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Population Dynamics of Marble Goby, *Oxyeleotris marmorata* (Bleeker, 1852) for Conservation and Sustainability in Huai Kho Reservoir, Na Chueak District, Maha Sarakham Province, Thailand

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ABSTRACT

A study on the population dynamics of Marble Goby (*Oxyeleotris marmorata*, Bleeker, 1852) was conducted to support the conservation and sustainability in Huai Kho Reservoir. Fishermen were instructed to set fishing nets monthly from January to December 2022. This study successfully collected 284 fish specimens, with lengths ranging from 115 to 236mm and an average length of 162.97± 24.60mm. The total weight ranged from 24 to 236g, with an average weight of 60.87± 31.00g. The growth performance index (ϕ) was calculated to be 3.986 per year, with an asymptotic length (L_∞) of 273.00mm, and a growth coefficient (K) of 0.13. The probability of capture was determined to be L25%= 137.18mm, L50%= 144.90mm, and L75%= 163.02mm. The length-weight relationship (LWR) was found to be $W= 0.02443L^{1.61202}$ ($r^2 = 0.92$). The rate of total mortality (Z) was 0.97 per year, natural mortality (M) was 0.26 per year, and fishing mortality (F) was 0.71 per year. The highest recruitment (maximum replacement rate) was observed annually from March to June, ranging from 11.63 to 18.82%. The total steady-state biomass was calculated to be 6.50 tons, with the current exploitation rate (E) rate being 0.73 (E>0.5). The results indicate that the marble goby stock was overexploited

INTRODUCTION

The marble goby (*Oxyeleotris marmorata* (Bleeker, 1852)) belongs to the family Eleotridae, order Perciformes, and class Actinopterygii. It is a tropical freshwater fish native to Thailand, found in all regions of the country, inhabiting both natural water bodies and reservoirs. The marble goby is considered an economically significant freshwater fish, commanding high prices and being a popular food item in Southeast Asia **(Asia-Pacific Fishery Commission, 2014; Yusof *et al.*, 2023)**. Its popularity stems from

its delicious taste and high protein content, leading to an increasing demand each year. The marble goby generates millions of baht in the annual revenue for Thailand.

Currently, the population of the marble goby in Thailand shows a declining trend. In 2021, the quantity amounted to 1,057 tons, and valued at 94,719 baht. In 2022, the quantity decreased to 756 tons, and valued at 72,988 baht. In 2023, the quantity furtherly decreased to 688 tons, and valued at 69,099 baht. Countries with high demand for importing this fish include Singapore, China, Malaysia, Indonesia, and Hong Kong **(Seetapan *et al.*, 2016; Department of Fisheries, 2021; Department of Fisheries, 2022; Department of Fisheries, 2023)**.

At present, the production of the marble goby is declining. The marble goby is a slow-growing freshwater fish, and there is a shortage of juveniles for farming. This shortage is due to the decreasing number of the marble goby juveniles collected from natural water sources. The natural habitats of the marble goby have undergone significant ecological changes due to population growth, agricultural activities, and urban expansion. These factors have led to a decline in the marble goby population in natural water bodies, compounded by overfishing by local fishermen. Overfishing has exceeded the natural reproductive capacity, resulting in an insufficient supply of the marble goby to meet consumer demand. Both farmers and government agencies have made efforts to promote and develop aquaculture processes to increase the production of the marble goby through farming. However, these efforts have not yet achieved the desired success **(Saensupa *et al.*, 2018; Seetapan *et al.*, 2019; Sena *et al.*, 2021)**.

The Huai Kho Reservoir, constructed in 1968, is the largest resevoir in Maha Sarakham province. This multipurpose reservoir offers numerous benefits, such as tourism, fisheries, water storage for agricultural use during the dry season, and flood control during the rainy season **(CMARE, 2020)**. The marble goby (*Oxyeleotris marmorata*) is considered one of the most important freshwater species in the Huai Kho Reservoir. This fish is known for its excellent taste and can be prepared in various dishes, such as steamed marble goby with lime, steamed marble goby with soy sauce, steamed marble goby with herbs, and marble goby tom yum soup. Due to the excellent and distinct taste of marble goby from Huai Kho Reservoir compared to those from other water sources; the fish has become a symbol of Na Chueak district. Consequently, the marble goby has been included in the district's slogan. The popularity of the marble goby has led to an increased fishing activity by fishermen from both Na Chueak district and the neighboring areas. Consequently, the population of the marble goby in the Huai Kho Reservoir has significantly declined.

