Aspects of the Biology and Ecology of the Naujan White Goby *Glossogobius aureus* Akihito and Meguro, 1975

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Abstract

Glossogobius aureus is a potential aquaculture species with limited data from the Philippines. 3,340 individuals were collected over 2 years to describe the biological features of the species from Naujan Lake. Gonads were collected to measure fecundity; total lengths were taken, and photos of the left side of the individuals were taken. Length data were used to model the species growth dynamics using FiSAT (FAO-ICLARM Stock Assessment Tool). Geometric morphometrics was used to describe individual shape variation using the photos taken from the samples. Size frequency indicated that sexually mature individuals are at least 14 cm long with an average reproductive output of 20,000 eggs. Site-specific variation in shape indicates non-homogeneity of the population, which may be an environmental response to genetic variation. Morpho-meristic data and the FiSAT model L∞ to be 23.27 cm, with Z, F, and M at 12.12^{-yr}, 7.85^{-yr}, and 4.27^{-yr}, respectively. The current exploitation rate is estimated to be 0.65, higher than the theoretical sustainable exploitation rate (Emax). This paper is the first biological description of G. aureus from the Philippines.

Keywords*:* FiSAT, gonado-somatic index, geometric morphometric, native fish species, population dynamics

1. Introduction

Glossogobius aureus from Naujan Lake was first described by Akihito and Meguro (1975) from museum samples from several Southeast Asian countries like the Philippines, Indonesia, Malaysia, Thailand, Cambodia, and Taiwan, as well as samples from Australia and Papua New Guinea. Samples from the Philippines were sourced from Laguna Lake, Naujan Lake, Lake Buhi, Lake Lanao, and probably Lake Paoay from Ilocos Norte. The species closely resembles *Glossogobius giuris* except for their cheek papillae pattern. Multiple lines of check papillae, particularly lines 6, 7, 8, and 9, distinguish *G. giuris* from *G. aureus*, which only have singular lines. Males of *G. aureus* bear a dark spot on the last part of the first dorsal fin, while G. giuris individuals bear a dark spot on the first spine of the first dorsal fin (Akihito and Meguro, 1975; Hoese and Hammer, 2021).

The use of DNA barcoding identified the Naujan White Goby (NWG) (Abdulmalik-Labe and Quilang, 2019; Abdulmalik-Labe *et al*., 2022) as *G.* aureus. The species is one of the biggest members of the Gobiidae, underlining its commercial importance as a protein source. A burgeoning commercial product from NWG is the split-dried fish called *Daing na Biya* where a kilo may fetch a price as high as PHP 1,200. Interest in the product puts pressure on the resource, and aquaculture may be one approach to conserve and exploit this native species.

The species' size relative to other *gobiids* increases the potential of *G. aureus* as a new aquaculture species, thus the need for baseline biological data. Limited information so far is available. The species spawns year-round in Vietnam, with peaks from August to October (Dinh *et al*., 2021). Fecundity is 1044 – 27,349 eggs per female, with a length at first maturity (*Lm*) 11.29. Interestingly, *Lm* is inversely proportional to salinity levels. The species' longevity was computed at 4.47 years, with a natural mortality of 1.52 y^{-1}, and an exploitation rate of 0.64 (Dinh *et al*., 2021).

This study provides baseline data on the biology of *G. aureus* of Naujan Lake and may serve as a basis for aquaculture development.

