

Research Paper

Morphology of Goby Species, *Glossogobius celebius* (Valenciennes 1837) and *Glossogobius giuris* (Hamilton 1822) in Lake Lanao Mindanao, Philippines

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Abstract

Morphological differences between two introduced species of freshwater gobies, *Glossogobius celebius* (Valenciennes 1837) and *Glossogobius giuris* (Hamilton 1822) were investigated in Lake Lanao. To achieve this, 24 morphometric measurements were made on each of the studied fish specimens (27 *Glossogobius celebius* and *Glossogobius giuris*). The results showed that the entire morphometric characters measured in both sexes within the two species were not significantly different ($P < 0.05$), male and female were not sexually dimorphic with apparent distinctions on their morphological attributes, particularly on their differences in sizes and lengths. And with the body proportionality between sexes of *G. celebius*, females compared to males had a relatively higher percentage of uncorrelated morphometric character which implies that the females' morphological attributes may have experienced slight changes over the Lake Lanao and males' morphological attributes were highly proportional regardless of their spatial distribution. With these, well-proportioned body structure in males would illustrate an attractive physical attribute that may help in the courtship of males to females. Meanwhile, in *Glossogobius giuris* body proportionality between the two sexes was in contrast with the *Glossogobius celebius* for the males were the ones to have a higher percentage of uncorrelated morphometric character than females. The results can provide a solid base for the identification, rational management, breeding and conservation of the two fish species.

Keywords: body proportionality; *Glossogobius*; gobies; morphometric; sexual dimorphism.

Introduction

Gobies represent the most diverse group among the freshwater fishes in the country, with about 16 species known to occur only in the Philippines^[1, 2]. The teleostei family Gobiidae, is one of the largest fish family that has more than 2,000 species in more than 200 genera. The indo-pacific genus *Glossogobius* is the most represented genera of gobioid species comprising of approximately fifty species^[3]. The species are easily identified by the presence of its unique feature that is a fused pelvic fin at the antero-ventral portion of the body that serves as a suction-like disc that allows them to dwell at the bottom substrate and for attachment to rocks or reefs. The species in *Glossogobius* genera resemble one another through as observation of the arrangement of the sensory canal pores and pit organ that is

essential for identification of the species. The difficulty of distinguishing between closely related species in a same genus was best described in the case of *Glossogobius aureus*^[4,5].

Extensive studies on gobioid fishes are available from many regions of the world^[6, 7, 8, 9]. In the Philippine setting particularly in Mindanao Island, goby fishes are less studied in which the last reference of the goby study and its life cycle was done by Manacop^[10] along the Cagayan de Oro River. Goby species represent the most abundant freshwater fish in the country which include the *Glossogobius celebius* (Valenciennes 1837) and *Glossogobius giuris* (Hamilton 1822). These species were considered as invasive species since they out-compete the native species populations for common food sources, habitat, and spawning sites which could possibly lead to extirpation of the native species present in rivers and lakes. Three invasive freshwater fishes have been accidentally introduced to Philippine lakes including the Lake Lanao, Lanao Del Sur^[11]. These invasive species are the native white goby (*Glossogobius giuris*) and the eleotrid (*Hypseleotris agilis*), and the exotic Asiatic/Thai catfish (*Clarias batrachus*). The two former species were responsible for the loss of the endemic cyprinids in Lake Lanao^[12]. Several other indigenous species as well as the highly invasive golden apple snail that was accidentally introduced in Lake Lanao has become invasive on endemic species. In just a span of 27 years, the cyprinid species in Lake Lanao has suffered a massive decline in their population of about 97.7% loss of endemic cyprinids^[13] prior to the accidental introduction of goby fishes during 1960's.

Lakes are restricted bodies of water and the introduced invasive freshwater fish populations living in such lake are also restricted to the limit provided by that environment and may have adopted over the years which are isolated from other freshwater fish populations of the same species. An attempt has been made to determine the body shape variation among the populations of goby populations in Lake Lanao and Lake Buluan, Mindanao, Philippines^[14] but there has been no attempt made to determine the apparent distinction of goby fish on their morphological attributes and determination of sexual dimorphism. Female goby may favor the males with an extreme expression of traits and this can remain reasonably through time is that males are considerably has exceptional morphometric variation than females. However, various fish taxa can have different sizes in both male and female and this trait is largely dependent on temperature on the water that there are small and large fish at almost all temperatures^[15]. This study examines the morphometric variation among individuals of the same species, both male and female, of *G. celebius* and *G. giuris* to assess the shape differences and sexual dimorphism after five decades prior to its accidental introduction to Lake Lanao, Mindanao, Philippines.