FiSAT_II is a widely used and internationally recognized software program for studying the dynamics of aquatic animal populations. It encompasses parameters such as age, growth, growth coefficient, length-weight relationships, total mortality rate, natural mortality, fishing mortality, and exploitation. This information is essential for developing conservation measures and strategies to ensure the sustainable use of aquatic resources

(Admodisastro *et al.*, 2021; Mutadi *et al.*, 2022; Mehanna, 2023; Ernaningsih *et al.*, 2024; Jana *et al.*, 2024; Mahmoud *et al.*, 2024). There have been no studies on the population dynamics of the marble goby (*Oxyeleotris marmorata*) in reservoirs in Thailand, and there is no available biological information on this species. Therefore, this study represents the first study of its kind in Thailand. Its objective was to investigate the population dynamics of the marble goby (*Oxyeleotris marmorata*) to assess the status and abundance of this species in Huai Kho Reservoir. The data obtained would serve as a foundational basis for the sustainable conservation and management of the marble goby resources, contributing to food security. Furthermore, this foundational information can be applied to establish measures to restore the abundance of the marble goby (*Oxyeleotris marmorata*). This would enable a sustainable harvesting of the marble goby from Huai Kho Reservoir throughout the year.

MATERIALS AND METHODS

1. Sample collection and laboratory analysis

Fishermen collected the marble goby (*Oxyeleotris marmorata*) samples monthly for one year (January to December 2022) from six locations (Fig. 1). Each location was sampled six times, using gill nets with mesh sizes of 3.0- 6.0cm. All collected fish were then weighed in grams (g) and measured in millimeters (mm).

2. Population dynamics parameters of calculation

284of the marble goby (*Oxyeleotris marmorata*) specimens were collected for biometric analysis, involving precise measurements of their lengths and weights. The data were subsequently stratified into 0.5mm length intervals to facilitate detailed statistical analysis **(Bahtiar *et al.*, 2022)**. The analytical process was conducted utilizing FiSAT_II software in conjunction with Microsoft Excel 2021, as described in the methodologies outlined by **Gayanilo *et al.* (2005)**.

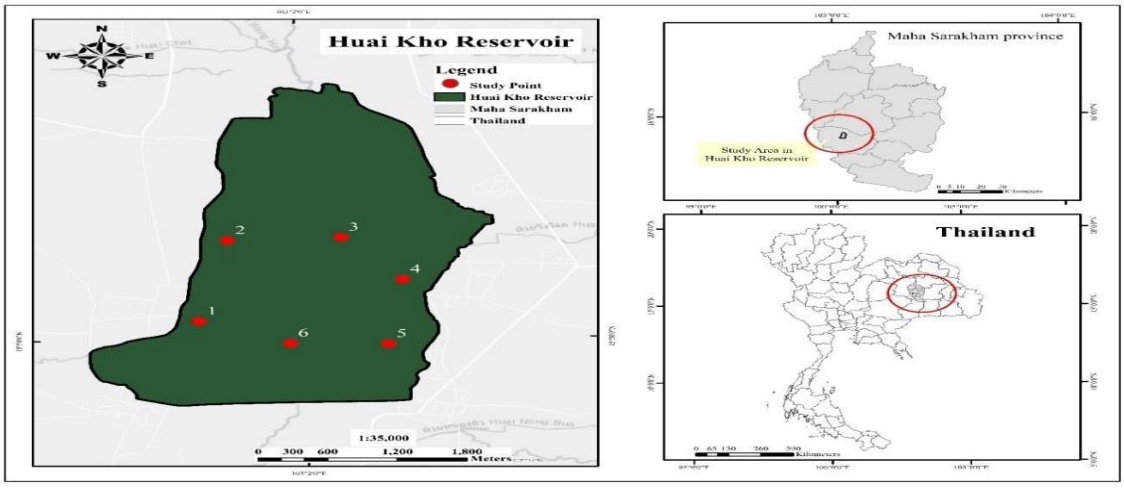

Fig. 1. Location of the six sampling stations in the Huai Kho Reservoir, where the marble goby samples were collected