2. Methodology

2.1 Collection Sites and Sampling

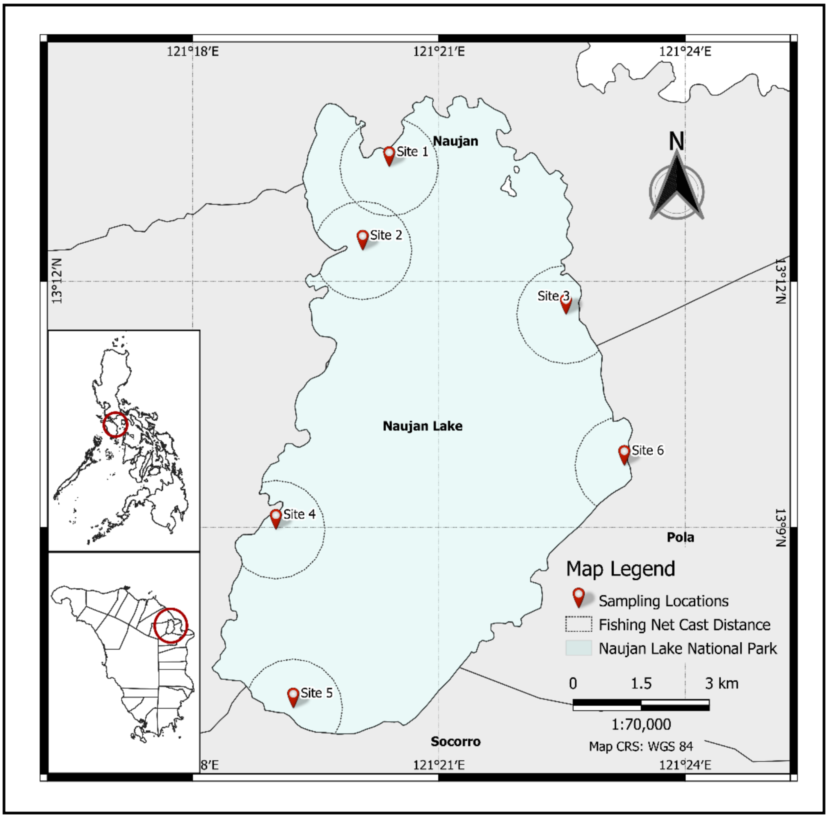

Figure 1. Sampling sites distributed around the Naujan Lake, Philippines where samples were sourced (Site 1: 13.132384°N 121.201624°E; Site 2: 13.115356°N 121.195507°E; Site 3: 13.1134°N 121.190150°E; Site 4: 13.085086°N 121.19015°E; Site 5: 13.110438°N 121.224307°E; Site 6: 13.1671901°N 121.3907821°E)

As shown in Figure 1, six sites were selected as collection sites for White Goby. For each site, a 12-hour experimental fishing of the species was conducted around each full moon from February 2020 to August 2021. As standard gear for the experimental fishing, a 1,500-m-long gill net with a mesh size of 14 mm was deployed on each site. All individuals caught within the 12-hour period were collected and processed in the laboratory.

2.2 Stock homogeneity

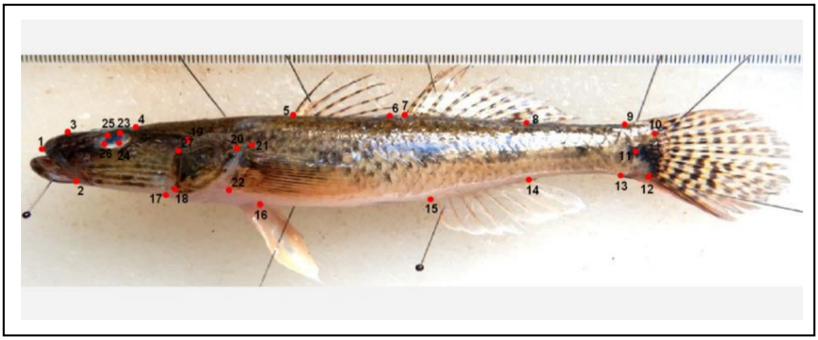

Figure 2. Landmarks used in defining the shape of *G. aureus*: tip of the snout (1); axis of the jaw (2); dorsal portion of the head of the nostril (3-4); anterior insertion of the first dorsal fin (5); posterior insertion of the first dorsal fin (6); anterior insertion of the second dorsal fin (7); posterior insertion of the second dorsal fin (8); caudal points (9-13); posterior insertion of the anal fin (14); posterior and anterior-most edges of the anal area (15-16); ventral portion of the head (17); insertion of the operculum (18); superior insertion of the pre-operculum (19); point of maximum curvature of the operculum (20); superior insertion of the pectoral fin (21); inferior insertion of the pectoral fin (22); eye orbital (23-26); superior margin of the operculum (27)

The total lengths were measured to the nearest 0.1 cm. Body weight was measured with an electronic scale to the nearest 0.1 g. Each individual is then fixed in paraffin wax and set with pins. Photos were taken and processed following the methods by Zelditch *et al*. (2004) for geometric morphometrics to assess the stock homogeneity of the white goby population within the lake. As shown in Figure 2, digital points were acquired from established landmarks by tpsDig (v.2.31, 2006). Acquired landmarks were loaded to tpsUtil (v.32, 2003) to convert files into NTS files to generate coordinate pairs. Converted data were then loaded to MorphoJ (v.1.08.02, 2010) for Procrustes ANOVA, a distance-based variance analysis. The coordinates were regressed with sites and visualized with CVA to maximize sample differences. Regression analysis of shape variables with the site was done using PAST (v.4.09, 2022) to project shape changes through a heat map.

