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Original Article

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Growth, mortality, and exploitation rate of *Glossogobius giuris* (Hamilton, 1822) in Lake Danao Natural Park, Ormoc City (Philippines)

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ABSTRACT. The tank goby (*Glossogobius giuris*) is the most abundant and economically important fish species in Lake Danao, Ormoc City, Philippines. However, it is an introduced, non-native species in the lake. Despite its economic and ecological importance, there has been a lack of studies on its biology and population parameters in the lake. This study aimed to provide baseline information on the population biology of *G. giuris* by analyzing 867 individuals collected bi-monthly from March 2021 to February 2022. Using the von Bertalanffy growth model, the estimated asymptotic length (L_∞), growth coefficient (K), longevity (t_{max}), and growth performance (Ø) were found to be 25.31 cm, 1.30 yr^{-1}, 2.31 years, and 2.91, respectively. Due to its high growth rates, the species has become abundant, potentially adversely impacting native fish populations. On the other hand, the fishing (F), natural (M), and total mortalities (Z) were 3.56 yr^{-1}, 2.15 yr^{-1}, and 5.71 yr^{-1}, respectively. The exploitation rate (E) was 0.62, which is above the optimal rate of 0.5. Recruitment peaks occurred in September and October, with high values for relative yield-per-recruit and biomass-per-recruit: $E_{max} = 0.421$, $E_{0.1} = 0.355$, and $E_{0.5} = 0.278$. The high fishing mortality and exploitation rate indicate overfishing of the species, which could benefit native species in the lake. However, caution is still needed as continuous intensive subsistence fishing practices may deplete the fish stock in the lake and negatively affect the local fishing community.

Keywords: exploitation rate, length-weight analysis, mortality, protected lake, tank goby

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1. Introduction

Globally, fish account for over half of all identified vertebrate species. Fish has long been a significant part of the human diet and a major contributor to national economies. Henderson and Tocher (1987) emphasized that approximately 39% of all fish species are freshwater fishes, primarily found in tropical regions. These fishes exhibit a wide range of diet preferences, from strictly herbivorous to entirely carnivorous. Freshwater fishes are considered to be the most threatened vertebrate taxon as they serve as direct indicators of the planet's environmental health. Recognizing their ecological role and economic importance, enhancing the protection and conservation of freshwater species is crucial (McGregor Reid, 2013).

The Philippines is home to 348 freshwater fish species, of which 195 (56%) are native, 96 (28%) are endemic, and 57 (16%) are introduced (Guerrero, 2014). Among the introduced species is *Glossogobius giuris* (Hamilton, 1822), a benthopelagic amphidromous species that inhabits marine, brackish, and freshwater environments across Asia (Azad et al., 2018). In freshwater environments, this carnivorous species thrives in a wide range of habitats, including canals, ditches, and ponds with rocky, gravelly, or sandy bottoms (Hossain et al., 2009). Its diet consists of crustaceans, small insects, fish larvae, and small fishes (Bejer, 2015). Moreover, *G. giuris* has the potential to become invasive and threaten the survival of native species. For instance, in Lake Lanao in Mindanao, Philippines, the introduction of *G. giuris* led to the disappearance of 15 endemic fish species (Juliano et al., 1989).

In the Philippines, *G. giuris* has been documented in several freshwater ecosystems, including the Mount Makiling Forest Reserve's watershed in Batangas and Laguna (Paller et al., 2011), Lake Taal, Batangas

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(Masagca and Ordoñez, 2003), Lake Buluan, Sultan Kudarat (Dorado et al., 2012), Lake Lanao, Lanao del Sur (Mahilum et al., 2013), and Lake Mainit, Surigao del Norte (Joseph et al., 2016). This species has also been observed in Lake Danao, Ormoc City, Philippines (Weliange et al., 2007). Locally known as 'bul-a,' this species was reportedly accidentally introduced to the lake during the construction of a nearby bridge (Romero et al., 2023). Since its introduction, fishers have attributed the decline of other freshwater fish commodities to *G. giuris*' predation of eggs of other fishes, making them the most dominant fish species in Lake Danao (Romero et al., 2023). Since only a small number of fishers harvest *G. giuris* in Lake Danao, primarily for household consumption, it has become one of the most frequently caught fish and now serves as a major source of alternative food for the local community (Romero et al., 2023).

Despite its abundance in Lake Danao, the biology and ecology of *G. giuris* remain insufficiently studied. The prevalence of this invasive species poses a significant threat to valuable native species in the lake, such as the giant mottled eel (*Anguilla marmorata*) and the walking catfish (*Clarias batrachus*) (Romero et al., 2023). Thus, baseline information on the biology and population dynamics of *G. giuris* is essential for developing effective management strategies to conserve and enhance local fisheries and biodiversity, considering that Lake Danao is a protected area. To address these gaps, this study examines key biology and population parameters of *G. giuris*, particularly length- weight relationships, growth, mortality, and exploitation rates.

