



## Sexual Dimorphism, Growth Rate, and Condition Factor Dynamics in *Glossogobius celebius* (Perciformes: Gobiidae)

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### Abstract

There is a paucity of information concerning diminutive gobies in the Philippines. Sexual dimorphism in Celebes goby *Glossogobius celebius* (Valenciennes, 1837) was described based on the external morphology of the specimens from Orani river systems, Bataan, Philippines. The mean body size of females was larger than males but not significantly different ( $p > 0.05$ ). The principal component analysis identified the longer snout-to-2<sup>nd</sup> dorsal fin length, snout-to-anal fin length, and deeper body of females, while males have longer median fins (anal fin and 2<sup>nd</sup> dorsal fin). Multivariate analysis of variance examined significant variation among and between the sex and maturity groups (Pillai trace = 1.52,  $F = 13.98$ ,  $p < 0.001$ ). In canonical variate analysis, a significant morphological deviation between immature and mature specimens is primarily explained by more posteriorly-located anal fin and 2<sup>nd</sup> dorsal fin, and longer 2<sup>nd</sup> dorsal fin by the latter. Moreover, the difference between sexes of mature specimens was evident in males having a more elongated 2<sup>nd</sup> dorsal fin. The observed variation can be attributed to developmental priorities (maturation-related morphology) and the health status of the specimens. Both sexes displayed statistically isometric growth rate (male  $b = 2.99$ ; female  $b = 3.03$ ). The relative condition factor (K) was closed to a K-value of 1.00, indicating a state of well-being for the collected fish specimens.

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## Introduction

*Glossogobius celebius* (Valenciennes, 1837) is a diminutive indigenous fish species commonly known as Celebes goby and locally named *biyang bato* or *bakuli* in the Philippines (Corpuz *et al.*, 2013). Like most of its congeners, this fish species is demersal and carnivorous. It is amphidromous and can complete its life history in freshwater, but larvae can also occur in brackish waters. It is an oviparous species that attaches its fertilized pyriform eggs to hard substrates. Naturally occurring populations are distributed in Asia and Oceania (Froese and Pauly, 2018). Similar to most gobioid assemblages, *G. celebius* populations are mainly thriving in freshwater streams of southern Luzon with a defined connection to the estuary (Paller *et al.*, 2011; Corpuz *et al.*, 2015a; 2015b).

Despite the cryptic features and diminutive adult sizes (50–100 mm), the population of *G. celebius* comprises a considerable portion of the local communal and subsistence fisheries, which is known to the natives of southern and northern Luzon as *ipon* (Herre, 1927; Blanco, 1956). Little is known about *G. celebius* inhabiting the Philippine waters. Reports on its population distribution (Paller *et al.*, 2011; Corpuz *et al.*, 2015b; Froese and Pauly, 2018), inter-population morphological variation (Corpuz *et al.*, 2013), and genetic diversity (Ardestani *et al.*, 2014; Alcabados *et al.*, 2017) have been documented.

Gobioid assemblages are recognized as one of the main nektonic bioindicators in freshwater and estuarine ecosystems (Ardestani *et al.*, 2014; Corpuz *et al.*, 2015a; Corpuz *et al.*, 2016). Understanding the key biological information of this gobioid species is vital to crafting conservation programs and sustainable fisheries management protocols both for the fish species and the aquatic environment. Important biological variables including the sexual differentiation, growth rate, and condition factor of the species in question, are not fully well characterized. Hence, this paper described the intersexual variation in external linear morphometry, length-weight relationship (LWR), and relative

condition factor dynamics of *G. celebius* based on specimens collected from central Luzon, Philippines.

## Material and methods

### Collection of specimens

A total of 103 *G. celebius* specimens (female = 57; male = 46) were utilized in the study. The specimens were collected upstream of the Orani river, Bataan, Philippines (14° 45.2" N; 120° 26.4" E.). Specimens were collected in July 2018 using hand nets, conical traps, and 12-v electro-fishing equipment. Sexes were verified through inspection of the genital papilla. Fish specimens were brought to the Fisheries laboratory for further fish analyses.

### Morphometrics

Twenty four morphometric characters were measured: standard length (SL), head length (H), predorsal length (PDL<sub>1</sub>), snout to 2<sup>nd</sup> dorsal fin origin (PDL<sub>2</sub>), prepelvic length (PPL), ventral fin to anus (VFA), snout to anus (SN), preanal length (PAL), caudal peduncle length (CPL), caudal peduncle depth (CPD), body depth at anal fin origin (BDAF), body depth at pelvic fin origin (BDVF), 1<sup>st</sup> dorsal fin base (DFB<sub>1</sub>), 2<sup>nd</sup> dorsal fin base (DFB<sub>2</sub>), pectoral fin length (PFL), anal fin base (AFB), ventral/pelvic fin length (VFL), dorsal fin length (DFL), anal fin length (AFL), caudal fin length (CFL), head width (HW), head depth (HD), eye diameter (E), pre-orbital length (Pre), post-orbital length (Post), lower jaw length (J). (Fig. 1). Measurements were taken from the left side of the body of the fish and measured to the nearest 0.01 cm using a digital caliper.