2.3 Gonadosomatic Index and Fecundity Estimation

Gonads were extracted and weighed using an analytical balance of 0.1 - 0.01 g accuracy. The average monthly Gonadosomatic Index (GSI) was computed following the equation of Nikolsky (1963) (Equation 1) to determine the peak spawning months of *G. giuris*.

$$GSI = (Gw \times 100)/Bw \tag{1}$$

Where:

GSI stands for Gonadosomatic index; *Gw* is the gonadal weight; and *Bw* is the body weight.

According to Lagler (1956), fecundity was estimated using the Gravimetric method (Equation 2), which involved counting the oocytes in three subsamples with known weights.

$$F = N \times Gw\,(g)\;/\;Sw(g) \tag{2}$$

Where:

F is fecundity; *N* is the number of eggs; *Gw* is the body weight; and *Sw* is the sample weight.

Length frequency data was subjected to FiSAT (Pauly, 1986) modeling to gather the population's status. The asymptotic growth parameter *(L∞)* was computed using the ELEFAN. Total mortality *(Z)* and natural mortality *(M)* were determined using the Beverton-Holt equation on the length-converted catch curve. Fishing mortality *(F)* was calculated as the difference between Z and M. Exploitation rate *(E)* was taken to be the proportion of *F* and *Z.*

Recruitment and the capture probability were also modeled from the length-converted catch curve using the Beverton-Holt equation. The recruitment potential was also computed from the growth parameters.

3. Results and Discussion

3.1 Gonadosomatic Index and Fecundity Estimation

For the population under study, the maximum size for males is 28 cm (*SD = 14.00*) and 23 cm (*SD = 10.11*) for females. The smallest fecund individual recorded was 8.3 cm. Reproduction appears to be year-round, with gravid individuals being recorded each month. The highest average GSI for females was recorded in June, with a secondary peak in November and December, while GSI was highest in March and December among males (Figure 3). Field observation indicates schooling fries occur in May but are also observable to a lesser extent until August.