2. Materials and methods

2.1. Study site

This study was conducted in Lake Danao, Ormoc City, Philippines (11°04′14.9″ N, 124°41′43.1″ E) (Fig. 1). The 139.8-hectare guitar-shaped lake is capable of storing more than 56,000,000 m^3 of water, making it an integral part of nearby communities that benefit from its ecosystem services such as tourism, fishing, farming, and source of water for drinking and utility (Romero et al., 2023; de la Cruz et al., 2024). Situated 600 m above sea level, Lake Danao is part of the LDNP, a protected area in Eastern Visayas. Under Republic Act 11038 or the Expanded National Integrated Protected Areas System (E-NIPAS) Act of 2018, protected areas are defined as "portions of land and water set aside by reason of their unique physical and biological significance, managed to enhance biological diversity and protected against destructive human exploitation". Prior to the data collection, a gratuitous permit was secured from the LDNP Protected Areas Management Board (Romero et al., 2023).

2.2. Fish sample collection

The collection of the *G. giuris* (Fig. 2) was done bi-monthly from March 2021 to February 2022. Samples were obtained from the landed catch of local subsistence fishers who used simple handlines and size 8 mesh (approximately 3 mm) fishing nets. The collected *G. giuris* were stored in an ice-cooled box and were transported to the laboratory for analysis. The samples were then separated based on their sex using the external morphology of urogenital papilla shape (oval in a female and triangle in a male) adapted from available guides (Cabuga et al., 2016; Dinh et al., 2017; Yeasmine et al., 2021). Only fish specimens with intact body parts were included in the study, while those with missing or damaged sections were excluded.

2.3. Fish measurements

Total lengths were measured using a ruler to the nearest 0.1 cm, while total body weight was measured with an accuracy of 0.01 g.

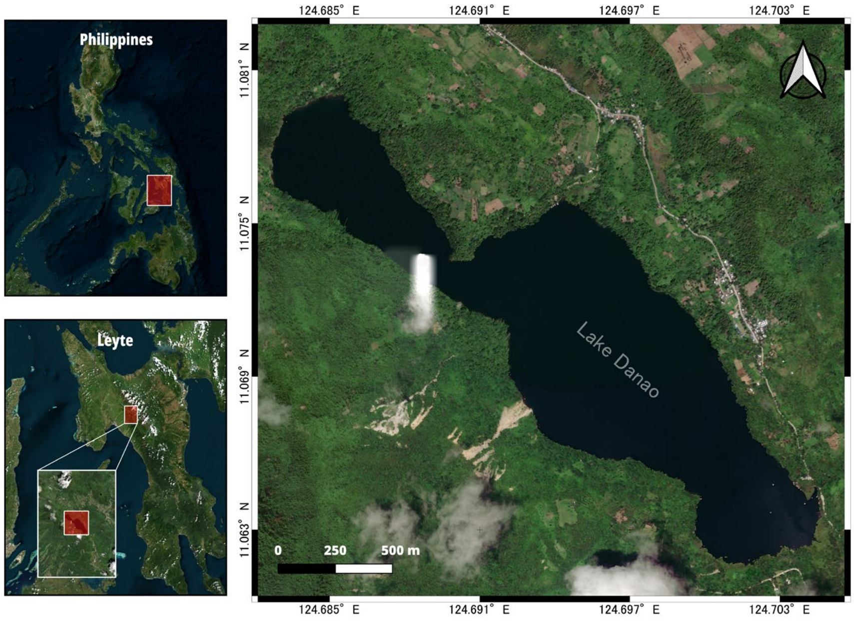

Fig.1. Map showing Lake Danao in Ormoc City, Leyte, Philippines.

Fig.2. Photograph of *G. giuris* from Lake Danao, Ormoc City courtesy of Romero et al. (2023).

2.3.1. Length-weight relationship

The length-weight relationship of *G. giuris* was analyzed for both sexes using the equation of Le Cren (1951):

$$W = aL^b,$$

where

W – weight of fish in g
L – total length of fish in cm
a – scaling coefficient
b – allometry coefficient.

The parameters a and b, commonly referred to as length-weight parameters, are determined using available length-weight data. Each fish species has a distinct length-weight relationship or specific parameters, which can vary between sexes, stocks, or geographical regions. The parameter a serves as a scaling coefficient for the weight (W) at a given length (L), while b represents a shape factor reflecting the body form of the species. (Kuriakose, 2014). The ideal value of b is 3, which indicates isometric growth (Ricker and Carter, 1958). Values not equal to 3 may be recorded due to various environmental factors or the condition of the fish themselves. If $b < 3$, fish become leaner as they grow in length, indicating negative allometric growth. Conversely, if $b > 3$, fish become heavier, demonstrating positive allometric growth and suggesting optimal growth conditions.

