The Journal of Animal & Plant Sciences, 30(5): 2020, Page: 1292-1297
ISSN (print): 1018-7081; ISSN (online): 2309-8694

SPAWNING SEASON, SEASONAL CONDITION FACTOR AND ALLOMETRIC GROWTH PATTERN OF *CHAENOGOBIUS GULOSUS* (SAUVAGE, 1882) INHABITING ROCKY SUBTIDAL HABITATS IN THE SOUTH-EASTERN KOREA

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ABSTRACT

This study presents data on spawning season, length-weight and length-length relationships, and seasonal condition factors of *Chaenogobius gulosus* (Sauvage, 1882) inhabiting rocky subtidal habitat in the south-eastern Korea. Monthly changes in the gonadosomatic index (GSI) indicated that the spawning period was from December to April. Values of the exponent *b*, estimated by nonlinear least squares from weight and length data, ranged from 2.860 for mature group to 3.184 for immature fishes, but it was similar between spawning and non-spawning seasons, and between female and male fishes. All relationships between total and standard length were linear (r^2> 0.947). The condition factors were significantly higher during the spawning season than during the non-spawning season, but those were not significant between immature and mature groups, and between female and male fishes. The results from this study can contribute to increasing our knowledge on biology of *C. gulosus*, and are useful data for conservation and management of this species.

Keywords: *Chaenogobius gulosus*, condition factor, LLR, LWR, Tongyeong.

https://doi.org/10.36899/JAPS.2020.5.0147 *Published online June 25, 2020*

INTRODUCTION

Measuring body morphometrics of fishes is a basic procedure in fishery sciences, because fishery species can identify and compare specific species, populations and stocks via morphometric relationships (King, 1995; Froese, 1998). The exponential parameter (*b*) and intercept (*a*) of length-weight relationship (LWR) and length-length relationship (LLR) parameters (*a*, *b*) have been applied in assessing fish stocks and populations (Ricker, 1968). For example, LWRs are useful to predict the average weight at a given length group and convert length data into weights to provide a measure of biomass (or vice versa) (Froese, 2006; Froese *et al*., 2011), because stock assessment models and management for fisheries require information about body weight for estimation and regulation of catches (Froese *et al*., 2014). LLRs are also important for comparative growth studies among taxonomical similar species (Moutopoulos and Stergiou, 2002). Fulton's condition factor is widely used to measure the health, i.e. fish well-being, and seasonal body condition of individual fish (Le Cren, 1951; Froese, 2006). This factor is based on the hypothesis that for a given length, heavier fishes are in better condition than lighter fishes, and fatness is used as a measure of fish health (Bagenal and Tesch, 1978).

Chaenogobius gulosus is a member of the family Gobiidae and mainly distributed in the shallow coastal area of western Pacific including Korea peninsula, Japan and Yellow Sea (Yamada *et al*., 1986; Kim *et al*., 2005).The species usually lives between rock matrices in subtidal zone of the temperate coastal area (Kim *et al*., 2005), and mainly consumed various rock-dwelling macro-invertebrates as well as seaweeds (Baeck *et al*., 2010). Although *C. gulosus* is not commercially caught, they are potential food resources for larger coastal residents such as rosefish *Helicolenus hilgendorfii* and scorpion fish *Sebastiscus marmoratus* (Baeck *et al*., 2011b, 2013). Several studies on biometric relationships and seasonal condition factors for gobies have been conducted globally (e.g. Hossain *et al*., 2009; Ghanbarifardi *et al*., 2015; Dinh, 2016), but a little is known regarding LWR and LLR parameters for Korean gobiid fishes. Only a few studies are available on the biometric relationships of this group of fishes in Korea (e.g. Baeck and Park, 2015; Park and Huh, 2015). In this paper, we provide the first LWR and LLR values and seasonal condition factors, and new maximum length for *C. gulosus*.

MATERIALS AND METHODS

Samplings: Fish specimens were collected in the rocky subtidal habitat of the south-eastern Korea (34°50′N, 127°33′E; Fig. 1). Samplings were conducted monthly from October 2008 to September 2009 during high tide of spring tide in each month and fish samples were collected using a shore-angling by dropping fishing hook between rocky matrices and then striking fishes. The tidal range during spring tide is approximately 1.8 m in the study area. Immediately after capture, individuals were snap frozen and taken to the laboratory. Total length (TL), standard length (SL), and wet body weight (BW) were measured to the nearest millimeter and nearest gram, respectively. The peritoneum of each fish specimen was excised, and the gonads were removed and weighed to the nearest 0.0001 g (GW). Sex was determined macroscopically by examining gonads. Fish maturity was estimated according to maturity size (i.e. immature, <8.0 cm SL; mature ≥8.0 cm SL), following Baeck *et al*. (2011a).