Geometric morphometry is a technique widely used among anthropologists and ichthyologists and, more recently, mammalogists. The advantage of this method when conducting a morphometric study is that it not only allows the investigator to measure size but also to look at the shape of the organism "using as data, point coordinates in two or three dimensions"^[16]. In this study, morphometry of males and females were used to evaluate whether these species of invasive goby establish sexual dimorphism and shape differences.

Materials and Methods

Sampling Area

Lake Lanao or Lake Ranaw (Figure 1) with coordinates of 7.8919° N, 124.2525° E is the second largest freshwater lake in the Philippines and is considered one of the deepest lakes in the Philippine archipelago. This lake is situated in the Province of Lanao del Sur, in the heart of Mindanao at 701.35 meters above sea level. It has an area of 354.60 square kilometers and a mean depth of 60 meters, with the deepest part at 112 meters. It used to be home to 18 endemic fish and are now extinct.

Collections of Goby Specimens

The samples were collected from different parts of the lake between the months of January to February 2013. The methods are intensive, ingenious and diverse: using a net held from two boats, several varieties of handheld spear and modified crossbow used by divers and the one most used is using a handheld seine, measuring 3 m by 1.5 m with 3.5 mm mesh and a heavy lead line, was used for the

collection of goby specimens. Seining was performed by three field assistants: two held each pole, while the other one had disturbed the substrate for fish to be caught in the net. Other methods used were small improvised spear guns, use of cast and stationary nets, use of kerosene- powered lamps for goby fishing and hook and line with earthworm baits.

Only 15 *G. celebius* (nine female and six male) of and 27 *Glossogobius giuris* (10 female and 17 male) were captured. Figure 2 shows the goby species captured at each collection site and were subjected to morphometric measurements.