2.3.2. Growth parameters

Length frequency data was firstly grouped over 2.5 cm intervals and was used to assess the biological parameters of the fish population. The Electronic Length-Frequency Analysis (ELEFAN I) procedure from the FAO-ICLARM Stock Assessment Tools II (FiSAT-II) software (Gayanilo Jr et al., 2005) was performed to determine the asymptotic length L_∞ (cm) and the growth parameter K. The growth performance index (Ø) was then computed using $Ø = log_{10}(K) + 2\ log_{10}(L_\infty)$ (Pauly, 1984).

2.3.3. Mortality and exploitation rates

The length-converted capture curve method in ELEFAN I was applied to estimate the total mortality rate (Z) using estimates of L_∞ and K (Beverton and Holt, 1979; Pauly, 1983). To estimate the natural mortality rate (M), Pauly's M empirical equation (Pauly, 1980) was utilized:

$$log_{10} M = -0.006 - 0.279\ log_{10} L_\infty + 0.6543\ log_{10} K + 0.4634\ log_{10} T,$$

where:

L_∞ – asymptotic length
K – growth parameter
T – mean habitat temperature (°C)

The longevity (t_{max}) of *G. giuris* was calculated as:

$$t_{max} = 3 / K.$$

Fishing mortality (F) can be calculated by subtracting the natural mortality rate (M) from the total mortality rate (Z):

$$F = Z - M.$$

Exploitation rate (E) is the ratio between fishing mortality (F) and total mortality (Z) (Ricker, 1975), and can be written as:

$$E = F / Z.$$

2.3.4. Length at first capture and length at first maturity

The ascending left arm of the length-converted catch curve incorporated in FiSAT II tool was used to estimate the probability of length at first capture (L_c) (Pauly, 1987). The length at first maturity was estimated using the expression:

$$L_m = (2 \times L_\infty) / 3$$

2.3.5. Relative yield per recruit and relative biomass per recruit

Analysis of relative yield per recruit (Y/R) and relative biomass per recruit (B/R) were performed using the knife selection method (Beverton and Holt, 1966). This analysis helps determine whether populations are overexploited by calculating E_{max} (the exploitation rate with maximum yield) and $E_{0.5}$ (the exploitation rate that retains 50% of the biomass).

3. Results

3.1. Length-weight relationship

A total of 867 samples were processed and analyzed in this study, composed of 527 females and 340 males. The total length of female *G. giuris* ranged from 4.10–18.50 cm with a mean length of 12.30 ± 10.9 cm, while the weight ranged from 2.16–106.00 g with a mean weight of 9.21 ± 8.85 g. Meanwhile, male *G. giuris* had a total length that ranged from 7.2–25.7 cm with a mean total length of 11.10 ± 2.46 and weight ranging from 2.81–134.00 g with a mean weight of

12.30±10.90 g. Table 1 outlines the descriptive statistics of the recorded length and weight of the samples. Female *G. giuris* yielded a length-weight equation of $W = 0.0178L^{2.66}$ ($r = 0.97$), while male *G. giuris* had $W = 0.0141L^{2.75}$ ($r = 0.97$). While female *G. giuris* had a lower b value, both groups showed negative allometry ($b < 3$). Fig. 3 shows the graphs for the length-weight relationship of male and female *G. giuris* specimens collected from Lake Danao.

3.2. Growth parameters

Table 2 shows the summary of fish samples according to their length groups. Samples from the length group of 9.2 cm – 11.7 cm (n = 354) were the most abundant, while the 24.8 cm – 27.3 cm length group had the least number of samples (n = 1). The length-frequency analysis of the collected *G. giuris* showed that there were five fish size groups, represented by blue lines (growth curves) (Fig. 4). The estimated length L_∞ (cm), the growth parameter K, and the growth performance index (Ø) were 25.31, 1.30, and 2.91, respectively.

3.3. Mortality rates and exploitation rates

The total mortality (Z), natural mortality (M), and fishing mortality (F) rates were 5.71, 2.15, and 3.56, respectively based on the length-converted catch curve analysis (Fig. 5A). Meanwhile, the exploitation rate (E) of 0.62 indicates high exploitative activity of catching this species. Two recruitment peaks were observed in September and October (Fig. 5B).

3.4. Length at the first capture and length at the first maturity

Based on the estimate from the capture probability analysis (Fig. 6), the length at the first capture (L_c) for *G. giuris* was 3.69 cm (*TL*). Most specimens caught were between 6.6 cm – 9.1 cm at 5.7 year^{-1} fishing rate. The highest peak of the fishing rate fell between 9.2 cm – 11.7 cm length intervals. Meanwhile, the length at first maturity (L_m) was 6.87 cm (*TL*).