Wet weight of fish and gonads were obtained using an electronic balance to compute for gonadosomatic index [GSI = (gonad weight/ body weight) x 100]. Sex and maturity sample groups were classified as determined by the condition of the gonads (Susatyo *et al.* 2018): immature females (IF, GSI ≤ 2%), immature males (IM, GSI < 0.4%), mature females (MF, GSI ≥ 7%), and mature males (MM, GSI ≥ 0.6%). Reproductive females with a considerable number of vitellogenic and spawning oocytes. Gravid specimens were categorized as MF.

### Data analyses

The size effect was corrected using the equation for the allometric adjustment of the morphometric data set (Elliot, 1995):

$$M_c = M (L_s / SL)^b$$

where:

$M_c$  = size corrected measurement,

$M$  = observed measurement,

$L_s$  = mean of standard length for all fish from all samples in each sampling site,

$SL$  = standard length of the fish,  $b$  is the slope of the regression of  $\log_{10} M$  on  $\log_{10} SL$ .

The  $SL$  was employed as the basis of transformation since several specimens have damaged caudal fins. Standardization efficiency was verified using the correlations coefficient of multiple determination ( $R^2$ ) between corrected data and  $SL$  ( $p < 0.05$ ).

Stepwise discriminant function analysis (DFA) was used to identify the most significant metric characters using the  $F$ -value criterion ( $F$ -entry, 3.84;  $F$ -removal, 2.71). Selected characters were size-adjusted and then subjected to principal component analysis (PCA, covariance matrix) to compare overall morphological patterns. Multivariate analysis of variance (MANOVA) was used to test significant overall differences between and among the sex and maturity sample groups according to Pillai Trace statistic ( $p < 0.05$ ). Classification success was derived from canonical variate analysis (CVA) and pairwise squared Mahalanobis distances to assign individual fish to recognized clustered groups. The correct classification rate was assessed using holdout cross-validation procedures. All statistical analyses were performed with Paleontological Statistics v 2.07 (Hammer *et al.*, 2001).

The most important metric characters selected from CVA were tested for a length-length relationship using actual metric data. It was fitted to the power equation:  $Y = aX^b$ , where  $Y$  = metric measurements,  $X$  =  $SL$ , and  $b$  = slope. The value of  $b$  was tested for

theoretical value for isometry, i.e., when  $b$  was significantly equal to 1, growth was regarded as isometric,  $b < 1$ , negatively allometric, and  $b > 1$ , positively allometric. Significance of deviation from  $b = 1$  ( $p < 0.01$ ) was tested using a  $t$ -test (Aya *et al.*, 2017). Analysis of covariance (ANCOVA) was used to test for any difference between regression models that showed the relationship between  $SL$  and metric characters of MF and MM.

The LWR was estimated using the equation (Ricker, 1973):

$$W = a TL^b$$

where,  $W$  = weight of an individual fish (g);  $TL$  = total length of an individual fish (mm);  $a$  and  $b$  are constants.

The fish body condition factor was calculated using the function:

$$K = W a TL^b$$

where,

$W$  = fish weight (g),  $TL$  = total length (mm),  $a$  = regression intercept and  $b$  = regression slope (Le Cren, 1951).

## Results and discussion

### Morphometric characters

Descriptive statistics of each morphometric character are presented in Fig. 2. The mean  $SL$  of females ( $58.54 \pm 1.75$  mm,  $n = 57$ ) was larger than that of male gobies ( $53.88 \pm 1.72$  mm,  $n = 46$ ), albeit not statistically different ( $p > 0.05$ ). The overall ratio of males to females was 1:1.24, which did not significantly deviate from the expected ratio of 1:1 ( $\chi^2 = 1.3$ ,  $df = 1$ ,  $p = 0.25$ ).

Two male specimens were recognized as outliers and were excluded from the analyses. No correlation was found between size-adjusted data and standard length after transformation ( $R^2 = 0$ ,  $p > 0.05$ ), which implies that the allometric standardization eliminated the size effect in the dataset. For sex variation, 17 out of the

original 23 morphometric characters were retained by stepwise discriminant analysis and were subjected to PCA and CVA. In sex and maturity sample groups,

only seven metric characters (i.e., H, PDL<sub>2</sub>, PAL, AFB, DFL, AFL, and Pre) were identified as the most important characters (Table 1).