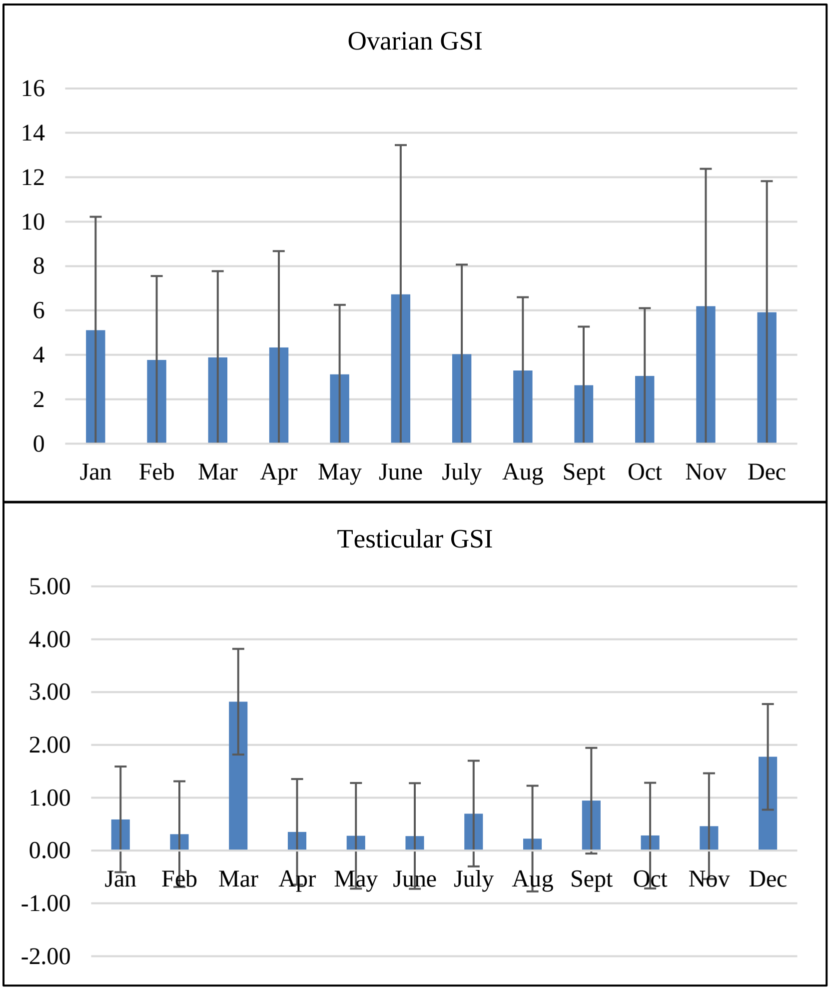

Figure 3. Gonado-somatic index (GSI) of the NWG (*N* female = 730; *N* male = 916)

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Fecundity data roughly validates the GSI, with peaks in the number of eggs occurring from February to July, a dip in April, and a secondary peak in November and December (Figure 4). However, both GSI and fecundity data show that eggs can be released year-round, with larvae available any time of the year but peaks from May to July when lake temperatures are highest (Figure 5).

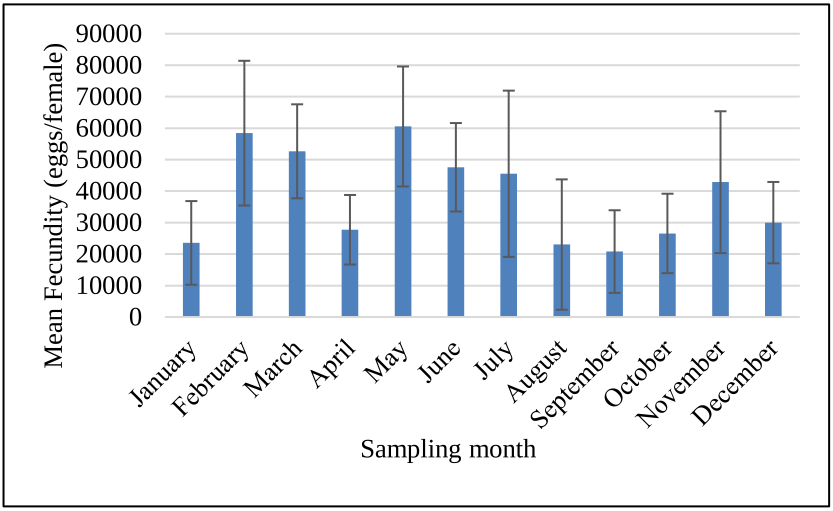

Figure 4. Average fecundity data of Naujan white goby *G. aureus* in 2020

The quality of the gonads indicates that spawning may occur during the waning or dark moon phase rather than during the waxing moon period when sampling was done—the number of eggs per female ranges from 38,000 to 60,000.