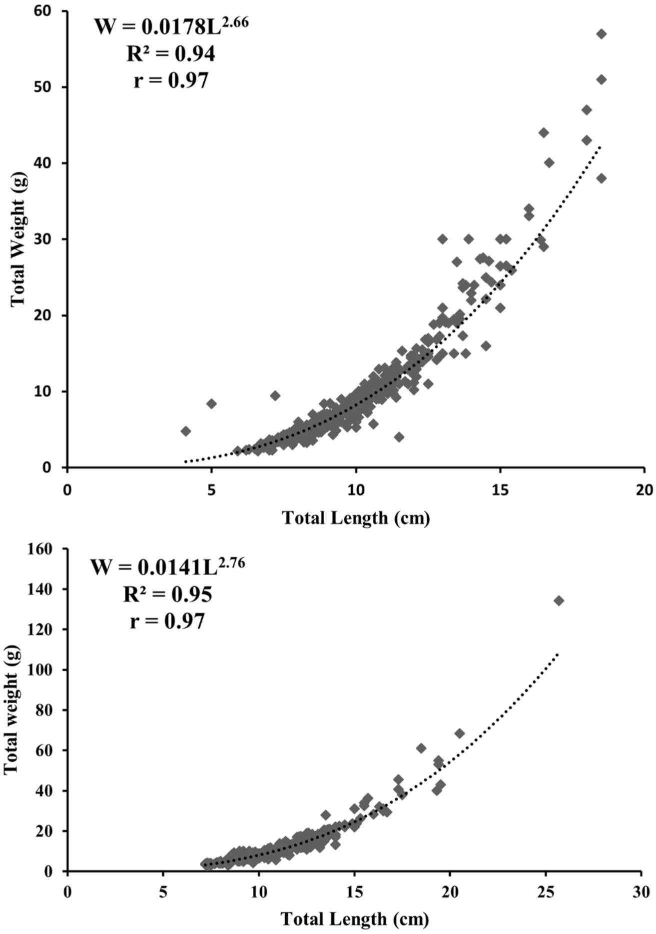

Fig.3. Length-weight relationship of female (top) and male (bottom) *G. giuris* collected from Lake Danao, Ormoc City.

3.5. Relative yield per recruit and relative biomass per recruit

The analyses of the yield-per-recruit and biomass-per-recruit of *G. giuris* showed that the optimum yield $E_{0.1} = 0.355$, the yield at the stock reduction of 50% $E_{0.5} = 0.27$, and the maximum sustainable yield $E_{max} = 0.42$ (Fig. 7A). The ratio of the length at first capture and the asymptotic length (e.g., the yield isopleths, Fig. 7B) of this fish was 0.05. Its growth per-

Table 1. Descriptive statistics of the recorded length and weight of *G. giuris* collected from Lake Danao, Ormoc City.

Month	N	No. of Female	No. of Male	Total Length (cm)			Total Weight (g)		
				Min	Max	Mean ± SD	Min	Max	Mean ± SD
March 2021	60	26	34	7.50	19.50	11.70 ± 2.90	4.00	61.00	15.40 ± 12.30
April 2021	89	51	38	6.20	19.40	10.90 ± 2.55	2.28	55.00	11.50 ± 9.73
May 2021	70	31	39	5.00	18.50	11.00 ± 2.89	3.00	57.00	12.80 ± 10.60
June 2021	29	17	12	7.00	14.70	10.00 ± 1.73	3.32	24.40	8.74 ± 4.44
July 2021	80	41	39	6.80	25.70	10.10 ± 2.55	2.29	134.00	10.00 ± 14.90
August 2021	127	95	32	6.50	17.30	10.60 ± 2.23	2.27	106.00	11.80 ± 12.10
September 2021	236	180	56	4.10	17.30	9.94 ± 2.11	2.16	45.50	9.17 ± 6.29
December 2021	17	10	7	7.10	9.60	8.44 ± 0.834	3.00	7.00	4.98 ± 1.17
January 2022	121	60	61	6.60	14.00	9.38 ± 1.84	2.72	20.80	7.62 ± 4.39
February 2022	38	16	22	6.80	20.50	10.60 ± 3.21	3.05	68.30	12.40 ± 12.80
Total	**867**	**527**	**340**						

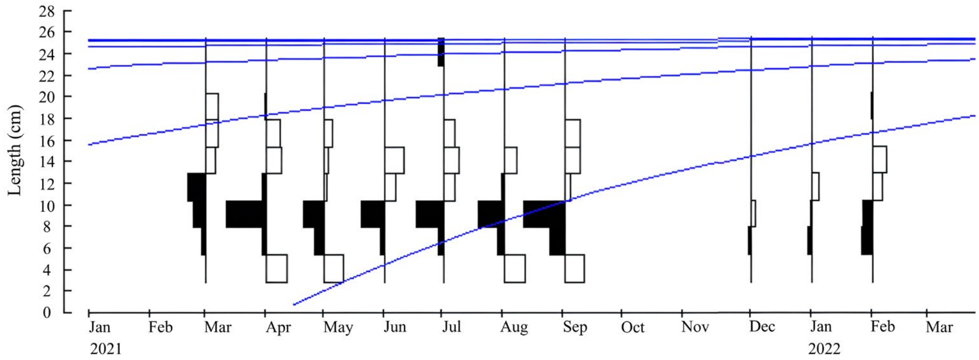

Fig.4. Length-frequency distribution and growth curves of *G. giuris* (n = 863). The black bars show the highest monthly frequencies of fish length, while the white bars show the lowest frequencies recorded. The blue lines represent growth curves, illustrating the estimated growth trends over time based on length-frequency data.

formance was 2.91, and its longevity was 2.31. Table 3 summarizes the population parameters of *G. giuris* collected from Lake Danao.