**Table 1.** Relative eigenvalues, percentage of variation, and weights of metric variables of the first three principal components (PC) derived from sex groups of *Glossogobius celebius*. Significant metric characters are set in bold.

	PC1	PC2	PC3
Eigenvalues	10.91	3.19	1.48
% Variation	50.67	14.82	6.88
Eigenvectors			
H	0.294	-0.210	0.168
PDL <sub>2</sub>	0.378	-0.372	0.377
PAL	0.365	-0.278	-0.100
VFA	0.267	-0.019	-0.206
CPD	0.124	-0.021	-0.114
BDAF	0.224	-0.021	-0.005
BDVF	0.314	0.014	-0.060
DFB <sub>1</sub>	0.075	0.086	0.217
DFB <sub>2</sub>	0.227	0.130	-0.065
PFL	0.268	0.046	-0.181
VFL	0.213	0.108	-0.074
DFL	0.278	0.719	0.009
AFL	0.197	0.348	-0.098
CFL	0.266	0.124	-0.075
HD	0.237	-0.072	-0.076
E	0.024	-0.059	0.084
Pre	0.059	0.174	0.802

The present study showed that the female's *G. celebius* are larger than males. A similar report was also observed in related congeners, *G. giuris* (Islam 2004). However, it contradicts the reports regarding *Tridentiger kuroiwae brevispinis* (Mashiko and Yamane, 1993), and *Neogobius melanostomus*

(Charlebois, 1997), in which male specimens are larger than females. A decrease in the abundance of males may be attributed to the cryptobenthic "hiding" behavior and nest-guarding (paternal care) of males during the period when the specimens were caught (Silva and Gordo, 1997).

**Table 2.** Relative eigenvalues, percentage of variation, and weights of significant metric variables of the first two canonical variates (CV) from sample groups of *Glossogobius celebius*.

	CV1	CV2
Eigenvalues	84.33	0.95
% Variation	98.83	1.12
Eigenvectors		
H	0.222	0.172
PDL <sub>2</sub>	0.594	-0.403
PAL	0.721	-0.625
AFB	0.159	0.181
DFL	0.566	0.933
AFL	0.336	0.638
Pre	0.072	-0.102

### Intersexual morphological variation

The PCA for significant morphometric character revealed 65.49% of the total variation from the first two principal components. The PDL2, PAL, and DFL were the most important metric variables in PC1, whilst the variation in PC2 was mostly explained by DFL, PDL2, and AFL (Table 1). In the PCA plot, the centroids and score distribution of male and female groups were clearly separated (Fig. 3). Multivariate analysis likewise confirmed this sexual differentiation

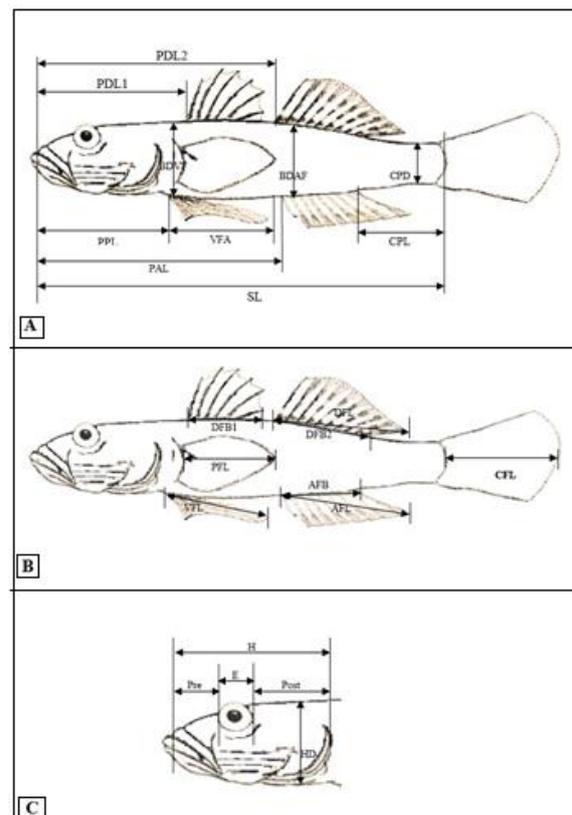
(Hotelling's  $T^2 = 194.28$ ,  $p < 0.05$ ). Significant differentiation was observed among and between the sex and maturity groups (Pillai trace = 1.52, approx.  $F_{(21, 285)} = 13.98$ ,  $p < 0.001$ ). In the pairwise comparison, MM and MF were significantly different (Hotelling's  $T^2 = 502.38$ ,  $p < 0.001$ ), whereas IM and IF were statistically homogenous ( $p = 0.03$ ). The deviation between immature and mature specimens was found highly significant (Hotelling's  $T^2 = 2,892.5$ ,  $p < 0.001$ ).