2.1 Length-weight relationship (LWR)

The mathematical expression used to compute the LWR was based on Le Cren formula **(Le Cren, 1951)**: $W = aL^b$, Where W = Weight gram; g) , L = Length (millimeters; mm) ; a is Intercept; b is growth pattern estimator of length-weight. Its mathematical expression was computed using the formula **(Scherrer, 1984)**: Log10W = log10a+b log10L.

2.2 Asymptotic length (L_∞) and growth coefficient (K)

The empirical formula was used to estimate the theoretical age at birth (t_0) with the Pauly formula **(Pauly, 1984a)**; log10 (-t0) = -0.3922 - 0.275 × log10 L∞ - 1.038 × log10K. Here t_0 is the theoretical age at length zero (year); L_∞ is the asymptotic length (centimeter; cm), and K is the growth constant (per year). In determining the growth performance index, the formula of **Munro and Pauly (1983)** was used as follows: $\phi = 2$ log10 L∞ + log10K. Applying the VBGF fitted in ELEFANT-I routine of FiSAT_II software were computed using the Pauly formula; Lt = L_∞ (1-e-K(t-to))). Here, L_t is the mean length at age t; t is the age of the marble goby, and t0 is the hypothetical age at which the length is zero.

2.3 Age

The analysis was conducted using the Bhattacharya method **(Bhattacharya, 1967)**. In this method, fish were divided into several length classes, and the frequency of each class length was converted into a logarithm, and then the difference between the logarithm of a class and the previous class was calculated.

2.4 Mortality rates (M)

The annual total mortality rate (Z) was derived from the length-converted catch curve analysis **(Pauly, 1984b)**. Concurrently, the natural mortality rate (M) was estimated utilizing Pauly's formula: log10 M = -0.0066 - 0.279 log10 L∞ + 0.6543 log10 K+0.4634 log10T, where the annual average surface water temperature in the Huai Kho Reservoir was used. To determine the fishing mortality rate (F), the formula F = Z – M was applied. The level of exploitation (E) was estimated using the formula E = F /Z **(Pauly, 1984a)**.

2.5 Probability of capture and recruitment pattern

The probability of capture was quantified by employing the length-converted catch curve routine, which facilitated the estimation of capture lengths at L_{25}, L_{50}, and L_{75} (i.e., lengths at which 25, 50, and 75% of the fish were captured), as described by **Sparre and Venema (1998)**. The recruitment pattern over a one-year period was estimated based on the monthly length measurements of the marble boby and the consistency of their length distribution, utilizing the Von Bertalanffy growth function, as detailed by **Moreau and Cuende (1991)**.

2.6 Virtual population analysis (VPA)

Through length-structured virtual population analysis (VPA), the population sizes and fishing mortality for each length group were computed using inputs such as a, b, M, F, L∞, and K in the FiSAT_II software, as described by **Pauly (1984a)**.

2.7 Relative yield per recruit (Y'/R) and biomass per recruit (B'/R)

Y'/R and B'/R were approximated in FiSAT_II software by applying the **Beverton and Holt model (1966)**.

RESULTS

1. Length-weight relationship (LWR)

The frequency distribution analysis of the size of the marble goby was carried out by collecting specimens from the reservoirs of Huai Kho over a period spanning from January to December 2022, encompassing a full year of data collection. A total of 284 individuals of the marble goby were sampled, ranging in weight from 24 to 236g, with an average weight of 60.87± 31.00g. The size frequency distribution of the total length at intervals of 0.50mm ranged from 115 to 262mm. The mean total length was 162.97± 24.60mm, with the prominent size class occurring between 145- 150mm, where 54 individuals (19.01%) were recorded, as shown in Figs. (2, 3). The length-weight relationship (LWR) of the marble goby is expressed as follows: $LWR = 0.02443L^{1.61202}$ ($r^2 = 0.92$); $Lt = 273.00 *(1-e^{-0.1}(^{t+0.642}))$ (Fig. 3).