4. Discussion

4.1. Length-weight relationship

This study provides initial insights into the wild population of *G. giuris* in Lake Danao. The results of the length-weight analysis indicate that female *G. giuris* exhibited a higher mean total length and weight than males. On the other hand, the calculated allometric coefficient (b) was higher in males ($b = 2.76$) than in females ($b = 2.66$). A similar trend has been observed in *G. giuris* populations from Mithamoin Haor, Kissorgonj, Bangladesh (Hossain and Sultana, 2014), Manchar Lake, Sindh, Pakistan (Qambrani et al., 2016), and Lapompakka Lake and Sidenreng Lake, South Sulawesi (Kudsiah et al., 2022; Suwarni et al., 2022). Differences in total length, weight, and allometry coefficient between male and female *G. giuris* can be attributed to several factors, including habitat, gonad maturity, fat accumulation, and metabolic activity (Tesch, 1971; Hossain and Sultana, 2014). The observed variations in growth patterns suggest that environmental factors in Lake Danao may be shaping the biological characteristics of *G. giuris*, which warrants further investigation.

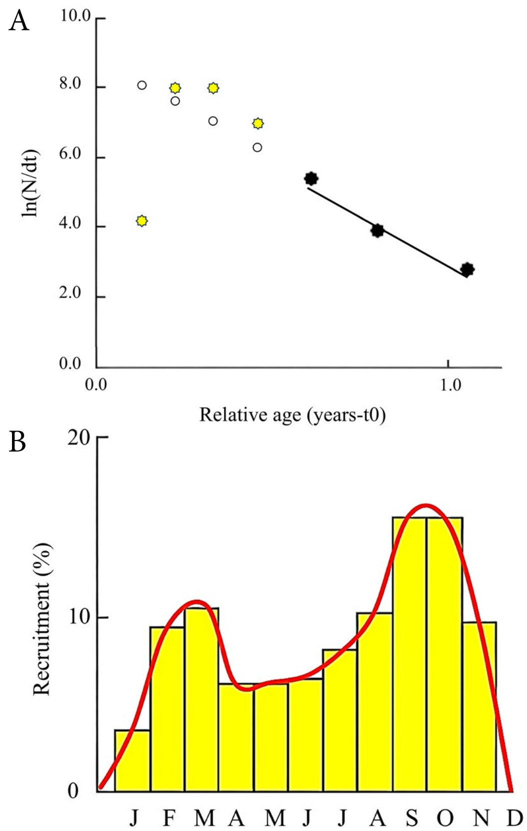

Fig.5. The (A) length-converted catch curve and (B) estimated recruitment pattern of *G. giuris* in Lake Danao, Ormoc City. The regression line in the length-converted catch curve was determined using the black circles. The yellow circles represented excluded points, while the white circles were extrapolated points.

Table 2. Number of *G. giuris* samples according to length groups (with 2.5 cm interval).

Month	Length Class (cm)									TOTAL
	4.0-6.5	6.6-9.1	9.2-11.7	11.8-14.3	14.4-16.9	17.0-19.5	19.6-22.1	22.2-24.7	24.8-27.3	
March 2021		13	17	20	6	3	1			60
April 2021	1	21	40	19	4	2	2			89
May 2021	1	21	24	13	8	3				70
June 2021		10	14	4	1					29
July 2021		28	41	8	1	1			1	80
August 2021	1	37	51	31	7					127
September 2021	3	87	106	30	8	2				236
December 2021		13	4							17
January 2022		56	45	20						121
February 2022		15	12	6	3		2			38
Total	**6**	**301**	**354**	**151**	**38**	**11**	**5**	**0**	**1**	**867**

4.2. Growth parameters

The analysis of the length-frequency distribution showed that the most frequently caught *G. giuris* was between 9.1 and 11.5 cm. The availability of food may have positively influenced the growth in terms of size of *G. giuris* in Lake Danao. *G. giuris* primarily preys on crustaceans, small insects, and small fishes (Achakzai et al., 2015), which are present and abundant in the lake (Weliange et al., 2007; Romero et al., 2023). Moreover, cannibalism has been observed for *G. giuris* in Lake Danao, along with predation on the eggs of other fish species, such as Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) (Romero et al., 2023).