**Table 3.** Direct and percentage of classification (in parentheses) based on canonical variate analysis.

A priori Group	A posteriori group				Total
	Immature female	Mature female	Immature male	Mature male	
Immature female	18 (90.0%)	0 (0.0%)	2 (10.0%)	0 (0.0%)	20
Mature female	0 (0.0%)	31 (83.78%)	0 (0.0%)	6 (16.21%)	37
Immature male	7 (38.88%)	0 (0.0%)	11 (61.11%)	0 (0.0%)	18
Mature male	0 (0.0%)	0 (0.0%)	0 (0.0%)	26 (100.0%)	26
Total	25	31	13	32	101

The clustering of three groups (MM, MF, and IM+IF) is thus evident in the CVA plot (Fig. 4). Squared Mahalanobis distance also validated these significant variations among the four samples. The pattern of variation among groups in CV1 is highly contributed by posteriorly-located 2<sup>nd</sup> dorsal and anal fin, and length of 2<sup>nd</sup> dorsal fin. Variation in CV2 can be explained primarily by the difference in the 2<sup>nd</sup> dorsal and anal fin lengths of MM and MF (Fig. 4, Table 2).

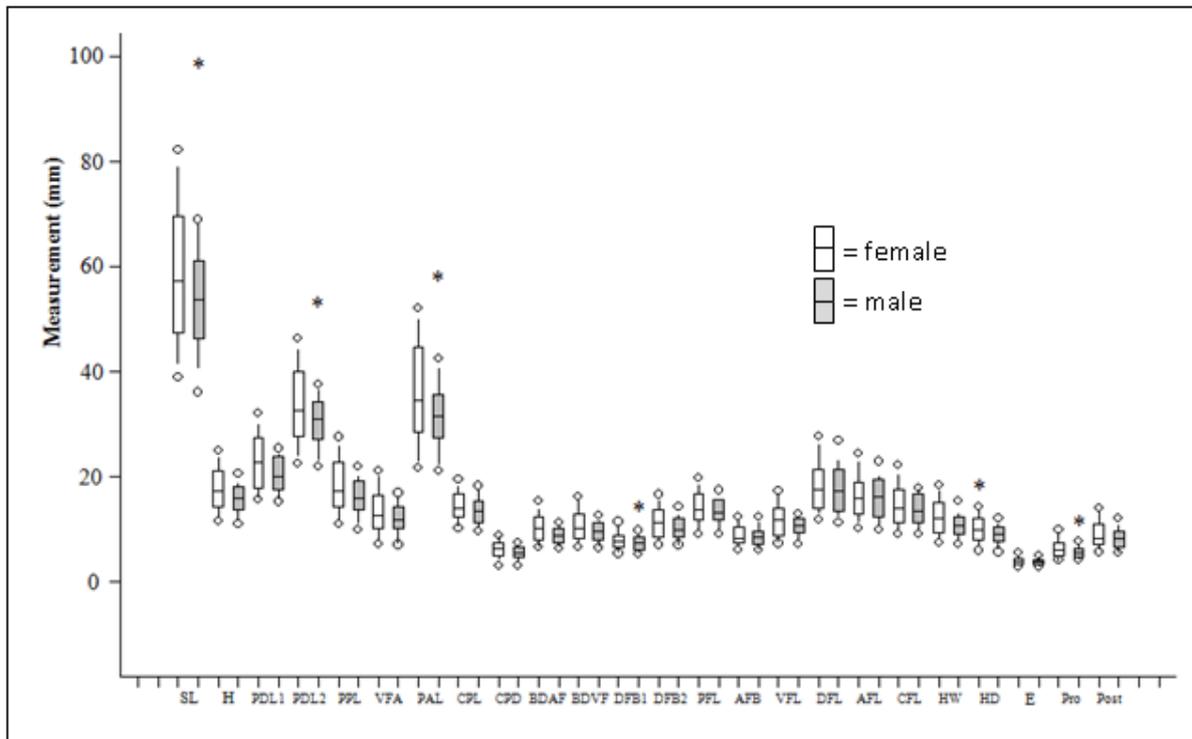
A high proportion of specimens correctly classified into their original group was computed ( $X = 84\%$ ) by the cross-validation testing procedure, with a 100% correct assignment rate was recorded for MM. Misclassification percentage was very low ( $X = 5.0\%$ ; range: 0–39%) (Table 3). As identified by PCA, the sexual difference in metric characters was realized in longer snout-to-2<sup>nd</sup> DFL, snout-to-AFL, and deeper BD of females, whereas males have longer median fins (anal fin and 2<sup>nd</sup> dorsal fin). The metric characters were marked with the same positive sign and were of similar magnitude, indicating that these metric characters are influenced by size-related variation.