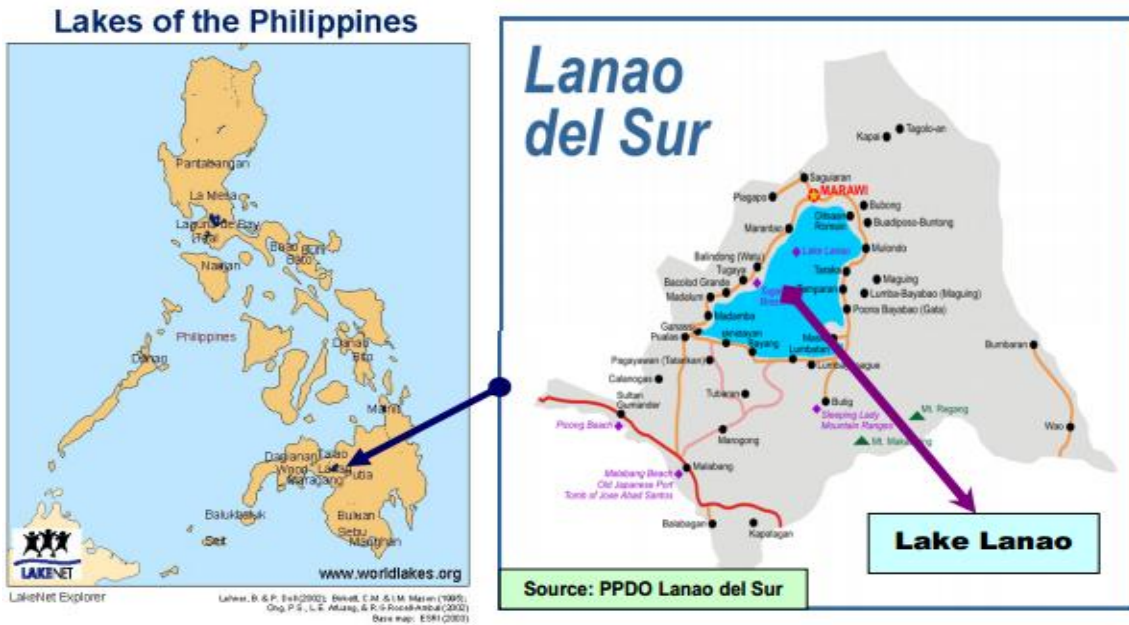


Figure 1: Map showing the Lake Lanao



Figure 2: (A) *Glossogobius celebius* and (B) *Glossogobius giuris* species

Morphometric Analyses

Twenty four morphometric characters (Figure 3) were used: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWAO), head depth (HD), head width (HW), and eye diameter (E). All measurements were rounded-off to nearest 0.01 mm using a vernier caliper, and measurements obtained were entered into a designated data sheet.

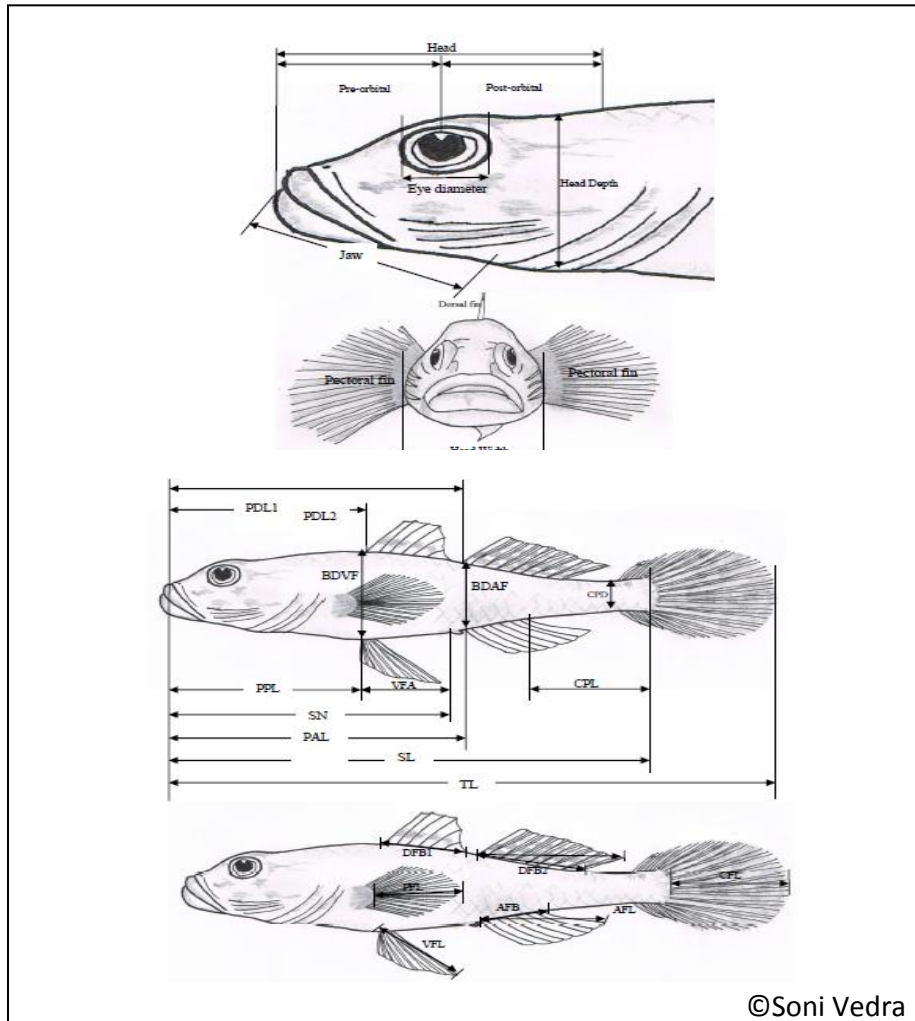


Figure 3: Morphometric characters used in the morphological descriptions on the indigenous goby population (adapted from Corpuz 2010): total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), and anal fin length (AFL) head depth (HD), head width (HW), and eye diameter

Statistical Analyses

Correlation analysis was employed for determining the different morphometric characters of each goby species to its body proportionality. The paired T - test was used for sexual dimorphism for each goby species per site per observation period. Statistical analysis was performed with the aid of the SPSS computer program (version 16.0 windows).

