	3.00	$4.51x10^{-6}$- $3.03x10^{-5}$	2.84-3.15	0.9603	1-1.66	1.21
Warm season *Male	25	275-590	290-2582	$2x10^{-7}$	3.67	$1.98x10^{-7}$- $2.01x10^{-7}$	3.43-3.90	0.9251	0.94-2.17	1.26
Warm season *Female	72	258-556	243-2060	$1.65 x10^{-5}$	2.94	$4.26x10^{-6}$- $3.61x10^{-5}$	2.81-3.16	0.9639	0.94-2.17	1.25
Small length	161	210-360	120-610	$1.80x10^{-4}$	2.53	$5.85x10^{-5}$ - $5.41x10^{-4}$	2.34-2.73	0.8441	0.94-2.17	1.26
Medium length	148	363-505	495-1890	$1.65x10^{-6}$	3.33	$4.15x10^{-7}$ - $6.95x10^{-6}$	3.10-3.57	0.8416	1-1.78	1.25
Big length	32	515-700	1403.1-5554	$1.63x10^{-6}$	3.33	$1.63X10^{-6}$ - $2.99X10^{-6}$	2.86-3.33	0.7862	0.96-1.78	1.35

n is sample size; min and max are the minimum and maximum length (mm) and weight (g); *a* and *b* are the parameters of the weight–length relationship, and $CL_{95\%}$ are 95% confidence limits; r^2 is the coefficient of determination of 332 analyzed specimens. *combinations by seasons per sex.

found in the present study for leopard grouper was positive allometric for most combinations, except for the warm season (isometric), and small sizes (negative allometric). This coincided with what was reported by Díaz-Uribe et al. (2001), who reported allometric growth (b = 2.6). According to the estimated age, most individuals caught by those authors were adult fish; they concluded that this is a slow-growing serranid. It should be noted, however, that the authors did not take into account sex or size when calculating the *W-L* relationship and their results should therefore be taken with caution.

According to Nash et al. (2006) environmental factors, feeding, and reproduction affect the condition of organisms. In this study the leopard grouper was found to be in good condition. This was more evident in males during the cold season (K=1.28). Big length individuals (K=1.35) were in better condition than small (K=1.26) and medium-sized individuals (K=1.25). This was attributed to the physiological processes through which individuals pass during their first stages of development. Low condition factor values in females during the warm season (K=1.25) coincide with what was reported by Estrada-Godínez et al. (2011), who stated that leopard groupers start reproducing during the warm season. The condition factor was therefore low because females use all their energy reserves for gonad maturation; once that process ends a good condition is re-established. This is the first study to provide data on the weight-length relationship and condition factor of leopard groupers in the Gulf of California.

Acknowledgments

All authors are grateful for economic support provided by the projects SIP-IPN (20130869) and CONACyT (Clave 205024). MSIA would like to acknowledge CONACyT and BEIFI for supporting this research. XGMS thanks the Instituto Politécnico Nacional (IPN) for economic support provided through the Contratación por Excelencia Program. XGMS and LAAC are grateful for support received through EDI and COFAA. XGMS, LAAC and JSRP thank the Red Interinstitucional Para la Evaluación, Manejo y Aprovechamiento de Los Recursos Acuáticos (RIEMARA).

Literature Cited

Craig, M.T. and Y. Sadovy. 2008. *Mycteroperca rosacea* [Internet]. IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. Available from: htpps://www.iucnredlist.org/.

Díaz-Uribe, J.G., J.F. Elorduy-Garay, and M.T. González-Valdovinos. 2001. Age and growth of the leopard grouper, *Mycteroperca rosacea*, in the southern Gulf of California, Mexico. Pacific Science 55: 171-182.

Estrada-Godínez, J.A., M. Maldonado-García, V. Gracia-López, and M. Carrillo. 2011. Reproductive cycle of the leopard grouper *Mycteroperca rosacea* in La Paz Bay, México. Ciencias Marinas 37(4):425-441.

Froese, R. 2006. Cube law, condition factor and length-weight relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology 22: 241-253.

Lesnoff, M. and R. Lancelot. 2012. Aod: analysis of overdispersed data. R. Package versión 1.3. Available from: http://cran.r-project.org/packagepaod.

Nash, R.D.M., A.H. Valencia, and A.J. Geffen. 2006. The origin of Fulton´s condition factor, setting the record straight. Fisheries 31(5): 236-238.

Renán, X., J. Trejo-Martínez, D. Caballero-Arango, and T. Brulé. 2015. Growth stanzas in an Epinephelidae-Lutjanidae complex: considerations to length-weight relationships. Revista de Biologìa Tropical 63(1):175-187.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:1-382.

R Core Team, 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: https://www.R-project.org/.

Sokal, R.R. and F. J. Rohlf. 1981. Biometry. The principles and practice of statistics in biological research, 2nd Edition. W. H. Freeman and Company, New York, USA.

Thomson, D.A., L.T. Findley, and A.N. Kerstich. 2000. Reef fishes of Sea of Cortez. University of Texas Press. Austin, Texas, USA.

Submitted 20 May 2016
Accepted 13 July 2016
Associate Editor was Paul Reilly