Meanwhile, the estimated asymptotic length ($L_\infty = 25.31$ cm) of *G. giuris* in this study exceeds those reported in previous studies from the Mekong Delta, Vietnam ($L_\infty = 20.53$ cm) (Dinh et al., 2017), Titas River, Brahmanbaria District, Bangladesh ($L_\infty = 19.6$ cm) (Ahmed and Latifa, 2012), and Rabnabad Channel, Southern Bangladesh ($L_\infty = 25$ cm) (Ahamed et al., 2023). The growth coefficient ($K = 1.30$) was also higher than those reported for *G. giuris* from the Mekong Delta, Vietnam ($K = 0.56$) and Rabnabad Channel, Southern Bangladesh ($K = 1.10$) but lower compared to the Titas River, Brahmanbaria District sample population ($K = 1.36$) (Ahmed and Latifa, 2012; Dinh et al., 2017; Ahamed et al., 2023). In addition, the growth performance index ($Ø = 2.91$) and longevity ($t_{max} = 2.31$) observed in this study suggest a relatively fast growing and short-lived population of *G. giuris* in Lake Danao compared to those from the Mekong Delta, Vietnam ($Ø = 2.37$, $t_{max} = 5.36$) and Rabnabad Channel, Southern Bangladesh ($Ø = 2.84$, $t_{max} = 2.70$). These variations can be attributed with certain factors, such as gear selectivity, sampling methods, and environmental differences across habitats (Ahamed et al., 2023).

Despite its rapid growth and high reproductive potential, the impact of *G. giuris* on Lake Danao's native fish community remains a concern that warrants urgent attention. However, given that its harvest is limited to subsistence fishing by a small number of fishers, the pressure on the population is relatively low. This scenario suggests that while *G. giuris* may pose a competitive threat to other species, its population is not currently being heavily exploited for economic gain. As such, continued monitoring is necessary to assess its long-term impact on the aquatic biodiversity and water quality of Lake Danao.

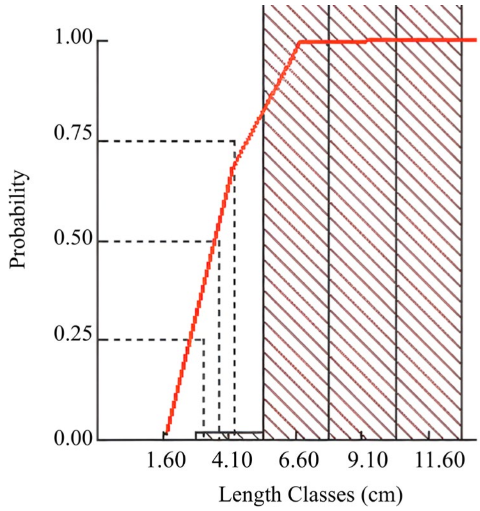

Fig.6. The probability of capture of *G. giuris* ($L_{25} = 3.09$, $L_{50} = 3.69$, and $L_{75} = 4.29$ cm, estimated from the logistic transform curve (red line).

4.3. Mortality rates and exploitation rates

The estimated values for natural mortality (*M*), fishing mortality (*F*), total mortality (*Z*), and exploitation rate (*E*) were all higher than those reported for *G. giuris* in the Mekong Delta, Vietnam (Dinh et al., 2017) and Rabnabad Channel, Bangladesh (Ahamed et al., 2023). Notably, the fishing mortality ($F = 3.56$) was higher than the natural mortality ($M = 2.15$), which implies overfishing on the population of *G. giuris* in Lake Danao. Studies show that fishing mortality can be influenced by fishing effort, fishing gear, and the economic value of the fish (Etim et al., 2002; Dinh et al., 2017), while natural mortality is driven by natural causes such as predation, diseases, and aging (Björnsson et al., 2022).