Results and Discussion

Sexual dimorphism between Male and Female

The most distinctive difference between the two species is the shape of their caudal fins, with *G. celebius* has fins that are more pointed (spear-like) while *G. giurus* have fins that are less pointed. Moreover, *G. celebius* has a larger head and fuller and rounded cheeks^[17].

The entire morphometric characters measured in both sexes within the two species of goby were not significantly different ($P < 0.05$) (Table 1) and (Table 2). This implies that male and female were not sexually dimorphic with apparent distinctions on their morphological attributes, particularly on their differences in sizes and lengths. Male and female in both goby species were not subjected to change prior to its introduction in the lake despite to its isolation in the lake for three decades or by pollution impacts rampant in the area and other unknown factors. Their domination and capable of out-competing the native species in the area does not also affect the morphology of male and female of these two goby species. However, differences in color and genital papillae may provide instant distinctions on their sexual attribute.

Glossogobius celebius body proportionality

In females *G. celebius*, only 9.45% not significantly correlated in $p > 0.05$ whereas the rest were highly correlated in $p < 0.01$. Among all morphometric characters measured, SL and DFB1 that constitute 100% had the most number of no significant correlations with the remaining 22 morphometric characters. (Table 3).

In males, all morphometric characters measured were significantly correlated to each other at $p > 0.01$ except for only 8.31% not significantly correlated. SL constitute 100%, is the only morphometric character that had no significant correlations with the other characters. HL PDL1 , PDL2, PPL , PAL , SA , VFA , CPL , CPD, DFB1 , DBF2 , AFB , CFL , PFL , VFL, AFL, BDPO, BDAF, BWAF, HD, HW, and E. (Table 4).

Between the sexes, females compared to males had a relatively higher percentage of uncorrelated morphometric character were measured. This only means that the females' morphological attributes may have experienced slight changes over the Lake Lanao. This might be due to their success rates in fecundity and spawning. Whereas, there is a high significant correlation to all morphometric characters measured in the males. This means that males' morphological attributes were highly proportional regardless of their spatial distribution in the Lake Lanao. With these, well-proportioned body structure in males would illustrate an attractive physical attribute that may help in the courtship of males to females which will in turn results into a successful spawning.

Table 1: Morphometric parameters of *Glossogobius celebius*

| Characters (%TL) | MALE | FEMALE | T VALUE | P VALUE |
|---------------------|--------------|---------------|---------|---------|
| Morphometric | | | | |
| SL | 81.009±2.446 | 79.796±0.509 | 0.441 | 0.670 |
| HL | 24.308±0.965 | 22.796±0.900 | 1.025 | 0.332 |
| PDL1 | 31.829±1.145 | 31.114±0.823 | 0.459 | 0.657 |
| PDL2 | 48.176±1.519 | 47.766±0.535 | 0.227 | 0.826 |
| PPL | 27.014±1.063 | 26.679±0.538 | 0.271 | 0.793 |
| PAL | 49.042±1.644 | 49.129±0.742 | 0.042 | 0.968 |
| SA | 44.697±1.778 | 43.838±1.223 | 0.499 | 0.629 |
| VFA | 19.632±0.828 | 19.797±0.676 | 0.126 | 0.902 |
| CPL | 16.620±0.865 | 16.669±0.739 | 0.050 | 0.961 |
| CPD | 7.275±0.258 | 7.097±0.334 | 0.519 | 0.616 |
| DFB1 | 11.368±0.594 | 11.171±0.767 | 0.229 | 0.824 |
| DFB2 | 17.416±0.733 | 17.339±0.756 | 0.064 | 0.951 |
| AFB | 13.530±0.714 | 12.938±0.386 | 0.756 | 0.469 |
| CFL | 21.892±1.205 | 20.113±0.785 | 1.210 | 0.257 |
| PFL | 17.398±0.628 | 17.469±0.690 | 0.074 | 0.943 |
| VFL | 16.227±0.871 | 16.561±0.520 | 0.414 | 0.689 |
| AFL | 21.143±1.465 | 20.098±01.444 | 0.814 | 0.437 |
| BDPO | 14.029±0.660 | 12.198±0.629 | 2.586 | 0.029 |
| BDAF | 12.422±0.545 | 11.626±0.438 | 1.213 | 0.256 |
| BWAF | 10.372±0.644 | 9.564±0.558 | 1.395 | 0.197 |
| HD | 12.019±0.514 | 11.519±0.459 | 1.030 | 0.330 |
| HW | 13.097±0.651 | 12.136±0.370 | 1.100 | 0.300 |
| E | 4.664±0.236 | 4.699±0.246 | 0.104 | 0.920 |