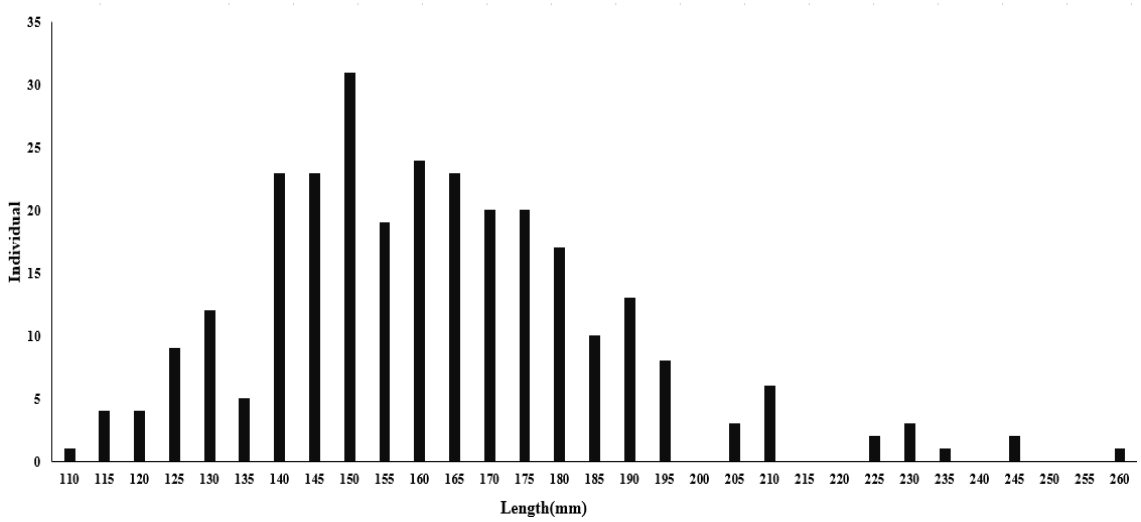

Fig. 2. Length frequency distribution ranging between 110- 260mm (TL) for both sexes of the marble goby (n = 284) using the landing data from Huai Kho Reservoir during January-December 2022

2. Age and growth parameters

The initial extreme length value was used in ELEFAN-I, incorporated in the FiSAT_II package, to produce the optimum growth curve. The observed extreme length was 260.00mm, and the predicted extreme length was 269.71mm. The length range of the 95% confidence interval was between 247.24 and 292.18mm. The analysis of length frequency distribution in each month revealed growth parameters for the marble goby in the study area, with a growth performance index (ϕ) value of 3.986 per year (Fig. 3), asymptotic length (L_∞) of 273.00mm, growth coefficient (K) of 0.13 per year, and t0 of 0.642 months (Figs. 4, 5). The maximum length (L_{max}) of the marble goby was estimated to be 260.00mm. Consequently, the sizes attained by individuals of the marble goby were 32, 87, 147, 187, 217, 232, 252, 262, and 267mm. It can be observed that the marble goby reaches ages of 1, 3, 6, 9, 12, 15, 20, 25 and 30 months, respectively (Fig. 6).