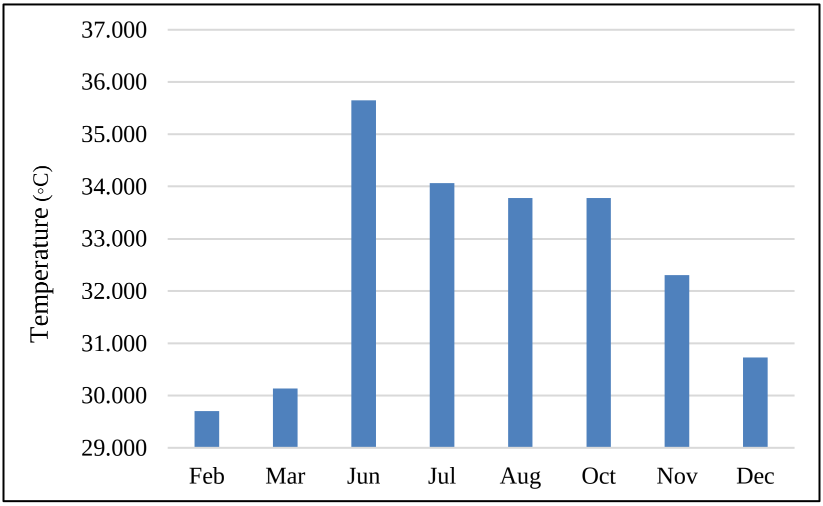

Figure 5. Average temperature trend in Naujan Lake surface water in 2020

3.2 Stock homogeneity

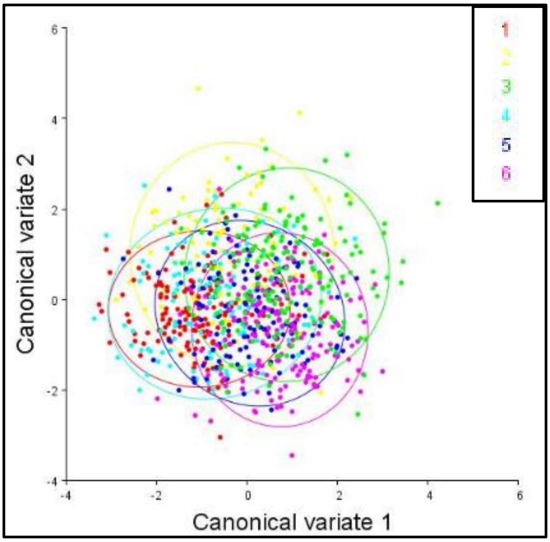

Figure 6. Canonical variance analysis (CVA) plot shows significant differences in shape variables between *G. aureus* (*N=2,233*) from different sites of Naujan Lake (Site codes: Site 1; Site 2; Site 3; Site 4; Site 5; Site 6)

Geometric morphometrics analysis revealed highly significant differences in shape variables of individuals per site ($p = < 0.0001$) and with time ($p = < 0.0001$). Canonical variance analysis illustrated the separation of samples with the site (Figure 6), indicating possible environmental constraints imposed on the individual or presenting a possibility that the NWG population is not homogenous.

Variations in shape have been found in *G. giuris* from different lakes around the Philippines (Campang and Ocampo, 2015) and in different rivers in Bangladesh (Islam *et al*., 2016; Azad *et al*., 2018; Mollah *et al*., 2012). The shape differentiation underlines the tool's utility in identifying fish stocks within and between ecosystems.

Further exploration of the body shape indicates that morphological changes are on dorsal parts, creating a hunchback figure (Figure 7). This movement affects the backward sliding of points on the head and gills and sliding ventrally in the mouth. Both *Prucastes* distances and *Mahalanobis* distances are most significant with samples from Sites 3 and 5, while the least distance is between samples from Sites 4 and 6. Site 3 individuals have a leaner belly and tail, while the head is smaller and the midsection rounder on the tail part of individuals from Site 5. The statistical distances between sites give an impression of an east-to-west zonation of morphological variations of individuals in the population.

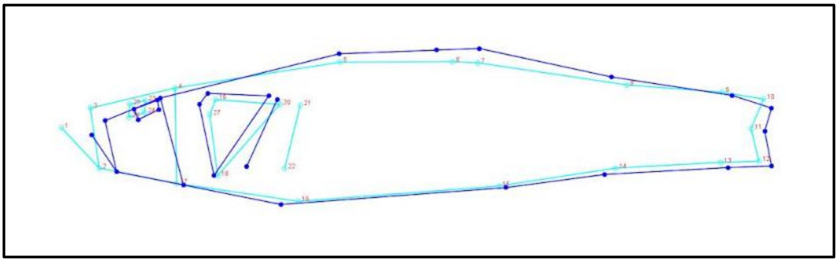

Figure 7. Wireframe figure of the deviation of shape among sites with the foreground figure representing Site 3 and the background from Site 5. All other sites are intermediate of the two extreme figures.

Tidal backflow is through Butas River (Site 1), and flow is towards Site 3. This established hydrodynamics creates an east-west zonation of the lake where the western sites are. As such, salinity may have an effect on the morphology of the NWG. In Vietnam, the length at maturity is inversely proportional to the salinity level (Dinh *et al*., 2017), indicating environmental impact on body shape. Martinez-Leiva *et al*. (2023) established the connection between changes in the morphological shape of Golden Gray Mullet *Chelon auratus* and energy use. Stout larvae metamorphosed into more laterally compressed adults to become more efficient in using their energy as they move from freshwater to saline water, connecting the ecological impact of salinity to body shape.