Data analysis: The gonadosomatic index (GSI) was calculated as follows: GSI = (GW/BW) × 100, where GW is gonad weight (g) and BW is body weight (g). One-way analysis of variance (ANOVA) followed by Tukey's post-hoc comparisons were used to assess whether there were significant differences of GSIs among months.

For each species, the length-weight function, $BW = aTL^b$, was fitted to the data using linear regressions of log10-transformed data, where BW represents wet body weight (g), TL is total length (cm), and *a* and *b* are the intercept and allometric coefficient, respectively. Extreme outliers were removed before fitting the regression because the data were increased measurement errors (Froese *et al*., 2011). The relationships between TL and SL were established using the linear regression function TL = *a* + *b*SL. The standard error (SE) of parameters *a* and *b*, and the statistical significance level of r^2 were estimated. We summarized LWR and LLR values in each seasons (spawning and non-spawning), maturities (immature and mature; Baeck *et al*., 2011a), genders (female and male), and all specimens combined. Analyses of covariance (ANCOVA) was used to test the effect of the categorical factors of season, maturity and gender in the relationships between body weight and total length. The relationships between BW and TL, and between TL and SL, and interactions between categorical factors and covariates on these relationships were investigated by ANCOVA.

The Fulton's condition factor (*K*) was calculated for each fish according to the equation $K = 100 \times BW/SL^3$ (Pauly, 1984; Froese, 2006). Differences in condition factors were examined with respect to season, maturity and gender. The assumptions of normality and homoscedasticity were met for the species (P > 0.05); three-way analysis of variances (ANOVAs) was used to assess whether there were significant influences on condition factor by season, maturity and gender as well as their two-way and three-way interactions. All statistical analyses were performed using SYSTAT software (Systat version 12.0, SPSS Inc., Chicago, IL, USA). An assumed significance level of 0.05 was used in all statistical analyses.

RESULTS

Monthly GSI values of female began to increase in December, reaching the highest level in February and decreasing thereafter (Fig. 2). ANOVA results showed that GSI values were significantly different among months, with the highest value in February, followed by January and March (ANOVA post-hoc test, P < 0.05). On the other hand, those of male did not change significantly among months (ANOVA, P > 0.05). Gonad development of female *C. gulosus* began in December, with spawning taking place primarily between December and April.

Length-weight and length-length regressions were applied to 330 specimens of *C. gulosus*. The estimated parameters of LWR and LLR, and descriptive statistics by season, maturity and gender and all fishes, are provided in Table 1. All LWRs were highly significant (P < 0.05), with r^2 values >0.872. The r^2 values ranged from 0.872 for mature group to 0.990 for individuals during the non-spawning period. ANCOVA results revealed that the slope (*b*-value) of the LWR did not differ significantly between non-spawning and spawning season, and between genders, but it was significant between immature and mature groups, with higher value for immature fishes than mature group (P < 0.05). The LLR values were highly correlated for all relations among the two length measurements ($r^2 > 0.947$, P < 0.05).

The mean seasonal values of condition factors of *C. gulosus* were 1.983 during non-spawning season and 2.161 during spawning, and showed significantly higher value the latter period (P < 0.05), but there were no significant two- and three-way interactions among categorical factors of season, maturity and gender (three-way ANOVAs, P > 0.05; Fig. 3).