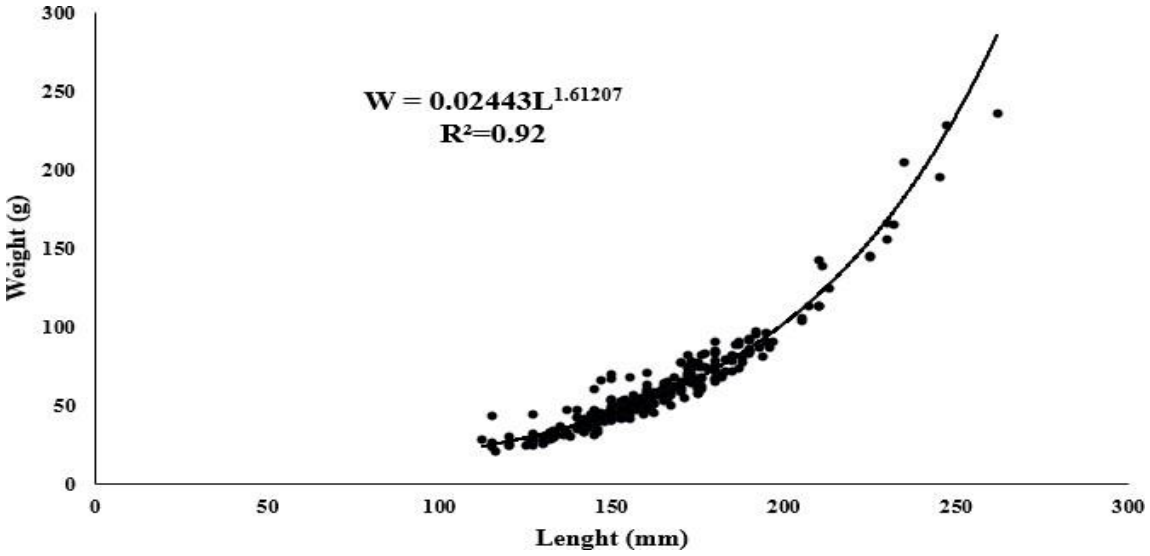

Fig. 3. Length-weight relationship (LWR) of the marble goby (n = 273) in the Huai Kho Reservoir

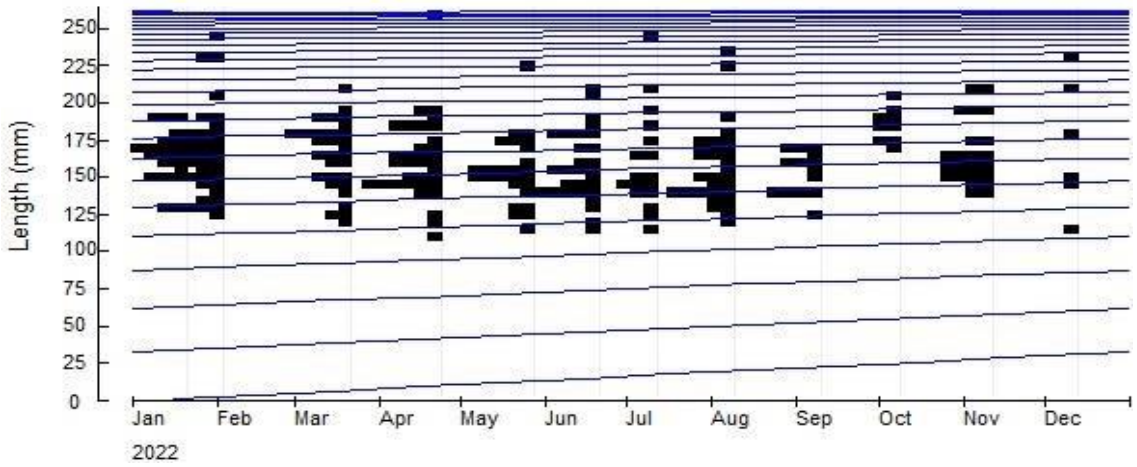

Fig. 4. Restructured length-frequency distribution of samples of the marble goby (n = 284) from gill nets catches in the Huai Kho Reservoir superimposed with growth curves analyzed using ELEFAN-1 from the K-scan of FiSAT_II

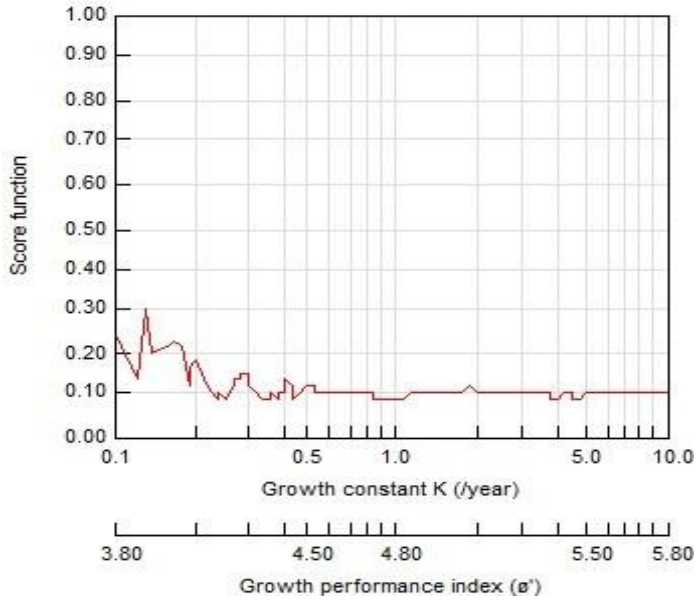

Fig. 5. ELEFAN I K-scan routine FiSAT II output for the marble goby (n = 284) in the Huai Kho Reservoir