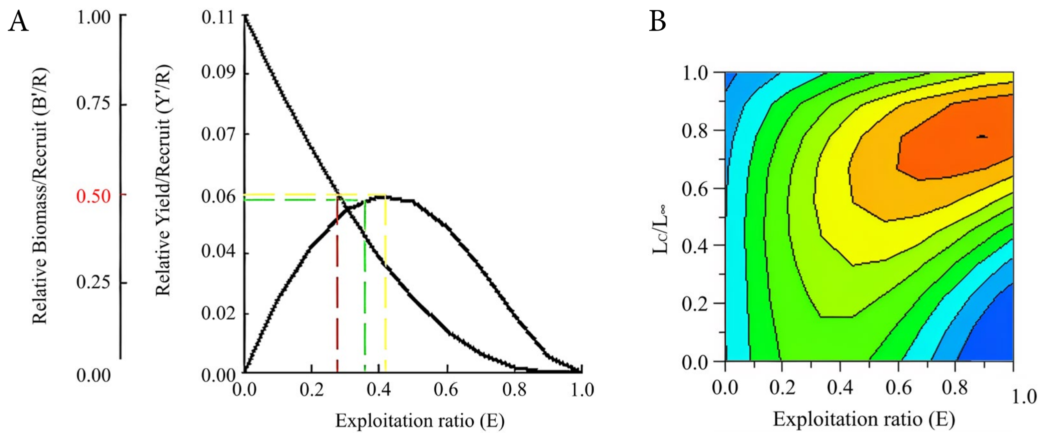

Fig.7. The relative yield-per-recruit and relative (A) biomass-per-recruit and ($E_{max} = 0.421$, $E_{0.1} = 0.355$ and $E_{0.5} = 0.278$), and the yield isopleths (B) for *G. giuris*. In (A), the yellow dashed line represents the maximum yield per recruit. On the other hand, the green and red dashed lines represent the exploitation that retains 10% and 50% of the biomass, respectively. In (B), the isopleths illustrate how changes in exploitation rate and the ratio of length at first capture to asymptotic length can affect the overall yield. Warmer colors (orange/red) indicate higher values. The highest yield isopleth is in the upper-left quadrant (Quadrant A), which suggests overexploitation.

Table 3. Growth and mortality parameters of *G. giuris* collected from Lake Danao, Ormoc City compared to other studies.

Population parameter	Value for this study	Dinh et al. (2017)	Ahamed et al. (2023)
Asymptotic length (L_∞)	25.31	20.53	25.0
Growth parameter (K)	1.30	0.56	1.10
Longevity (t_{max})	2.31	5.36	2.70
Total mortality (Z)	5.17	3.17	2.24
Natural mortality (M)	2.15	1.40	2.00
Fishing mortality (F)	3.56	1.77	0.42
Growth performance index (Φ)	2.91	2.37	2.84
Length at first capture (L_c, cm)	3.69	7.41	-
Length at first maturity (L_m, cm)	16.87	-	-
Annual exploitation rate (E)	0.62	0.56	0.17
Exploitation at maximum economic yield ($E_{0.1}$)	0.35	0.515	0.24
Exploitation that retains 50% of the biomass ($E_{0.5}$)	0.27	0.323	0.31
Exploitation rate with maximum sustainable yield (E_{max})	0.42	0.633	0.37

Although the results suggest overfishing, it is important to contextualize this within the local fishing practices. In Lake Danao, most fishers go out fishing at least once a day and spend 1 - 4 hours per fishing operation, depending on the type of gear. Local fishers intimated that the *G. giuris* they catch were typically about the size of a human thumb, and the volume of catch is just enough to satisfy their daily needs. At the same time, some fishers use smaller *G. giuris* as bait to catch other larger fish, such as the giant mottled eel (Romero et al., 2023). Larger gobies are rarely caught as they tend to inhabit the deeper parts of the lake. Since only a small number of fishers harvest *G. giuris* in Lake Danao, primarily for household consumption (Romero et al., 2023), the overall exploitation remains limited compared to commercial fisheries. Even in the absence of direct commercial exploitation and under low fishing pressure, a higher fishing mortality rate (*F*) than natural mortality (*M*) in a fish population indicates overfishing. This means the population is being harvested faster than it can replenish itself, leading to a decline in fish stocks, an important indicator of unsustainable fishing practices among local fishers. Therefore, continued subsistence fishing without appropriate management interventions could result in gradual stock depletion, threatening both ecological balance and local food security

4.4. Length at first capture and length at first maturity

The length at the first maturity ($L_m = 16.87$ cm) was relatively higher than the length at the first capture ($L_c = 3.69$ cm), suggesting that the *G. giuris* is harvested before reaching reproductive maturity, a key characteristic of growth overfishing. The L_m recorded in this study was higher compared to those reported for *G. giuris* in the Mekong Delta, Vietnam ($L_m = 4.8$-6.1 cm) and Rabnabad Channel, Southern Bangladesh ($L_m = 8.5$ cm) (Dinh et al., 2017; Ahamed et al., 2023). Length at first maturity can be influenced by environmental factors such as climate, trophic state, and hydrodynamics (Sinovčić and Zorica, 2006). Kuparinen et al. (2011) observed that fish in warmer environments tend to reach maturity sooner at smaller body sizes compared to those in cooler environments. Furthermore, the Lc/L_∞ ratio (0.14) from the study suggests that the harvested catch mostly comprises small-sized *G. giuris*. This observation supports the earlier claim that growth overfishing exists within the fishery of *G. giuris* in Lake Danao. Although early harvesting is evident, the non-commercial nature of *G. giuris* fishing suggests that its intensity is not as severe as in large-scale fisheries. However, the unsustainable practices observed, indicated by *F* exceeding *M*, could still impair the population. Therefore, implementing regulations such as size limits and seasonal or gear restrictions would help sustain the *G. giuris* population while preserving it as a viable alternative food source for nearby communities.