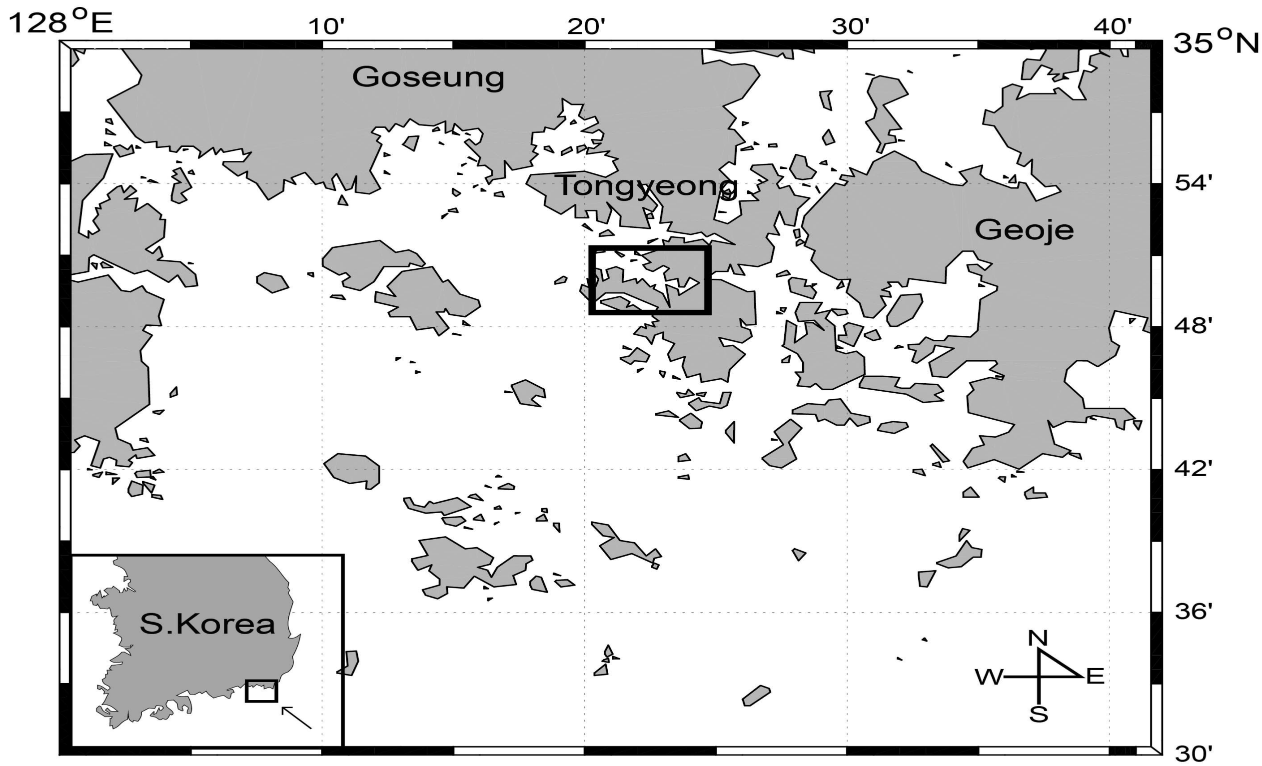

Fig. 1. Location of sampling area in the south-eastern Korean waters. Samples were collected along the shore lines within boxed area.

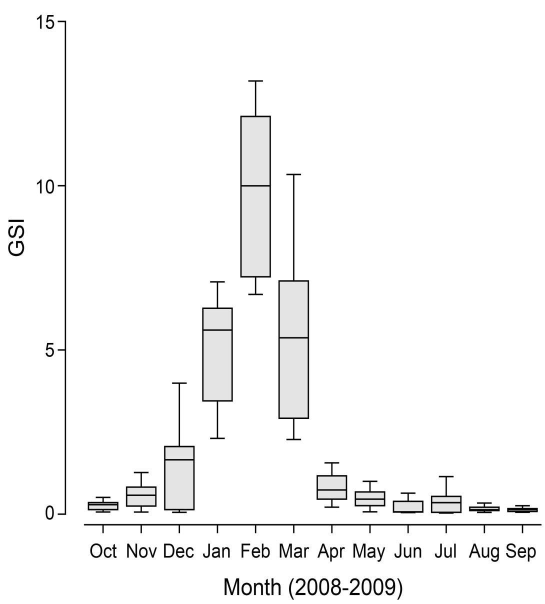

Fig. 2. Monthly changes in GSI of female *Chaenogobius gulosus* inhabiting rocky subtidal habitats in the south-eastern Korea.

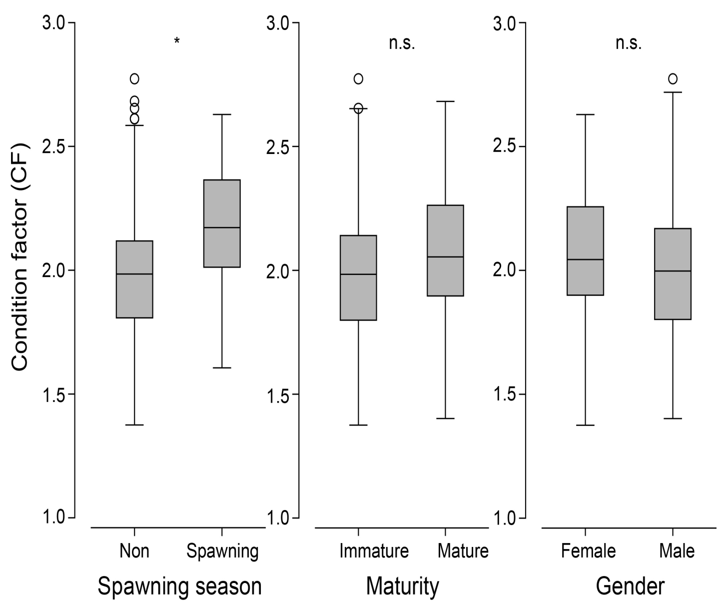

Fig. 3. Box plots of condition factors for *Chaenogobius gulosus* in relation to spawning, maturity and gender. Open cycles represent outliers. *=statistical significance at 0.05, n.s.=no significance.