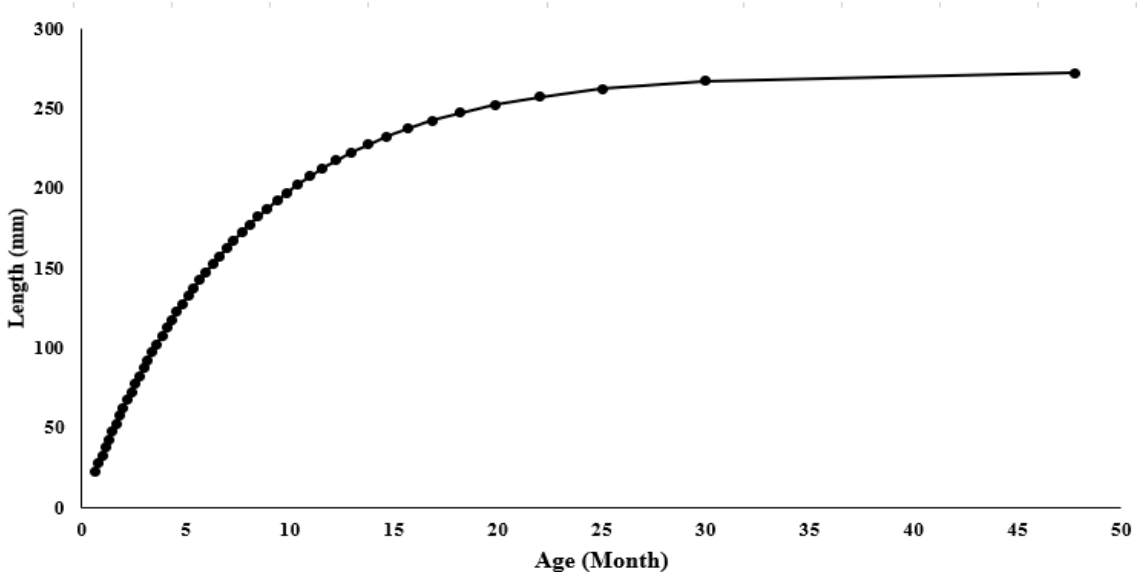

Fig. 6. The correlation between age (in months) and length (in mm) of the marble goby (n = 284) in the Huai Kho Reservoir

3. Total mortality (Z)

Total mortality (Z) was 0.97 per year with a CI 95% confidence interval of 2.216-4.068 (r^2 = 0.98) assembled from the input values of VBGF growth parameters (L_∞ and K). The natural mortality (M) was 0.26 per year. Consequently, the fishing mortality (F), expressed as F = Z - M, was calculated to be 0.71 per year (Fig. 7). The study determined that the exploitation rate (E) of the marble goby fish in the Huai Kho Reservoir was 0.73.

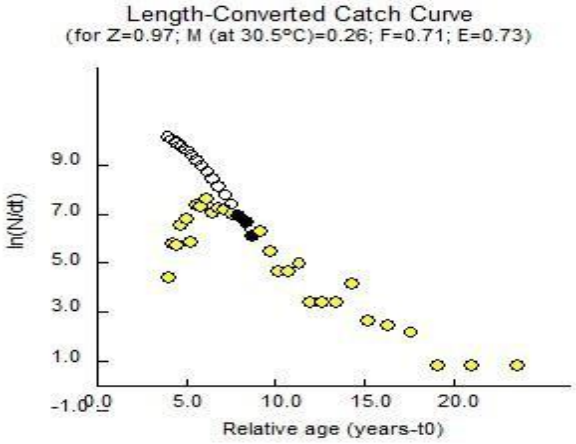

Fig. 7. The length-converted catch curve for the marble goby (n = 284) in the Huai Kho Reservoir was utilized for estimating various mortality rates and the exploitation rate

4. Probability of capture

The probability of capture for the marble goby was calculated in fork length as L25%= 137.18mm, L50%= 144.90mm, and L75%= 163.02mm (Fig. 8).