* Significantly different at α 0.05

Descriptions: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWAO), head depth (HD), head width (HW), and eye diameter (E).

Table 2: Morphometric parameters of *Glossogobius giuris*

| CHARACTERS (% TL) Morphometric | MALE | FEMALE | T VALUE | P VALUE |
|--------------------------------------|---------------|--------------|---------|---------|
| SL | 78.690±0.316 | 79.03±1.060 | 1.106 | 0.319 |
| HL | 24.407±0.619 | 25.070±0.453 | 0.858 | 0.430 |
| PDL1 | 31.605±2.355 | 31.605±0.350 | 0.338 | 0.749 |
| PDL2 | 45.387±0.626 | 46.569±0.309 | 1.861 | 0.122 |
| PPL | 25.696±1.595 | 25.089±0.442 | 0.450 | 0.672 |
| PAL | 48.264±0.583 | 49.932±0.430 | 2.640 | 0.460 |
| SA | 43.425±0.343 | 45.291±0.537 | 3.094 | 0.270 |
| VFA | 23.124±5.251 | 21.307±0.471 | 0.349 | 0.741 |
| CPL | 24,115±3.161 | 19.640±0.720 | 1.211 | 0.280 |
| CPD | 7.986±0.169 | 7.776±0.201 | 0.597 | 0.577 |
| DFB1 | 12.068±0.532 | 12.846±0.676 | 1.025 | 0.353 |
| DBF2 | 16.226±0.137 | 16.526±0.254 | 1.041 | 0.346 |
| AFB | 12.906±0.355 | 12.189±0.203 | 1.623 | 0.166 |
| CFL | 20.787±0.362 | 20.677±0.886 | 0.103 | 0.922 |
| PFL | 17.067±0.566 | 15.809±0.402 | 3.711 | 0.114 |
| VFL | 14.069±0.983 | 16.630±0.826 | 2.069 | 0.093 |
| AFL | 23.459±0.834 | 21.905±1.709 | 0.940 | 0.390 |
| BDPO | 11.946±0.283 | 12.808±0.304 | 2.509 | 0.054 |
| BDAF | 12.385±0.149 | 18.816±6.357 | 1.015 | 0.357 |
| BWAF | 10.186±0.0336 | 11.157±0.174 | 2.323 | 0.068 |
| HD | 11.160±0.326 | 11.414±0.269 | 0.426 | 0.688 |
| HW | 13.213±0.354 | 13.277±0.516 | 0.095 | 0.928 |
| E | 3.675±0.184 | 3.653±0.185 | 0.179 | 0.865 |

* significantly different at α 0.05

Descriptions: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWAO), head depth (HD), head width (HW), and eye diameter (E).

Table 3: Modified correlation matrix on the morphometric characters of the female *G. celebius*