Meanwhile, the *G. giuris* in Lake Danao were observed to have two spawning peaks, in September and October. Similar spawning periods have been documented for *G. giuris* populations in Mithamoin Haor, Kissorgonj, Bangladesh (Hossain, 2014), Can Tho City, Vietnam (Pham and Tran, 2013), Payra River, Patuakhali, Bangladesh (Roy et al., 2014), Mekong Delta, Vietnam, (Dinh et al., 2017) and Rabnabad Channel, Bangladesh (Ahamed et al., 2023). While spawning periods vary by location, *G. giuris* generally reproduces during the wet or rainy season (Pham and Tran, 2013; Ahamed et al., 2023). The observed spawning pattern suggests that environmental factors, such as seasonal rainfall and water temperature, may play a crucial role in regulating the reproductive cycle of *G. giuris* in Lake Danao. Understanding these seasonal spawning trends is essential for developing management strategies, such as seasonal fishing restrictions, to prevent excessive harvesting during peak reproductive periods and ensure the sustainability of the species.

4.5. Relative yield per recruit and relative biomass per recruit

The calculated exploitation rate ($E = 0.62$) in Lake Danao was higher compared to those reported for *G. giuris* in the Mekong Delta ($E = 0.56$) (Dinh et al., 2017) and Rabnabad Channel, Bangladesh ($E = 0.17$) (Ahamed et al., 2023). Moreover, the estimated exploitation rate also exceeded the sustainable threshold values, particularly the exploitation rate for maintaining 50% of the biomass ($E_{0.5} = 0.27$) and the exploitation rate corresponding to the maximum sustainable yield ($E_{max} = 0.42$), providing further evidence of *G. giuris* overfishing. Furthermore, a combination of yield isopleths (L_c/L_∞) and exploitation rate (E) analysis revealed that this gobiid species falls in the overfishing quadrant (D), as described by Pauly and Soriano (1986). The goby's short length at the time of capture corroborates this finding.

Despite indications of overfishing, it is essential to consider the subsistence nature of fishing in LDNP (Romero et al., 2023). The limited number of fishers in the area suggests that the primary concern is not commercial overexploitation but rather the long-term sustainability of local fishing practices. If left unmanaged, even small-scale subsistence fishing could alter the population dynamics of *G. giuris*, potentially affecting both its abundance and its ecological interactions within the lake. Meanwhile, the reduction of *G. giuris* through fishing may benefit native fish species by decreasing competition for resources, thereby promoting biodiversity. However, caution is necessary, as persistent overfishing could diminish recruitment potential and disrupt the lake's ecological balance. To ensure sustainable fishery management, measures such as implementing a closed season during peak spawning periods and regulating the harvest of immature fish should be considered. These strategies would help balance the ecological impact of *G. giuris* with its role as a vital food source for local communities.

5. Conclusion

The study provides a preliminary assessment of the growth, mortality, exploitation, and population dynamics of *G. giuris* in Lake Danao, Ormoc City. Findings indicate that this introduced species is being overfished, primarily due to subsistence fishing rather than commercial exploitation. While reducing *G. giuris* populations may alleviate competition for resources and potentially benefit native fish species, continued overfishing could disrupt the lake's ecological balance and threaten its role as a food source for local communities. The high exploitation rate and the capture of juvenile individuals suggest the presence of growth overfishing, which may hinder the long-term sustainability of the subsistence fishery. Moreover, as subsistence fishing is the primary means of harvesting *G. giuris*, any decline in its population could negatively affect the food security and economic stability of families that rely on it. Thus, a balanced approach is necessary to manage *G. giuris* effectively, mitigating its ecological impact while ensuring its sustainable utilization by local fishers.

Future research should focus on conducting long-term monitoring of *G. giuris* and other fish populations in Lake Danao to better understand population trends, reproductive patterns, and ecological interactions. Studies on the diet composition of *G. giuris* could provide further insights into its impact on native species and help refine conservation strategies. Moreover, conservation initiatives should include regulating fishing gear and mesh sizes to prevent the capture of immature individuals, implementing closed fishing seasons during peak spawning periods, and promoting alternative livelihood programs for local fishers to reduce dependency on the species. Since subsistence fishers rely on *G. giuris* as one of the primary sources of alternative food, management strategies should also incorporate community-based fisheries management approaches to ensure that conservation efforts do not adversely impact the livelihoods of local fishing families. These measures will contribute to a more comprehensive and adaptive fisheries management approach, balancing ecological sustainability with the socio-economic needs of the community. Local authorities, researchers, and other scholars can use the findings of this study as a guide for developing evidence-based regulations and research initiatives for the sustainable utilization and management of *G. giuris* and the protection and conservation of the aquatic biodiversity in Lake Danao Natural Park (LDNP).

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Conflict of Interest

The authors declare no conflicts of interest.

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