**Fig. 1.** Morphometric measurements from the left side of the (A) body, (B) fins, and (C) head of *Glossogobius celebius*. Modified pictures from Herre (1927) and Corpuz (2011).

In CV plot (Fig. 4), mature specimens of both sexes had clearly more scattered scores indicating higher phenotypic plasticity of mature specimens than that of immature specimens. Clustering of groups as inferred by the increased distance between the left and right readings in CV1 can be associated with maturation-linked morphological variation (maturity group heterogeneity), which is mainly derived from

the posteriorly-located anal fin and 2<sup>nd</sup> dorsal fin, and dorsal fin length. Notably, morphological differentiation between IM and IF is inconspicuous, whereas variation between sexes of mature specimens (up and down reading) can be explained mainly by elongated 2<sup>nd</sup> dorsal fin. Hence, the length of the 2<sup>nd</sup> dorsal fin also serves as an indicator of maturation in this species.



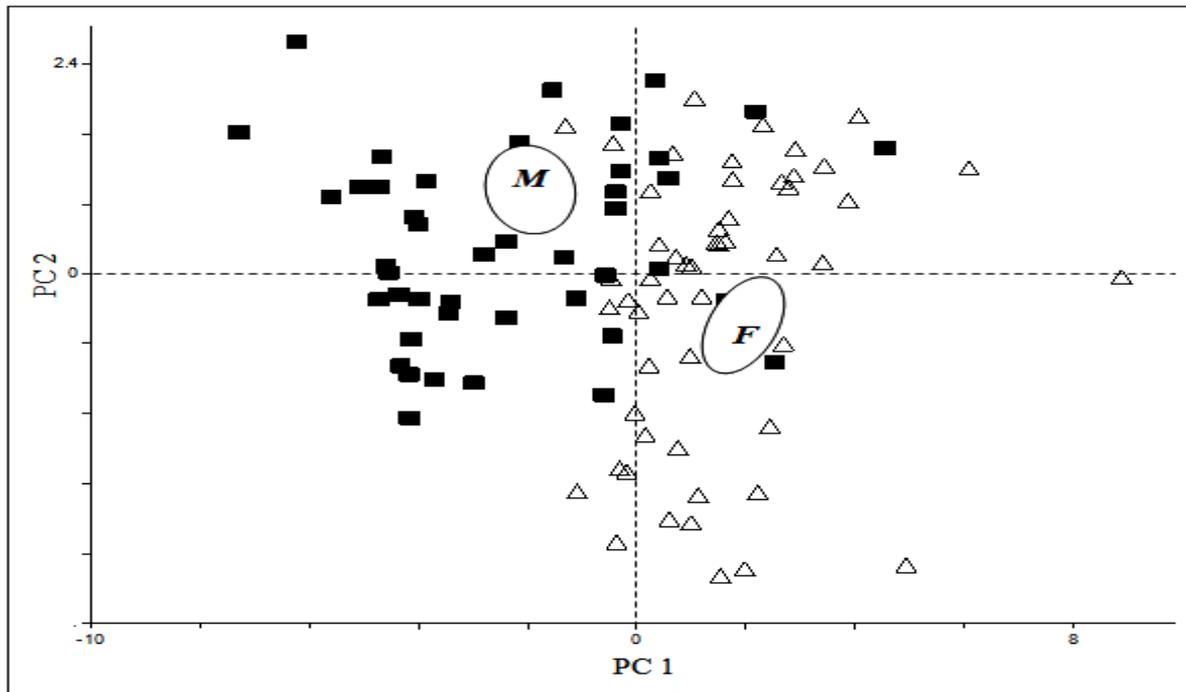
**Fig. 2.** Box plot of morphometric characters of females and males *Glossogobius celebius*. outliers = (\*), 5<sup>th</sup> and 95<sup>th</sup> percentiles = (o).