| | S L | H L | P D L 1 | P D L 2 | P P L | P A L | S A | V F A | C P L | C P D | D F B 1 | D F B 2 | A F B | C F L | P F L | V F L | A F L | B D P O | B D A F | B W A F | H D | H W | E |
|----------|--------|--------|------------------|------------------|-------------|-------------|--------|-------------|-------------|-------------|------------------|------------------|-------------|-------------|-------------|-------------|-------------|------------------|------------------|------------------|--------|--------|--------|
| SL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| HL | Green | Yellow | Blue | Red | Blue | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| PDL1 | Green | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| PDL2 | Green | Red | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Red | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Red | Blue | Blue | Red |
| PPL | Green | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| PAL | Green | Green | Blue | Blue | Blue | Yellow | Blue | Red | Red | Green | Blue | Blue | Red | Blue | Red | Red | Blue | Red | Red | Red | Red | Red | Red |
| SA | Green | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| VFA | Green | Blue | Blue | Blue | Blue | Red | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| CPL | Green | Blue | Blue | Blue | Blue | Red | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| CPD | Green | Blue | Blue | Red | Blue | Green | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| DFB1 | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| DBF2 | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| AFB | Green | Blue | Blue | Blue | Blue | Green | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| CFL | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| PFL | Green | Blue | Blue | Blue | Blue | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| VFL | Green | Blue | Blue | Blue | Blue | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue | Blue |
| AFL | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue | Blue |
| BDP O | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue | Blue |
| BDAF | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue | Blue |
| BWA F | Green | Blue | Blue | Red | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue | Blue |
| HD | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue | Blue |
| HW | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow | Blue |
| E | Green | Blue | Blue | Red | Blue | Green | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Blue | Yellow |

Legend:

- Correlation is significant at the 0.01 level
- Correlation is significant at the 0.05 level
- Same value correlated
- Not significantly correlated

Descriptions: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWA), head depth (HD), head width (HW), and eye diameter (E).

Table 4: Modified correlation matrix on the morphometric characters of the male *G. celebius*

| | S L | H L | P D L 1 | P D L 2 | P P L | P A L | S A | V F A | C P L | C P D | D F B 1 | D F B 2 | A F B | C F L | P F L | V F L | A F L | B D P O | B D A F | B W A F | H D | H W | E |
|------|--------|--------|------------------|------------------|-------------|-------------|--------|-------------|-------------|-------------|------------------|------------------|-------------|-------------|-------------|-------------|-------------|------------------|------------------|------------------|--------|--------|--------|
| SL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| HL | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PDL1 | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PDL2 | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PPL | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PAL | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| SA | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| VFA | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CPL | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CPD | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| DFB1 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| DFB2 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| AFB | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green |
| VFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green |
| AFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green |
| BDPO | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green |
| BDAF | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green |
| BWAF | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green |
| HD | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green |
| HW | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green |
| E | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow |

Legend:

- Correlation is significant at the 0.01 level
- Same value correlated
- Not significantly correlated
- Correlation is significant at the 0.05 level

Descriptions: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWAO), head depth (HD), head width (HW), and eye diameter (E).

Glossogobius giuris Body Proportionality

Results on the analysis of body proportionality of female *G. giuris* revealed that 91.68% out of all morphometric characters measured were not significantly correlated ($P>0.05$), while the rest were highly correlated ($P<0.01$) (Table 5). In males, 95% of the morphometric characters measured were not significantly correlated ($P>0.05$) (Table 6). Based on the morphometric characters measured, males had relatively higher percentage of no significant correlation than females. This implies that the males were the ones that may experience some morphological changes across the Lake Lanao. Males with relatively low correlations on their morphometric characters might not possess a well-proportioned body structure, which can't probably attract the females and in turn, can't help attain successful courtship, mating and successful spawning.

Table 5: Modified correlation matrix on the morphometric characters of the female *G. giuris*

| | S L | H L | P D L 1 | P D L 2 | P P L | P A L | S A | V F A | C P L | C P D | D F B 1 | D F B 2 | A F B | C F L | P F L | V F L | A F L | B D P O | B D A F | B W A F | H D | H W | E | |
|----------|--------|--------|------------------|------------------|-------------|-------------|--------|-------------|-------------|-------------|------------------|------------------|-------------|-------------|-------------|-------------|-------------|------------------|------------------|------------------|--------|--------|--------|--------|
| SL | Yellow | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Blue | Blue | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| HL | Green | Yellow | Green | Blue | Green | Green | Green | Green | Green | Blue | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PDL1 | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green |
| PDL2 | Green | Blue | Green | Yellow | Green | Green | Green | Green | Blue | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PPL | Green | Green | Green | Green | Yellow | Green | Green | Blue | Green | Green | Green | Green | Red | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green |
| PAL | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| SA | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green |
| VFA | Green | Green | Green | Green | Blue | Green | Green | Yellow | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CPL | Red | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Blue | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CPD | Green | Blue | Green | Blue | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| DFB1 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Red | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red |
| DBF2 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Yellow | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| AFB | Green | Green | Green | Green | Red | Green | Green | Red | Green | Red | Red | Red | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CFL | Blue | Green | Green | Green | Green | Green | Green | Green | Blue | Green | Green | Green | Green | Yellow | Red | Red | Green | Green | Green | Green | Green | Green | Green | Green |
| PFL | Blue | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Red | Yellow | Green | Green | Green | Green | Green | Green | Green | Red | Green |
| VFL | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Yellow | Green | Green | Red | Green | Green | Green | Green | Green |
| AFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green |
| BDP O | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green |
| BDAF | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Yellow | Green | Green | Blue | Green | Green |
| BWA F | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green |
| HD | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green |
| HW | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Blue | Green | Green | Green | Yellow | Green |
| E | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Yellow |