Table 1. Length-weight relationship (LWR) and length-length relationship (LLR) parameters of *Chaenogobius gulosus* inhabiting rocky subtidal habitat in the south-eastern Korea.

Factors	N	SL (cm)	TL (cm)	BW (g)	$W=aL^b$						TL = a + bSL					
					A	SE	*b*	SE	r^2	ANCOVA	*a*	SE	*b*	SE	r^2	ANCOVA
Season																
Non-spawning	248	2.0-11.8	2.4-14.0	0.11-37.55	0.0088	0.019	3.135	0.020	0.990	0.142	0.243	0.043	1.150	0.005	0.995	0.162
Spawning	82	6.4-12.6	7.8-14.7	5.91-45.35	0.0100	0.110	3.103	0.101	0.916		0.667	0.252	1.117	0.027	0.957	
Maturity																
Immature	122	2.0-7.9	2.4-9.6	0.11-11.88	0.0081	0.029	3.184	0.036	0.985	<0.001	0.165	0.062	1.166	0.011	0.989	0.035
Mature	208	8.0-12.6	9.4-14.7	10.30-45.35	0.0175	0.080	2.860	0.086	0.872		0.578	0.177	1.119	0.018	0.947	
Gender																
Female	152	2.0-12.6	2.4-14.7	0.11-45.35	0.0086	0.026	3.157	0.027	0.989	0.914	0.182	0.065	1.166	0.008	0.993	0.069
Male	178	2.4-12.1	3.0-14.2	0.31-38.43	0.0085	0.026	3.151	0.027	0.987		0.273	0.063	1.146	0.007	0.993	
Total	330	2.0-12.6	2.4-14.7	0.11-47.35	0.0086	0.017	3.155	0.018	0.990		0.023	0.046	1.155	0.005	0.993	

N=number of individuals, SL=standard length, TL=total length, BW=wet body weight, *a*=intercept, *b*=slope, r^2=coefficient of determination, SE=standard error.

DISCUSSION

The length-weight and length-length regressions for many fish species are available in FishBase, a global biological database on fishes (Froese and Pauly, 2017). Our result provides the first quantitative LWR and LLR estimates for *C. gulosus*, and also gives new maximum length for *C. gulosus* (i.e. 12.6 cm SL and 14.7 cm TL). The estimated *b* values from this study were within the standard range of 2.5-3.5 which indicate for the majority of fish species (Froese, 2006). The *b* values were the higher end of the expected range, indicating towards positive allometry, but that of mature group was shown negative allometry.

In this study, the condition factors were significantly different between non-spawning and spawning, but not between maturities or genders. Because there were no significant interactions among those factors, variations of condition factor of this species were attributed to seasonal changes in body condition in relation to spawning behavior and/or food intakes. Seasonal changes in body condition were related with seasonal variations in energy reserves (protein, lipid, glycogen and total energy) which are usually driven by food availability, environmental conditions, and reproductive status (Chellappa *et al*., 1995; Weatherley and Gill, 1987). Fulton's condition factor differed seasonally in many fish species because of fluctuations in food availability and environmental conditions, consequently, changes in food reserves throughout the year (Hossain, 2010; Lavergne *et al*., 2013). While several goby species such as *Periophthalmus barbarus* and *Trypauchen vagina* showed relatively low condition factor during the breeding season (e.g. King and Udo, 1998; Chukwu and Deekae, 2011; Dinh, 2016). In some goby species (e.g. *Periophthalmus* mudskippers), low condition factors in breeding season were results from insufficient available food resources and limited foraging opportunities for guarding parents that remain in the space adjacent to the burrow (Colombini *et al*., 1996; Baeck and Park, 2015). Thus, seasonal changes of body condition look species-specific at least gobiid fishes.

Conclusion: This study provides data on the spawning season, LWR, LLR, and seasonal condition factors of *C. gulosus* captured from rocky subtidal habitat in the south-eastern Korea. These results contribute towards future conservation studies of the species, and be useful for fishery biologists and managers in Korea.

Acknowledgments: We would like to thank to Mr. Sang Jin Ye for his assistancein the sample collection and measurement of fish samples. This research was supported by a grant from the National Institute of Fisheries Science, Korea (R2020021).

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