#### Growth coefficients and condition factor

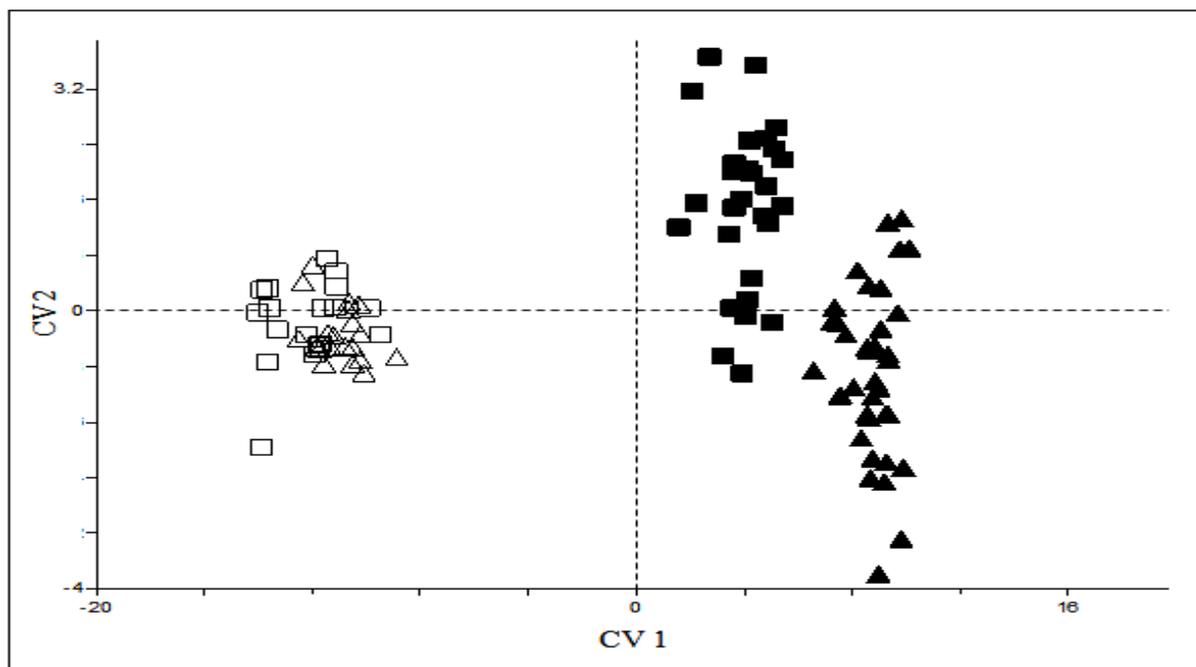
Isometric growth was observed in  $PFL_{MM}$  ( $b = 1.04$ ),  $PDL2_{MF}$  ( $b = 0.95$ ),  $AFL_{MM}$  ( $b = 1.08$ ), and  $AFL_{MF}$  ( $b = 1.10$ ), ( $t$  test of  $b = 1$ ,  $t < 4.30$ ,  $p > 0.05$ ). Positive allometric growth was computed for  $DFL_{MM}$  ( $b = 1.24$ ),  $DFL_{MF}$  ( $b = 1.14$ ), and  $PFL_{MF}$  ( $b = 1.14$ ), while negative allometric growth was observed for  $PDL2_{MM}$  ( $b = 0.91$ ). The ANCOVA revealed a highly statistical difference between sexes of mature specimens for  $DFL$  ( $F_{1, 64} = 29.77$ ,  $p < 0.01$ ),  $PDL2$  ( $F_{1, 64} = 11.17$ ,  $p < 0.01$ ),  $PAL$  ( $F_{1, 64} = 10.99$ ,  $p < 0.01$ ), and  $AFL$  ( $F_{1, 64} = 25.42$ ,  $p < 0.01$ ).

The LWR of males ( $b = 2.99$ ,  $p < 0.05$ ) and females ( $b = 3.03$ ,  $p < 0.05$ ) were relatively homogenous,

displaying isometric growth rate. The overall relative condition factor of *G. celebius* specimens ( $K = 1.012$ ) was higher than the ideal threshold of  $K$  value of 1.0, signifying the well-being of the collected fish specimens. The distinctive variation in the relative length of the anterior body parts and median fins between sexes may reflect the importance of reproductive roles in sexually dimorphic gobies. In females, the allometric growth of the abdomen can be influenced by maturation and spawning oocytes, making the females' bodies longer and ventrally deeper than males. As for males, the 2<sup>nd</sup> dorsal fin and anal fin are essential for their lateral advertisement during their courting phase and egg incubation.



**Fig. 3.** Group centroids (5% ellipses) and plot of first and second principal component scores (PC) scores of size-adjusted metric characters from sex sample groups of *Glossogobius ceblebius*. Female: ( $\Delta$ ); male: ( $\blacksquare$ ). PC1 = 50.67% variation; PC2 = 14.82% variation.



**Fig. 4.** Plot of first and second canonical variate (CV) scores of size-adjusted metric characters from four sample groups of *Glossogobius ceblebius*. Immature female: ( $\Delta$ ); mature female: ( $\blacktriangle$ ); immature male: ( $\square$ ); mature male: ( $\blacksquare$ ). CV1 = 98.83% variation; CV2 = 1.12% variation.