Legend:

- Correlation is significant at the 0.01 level
- Correlation is significant at the 0.05 level
- Same value correlated
- Not significantly correlated

Descriptions: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWAO), head depth (HD), head width (HW), and eye diameter (E).

Table 6: Modified correlation matrix on the morphometric characters of the male *G. giuris*

| | S L | H L | P D L 1 | P D L 2 | P P L | P A L | S A | V F A | C P L | C P D | D F B 1 | D F B 2 | A F B | C F L | P F L | V F L | A F L | B D P O | B D A F | B W A F | H D | H W | E |
|------|--------|--------|------------------|------------------|-------------|-------------|--------|-------------|-------------|-------------|------------------|------------------|-------------|-------------|-------------|-------------|-------------|------------------|------------------|------------------|--------|--------|--------|
| SL | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| HL | Green | Yellow | Green | Blue | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red |
| PDL1 | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Red | Green | Green | Green | Green |
| PDL2 | Green | Blue | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Red | Green | Green | Green | Green |
| PPL | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Blue | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| PAL | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green |
| SA | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green |
| VFA | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CPL | Green | Green | Green | Green | Blue | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| CPD | Green | Green | Green | Green | Green | Red | Green | Green | Green | Yellow | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| DFB1 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| DFB2 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| AFB | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Red | Red | Green |
| CFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green | Red |
| PFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green | Green |
| VFL | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green | Green |
| AFL | Green | Green | Green | Red | Green | Red | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green | Green |
| BDPO | Green | Green | Red | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green | Green |
| BDAF | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green | Green |
| BWAF | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green | Green |
| HD | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Yellow | Green | Green |
| HW | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Yellow | Green |
| E | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Green | Green | Green | Green | Green | Green | Green | Green | Yellow |

Legend:

- Correlation is significant at the 0.01 level
- Correlation is significant at the 0.05 level
- Same value correlated
- Not significantly correlated

Descriptions: total length (TL), standard length (SL), head length (HL), predorsal length (PDL1), snout to second dorsal fin origin (PDL2), prepelvic length (PPL), preanal length (PAL), snout to anus (SA), ventral fin to anus (VFA), caudal peduncle length (CPL), caudal peduncle depth (CPD), first dorsal fin base (DFB1), second dorsal fin base (DFB2), anal fin base (AFB), caudal fin length (CFL), pectoral fin length (PFL), ventral/pelvic fin length (VFL), anal fin length (AFL), body depth at pelvic origin (BDPO), body depth at anal fin origin (BDAO), body width at anal fin origin (BWAO), head depth (HD), head width (HW), and eye diameter (E).

Conclusion and Recommendations

Data on the morphometric characters were not significantly different from the two species of freshwater gobies. Body proportionality measures showed a well-proportioned body structure in *Glossogobius celebius*, which may be related to the success of their courting, mating and spawning behaviors not like the *Glossogobius giuris* showed a not proportioned body structure which may affect their different behaviors success.

The results of this study suggest that goby population in Lake Lanao establishes a successful domination among other endemic species and caused to its extinction. As being isolated in the Lake for several decades, they have propagated morphological adaptations despite of the various pollutants and contaminants that might lead to morphological differences of the goby populations. It is highly recommended to have a proper waste disposal, management and regulation of the people in Lake Lanao that might have some extreme impacts not only gobies wellbeing but also to their health as they are consuming these gobies.

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