3.3 Population dynamics with FiSAT

The asymptotic growth ($L\infty$) of the species is estimated to be 23.27 cm, while the growth constant (K) is estimated at 3.6^{-yr} (Figure 6a). The total mortality (Z) of the species is 12.12–yr, natural mortality (M) is 4.27^{-yr} while fishing mortality (F) is 7.85^{-yr}. All mortality values are higher than the Vietnam population, as studied by Dinh *et al*. (2021). The estimated exploitation rate (E) is 0.65, higher than the E_{max}, E_{50}, or E_{10} (Figure 8b).

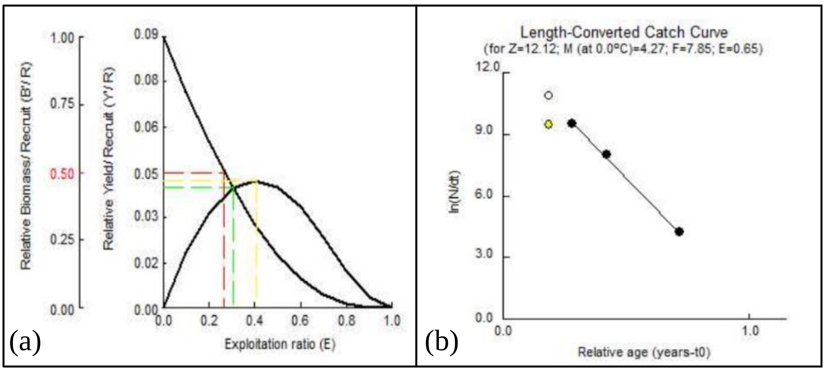

Figure 8. Length-converted catch curve of *G. aureus* showing natural mortality (Z), fishing mortality (F) and exploitation rate E. Individuals with lengths of 1 – 9 cm were assumed to be not included in the fishery (a); the full parabolic line represents the trend in population size

while the inverse line represent fish biomass (b). The sustainable exploitation rate E_{10} (---) and E_{50} (---) are when population continues to grow despite exploitation; E_{max} (---) is when population remains unchanged given exploitation rate.

These theoretical exploitation values are lower than the computed exploitation rate based on the lengths of caught individuals, indicating that population size may be declining.

Compared to other exploited freshwater species from both lotic and lentic environments, the exploitation rate of NWG is higher than that of *G. aureus* from the Mekong Delta (Dinh, 2017b) and *Sardinella tawilis* from Lake Taal (Mutia *et al*., 2018) (Table 1). *Tawilis* is an endemic and threatened species protected by a seasonally closed fishing policy.

Table 1. Comparative exploitation rate values (E) of different Asian freshwater species

Species	Computed Exploitation Rate (E)	Area	Source
Trypauchen vagina	0.53	Hau River, Vietnam	Dinh, 2017a
G. aureus	0.64	Mekong Delta, Vietnam	Dinh *et al*., 2021
G. giuris	0.56	Mekong Delta, Vietnam	Dinh *et al*., 2017
Sardinella tawilis	0.52 to 0.65	Taal Lake, Philippines	Mutia *et al*., 2018
Channa striata	0.55	Lake Temba, South Sulawesi, Indonesia	Wakiah *et al*., 2020
G. aureus	0.65	Naujan Lake, Philippines	This study

4. Conclusion and Recommendation

G. aureus presented some unique characteristics relative to published data from Vietnam. The NWG reproductive period coincides with the hot-dry months rather than the rainy season in Vietnam. The NWG also has a higher fecundity rate than its conspecifics from Vietnam. A probable effect of salinity on the morphology of NWG was observed, as shown by the change in the morphology of the fish's body. Stock assessment by FiSAT indicates depleted fish stocks at a higher rate than the Mekong River population. The $L\infty$ of NWG is 23.27 cm, lower than Vietnam's 27.97 cm.

Morphological heterogeneity indicates broodstock harvesting for aquaculture should be site-specific to reduce possible genetic mixing. While morphological differences of stocks from different fishing grounds may only be due to the environmental plasticity of the species, this also gives an idea of how broodstocks may morph when in culture tanks. Some morphs are stocky, possibly giving more meat, while others are more streamlined. Regarding broodstock collection, individuals should not be mixed to preserve genetic integrity. Developing aquaculture techniques for the species is a practical step for conserving the species and optimizing its economic importance.

5. Acknowledgement

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