This behavior of displaying the erected median fins (1<sup>st</sup> dorsal, 2<sup>nd</sup> dorsal, and anal fins) by males has been reported in other gobiid species (Charlebois *et al.*, 1997; Jones and Reynolds, 1999). This lateral

displaying of mature males was also observed in the laboratory in the form of indefinite yellow to orange coloration at the periphery of the expanded median fins. Aside from the maturation-related morphology

and growth rate, the observed intersexual variation may be linked to nutritional status and environmental stress. Males do not feed during egg incubation (Miller, 1984) and this prolonged starvation may lead to emaciation and skin ulceration. Hence, poor health conditions may result in fluctuating deformation in anterior body parts and abdominal region, which was observed in several MM specimens. Morphometric plasticity and variability in length-weight factor in fishes are the repercussions of several interplaying environmental variables including habitat heterogeneity (Corpuz, 2011), the seasonal effect (De Leon *et al.*, 2017; Santos *et al.*, 2020), and the degree of stomach fullness (Tesch, 1971; Santos *et al.*, 2020).

Recent field surveys reported the fluctuating environmental and habitat variables in the collection sites (Romero *et al.*, 2016; Rabadon and Corpuz, 2021), albeit only providing narrow information on the ecological health status of the river. Nonetheless, the correlation of the abovementioned environmental parameters to linear metric characters, LWR, and K of *G. celebius* are subject for further studies.

### Conclusion

This preliminary study divulged the sexual dimorphism of *G. celebius* as evidenced by the dissimilarity of their median fins and body morphometry. These observations were more pronounced in mature specimens. The present study also provided evidence of the good condition of Orani River as inferred from the fish estimated growth coefficients and relative length-weight factor. The baseline information assessed the population structure of *G. celebius* which can be valuable for improved management of this important fishery resource.

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### References

- Alcabedos RM, Dela Viña CB, Reyes RC, Laude RP.** 2017. Genetic diversity within and among natural populations of five gobies based on cytogenetic and isozyme analyses. *Philippine Science Letters* **10(1)**, 58–71.
- Ardestani G, Rogelio DR, Reyes RC, Laude RP.** 2014. Genetic diversity of two Philippine native freshwater goby species (Perciformes: Gobiidae): implications for conservation. *Aquatic Conservation Marine and Freshwater Ecosystems* **24(5)**, 592–600. <http://dx.doi.org/10.1002/aqc.2462>
- Aya FA, Corpuz MNC, Laron MA, Garcia LBM.** 2017. Larval and early juvenile development of silver therapon, *Leiopotherapon plumbeus* (Actinopterygii: Perciformes: Terapontidae), reared in mesocosms. *Acta Ichthyologica et Piscatoria* **47(4)**, 347–356. <http://dx.doi.org/10.3750/AIEP/02222>
- Blanco GJ.** 1956. Assay of the goby fry (ipon) fisheries of the Laoag River and its adjacent marine shores, Ilocos Norte Province. *Philippine Journal of Fisheries* **4**, 31–80.
- Charlebois PM, Marsden JE, Goettel RG, Wolfe RK, Jude DJ, Rudnika S.** 1997. The round goby *Neogobius melanostomus* (Pallas). A review of European and North American Literature. Illinois-Indiana Sea Grant Program and Illinois Natural History Survey. INHS Special Publications. Champaign, IL. **20**, 76.
- Corpuz MNC.** 2011. Morphological variations, sexual dimorphism, and gonadal analysis of populations of the Celebes Goby, *Glossogobius celebius* (Perciformes: Gobiidae) from Southern Luzon, Philippines. MSc thesis, University of the Philippines Los Baños, College, Laguna, Philippines. (Available at the UPLB Library). <http://dx.doi.org/10.13140/RG.2.2.22326.96321>
- Corpuz MN, Camacho MV, Ocampo PP.** 2013. Morphometric and morphomeristic variations in five

populations of indigenous Celebes goby *Glossogobius celebius* (Perciformes: Gobiidae) from southern Luzon, Philippines. The Philippine Agricultural Scientist **96(1)**, 75–85.

<http://dx.doi.org/10.1111/j.1095-8649.2009.02314.x>

**Corpuz MNC, Paller VGV, Ocampo PP.** 2015. Environmental variables structuring the stream gobioid assemblages in the three protected areas in southern Luzon, Philippines. Raffles Bulletin of Zoology **63**, 357–365.

**Corpuz MNC, Paller VGV, Ocampo PP.** 2015. Ichthyofaunal survey in selected freshwater habitats in Camarines Sur, Philippines. Asian Journal of Biodiversity **6**, 80–99.

<http://dx.doi.org/10.7828/ajob.v6i1.696>

**Corpuz MNC, Paller VGV, Ocampo PP.** 2016. Diversity and distribution of freshwater fish assemblages in Lake Taal River system in Batangas, Philippines. Journal of Environmental Science and Management **19(1)**, 85–95.

[http://dx.doi.org/10.47125/jesam/2016\\_1/09](http://dx.doi.org/10.47125/jesam/2016_1/09)

**De Leon KJA, Manliclic ADC, Corpuz MNC.** 2017. Spatial and sexual variation on morphometrics, length and weight, and condition factor dynamics of endemic silver tharapon (*Leiopotherapon plumbeus*, Kner). International Journal of Agricultural Technology **13(7)**, 1567–1577.

**Elliot NG, Haskard K, Koslow JA.** 1995. Morphometric analysis of orange roughy (*Haplostethus atlanticus*) off the continental slope of southern Australia. Journal of Fish Biology **46**, 202–220.

<http://dx.doi.org/10.1111/j.10958649.1995.tb05962.x>

**Froese R, Pauly D.** 2018. FishBase. World Wide Web electronic publication. Available at: <http://www.fishbase.org>, Accessed date: 20 August 2018.

**Hammer O, Harper DAT, Ryan PD.** 2001. PAST:

Paleontological Statistics software package for education and data analysis. Palaeo Electronica **4**, 1–9.

**Herre AH, ed.** 1927 Gobies of the Philippines and the China Sea. Monograph Bureau of Science Manila. Bureau of Printing, Manila. 352.

**Islam MN.** 2004. Eco-biology of freshwater gobi, *Glossogobius giuris* (Hamilton) of the River Padma in relation to its fishery: a review. Journal of Biological Sciences **4**, 780–793.

<http://dx.doi.org/10.3923/jbs.2004.780.793>

**Jones JC, Reynolds JD.** 1999. Costs of egg ventilation for male common gobies breeding in conditions of low dissolved oxygen. Animal Behavior **57**, 181–188.

<http://dx.doi.org/10.1006/anbe.1998.0939>

**Le Cren ED.** 1951. The length–weight relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal of Animal Ecology **20**, 201–219.

<http://dx.doi.org/10.2307/1540>

**Mashiko K, Yamane S.** 1993. Sexual dimorphism in the goby *Tridentiger kuroiwae brevispinis*. Japan Journal of Ichthyology **40**, 363–368.

**Miller PJ.** 1984. The tokology of gobioid fishes. In Fish Reproduction Strategies and Tactics. Academic Press, London. Edited by Potts GW, Wootton RJ. 119–153.

**Paller VV, Ocampo PP, Corpuz MNC.** 2011. Fish Ark Philippines: direction for the conservation of native and endemic Philippine Freshwater Fishes Project 1: Survey of diminutive freshwater fishes indigenous to isolated crater lakes, mountain crater lakes, mountain streams and cataracts in Southern Luzon, Philippines. Accessed date: December 2018.

<http://agris.fao.org/agrissearch/search.do?recordID=PH2012000274>.

**Rabadon MLL Corpuz MNC.** 2021. Multivariate analyses of selected hydro-bacterial variables along the longitudinal gradient of Orani River, Philippines. IOP Conference Series Earth and Environmental Science **798(1)**, 012004.1.

<http://dx.doi.org/10.1088/1755-1315/798/1/012004>

**Ricker WE.** 1973. Linear regressions in fishery research. Journal of Fisheries Research Board of Canada **30**, 409–434.

<http://dx.doi.org/10.1139/f73-072>

**Romero CS, Villaflor KC, Dela Rosa D, Corpuz MNC.** 2016. Environmental variables affecting the riverine ichthyofaunas and macroinvertebrate communities in Orani river systems (Tala-Silahis continuum), Bataan, Philippines. 2nd International Conference in Research, Education, Management, and the Social Sciences, Harbour Hotel, Canal Road, Subic Bay Freeport Zone, Zambales p 31-48.

**Santos DA, Manliclic ADC, Corpuz MNC.** 2020. Length-weight relationship and condition factor of silver therapon, *Leiopotherapon plumbeus*

(Terapontidae) from two brackishwater habitats. AACL Bioflux **13(2)**, 1495–1503.

**Silva MN, Gordo LS.** 1997. Age, growth and reproduction of the black goby, *Gobius niger* from Obidos Lagoon, Portugal. Cahiers de Biologie Marine **38**, 175–180.

**Susatyo P, Setyaningrum N, Winarni E, Chasanah T, Atang T.** 2018. Reproduction characteristics of ricefield eel (*Monopterus albus* Zuiewu) on several functionally changed lands in Banyumas Regency. Journal of Tropical Life Science **8(2)**, 177–186.

<http://dx.doi.org/10.11594/jtls.08.02.12>

**Tesch FW.** 1971. Age and growth. In: Methods for Assessment of Fish Production in Fresh Waters. Blackwell Scientific Publications, Oxford. Edited by Ricker E. 99–130.