5. Recruitment pattern

The recruitment pattern demonstrated a single annual peak for the marble goby, with a replacement rate ranging from 0.00 to 18.82%. The highest replacement rates occurred between March and June, peaking at 18.82% in May, while the lowest replacement rates were recorded in December, reaching 0.00% (Fig. 9).

6. Virtual population analysis (VPA)

VPA was used to form the length-structured virtual population analysis, and VPA was conducted using FiSAT_II software for the marble goby in the Huai Kho Reservoir. Throughout the year 2022, a total of 10,773.48 individuals of the marble goby were observed. Among them, the smallest size of the marble goby, starting to replace individuals, was at a length of 110mm, with a count of 1,140.09 individuals. The numbers are expected to decrease with increasing age or length. The mortality rate was observed to be higher within the length range of 160 to 180mm, with the maximum value occurring at a length of 175mm, totaling 1,917 individuals, repeatedly indicating high fishing mortality in the juvenile marble goby. The total steady-state biomass was found to be 6.50 tons; the total steady-state biomass ranged from 0.030 to 0.310 tons. Mortality caused by fishing gear ranged from 0.000 to 0.1917 per year; at a length of 175mm F_{max} was 0.1917 per year (Fig. 10).

7. Relative yield per recruit (Y/R) and biomass per recruit (B/R)

The Y/R and B/R analysis of the marble goby was estimated using the knife-edge procedure of FiSAT_II software. The values of the exploitation rate at L_c/L_∞, M/K, E_{10}, E_{50}, and E_{max} were found to be 0.53, 1.93, 0.609, 0.374, and 0.693, respectively (Fig. 11)

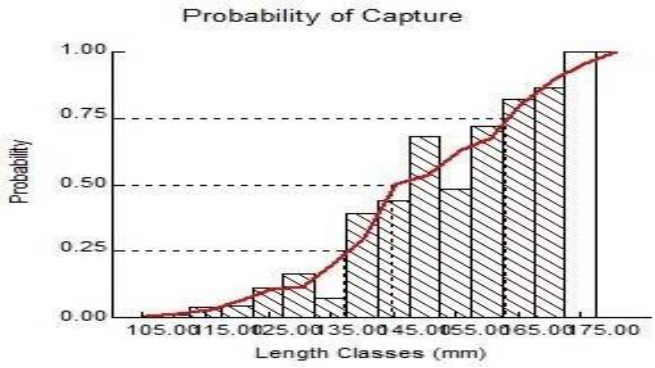

Fig. 8. The selectivity curve of the marble goby (n=284) in the Huai Kho Reservoir

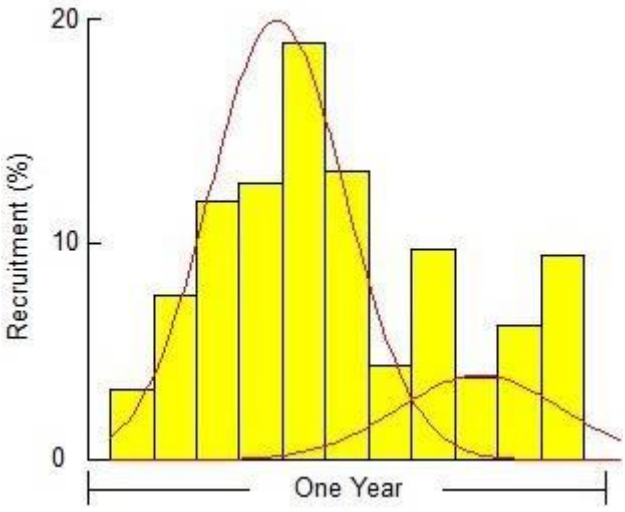

Fig. 9. Recruitment pattern of the marble goby (n=284) in the Huai Kho Reservoir

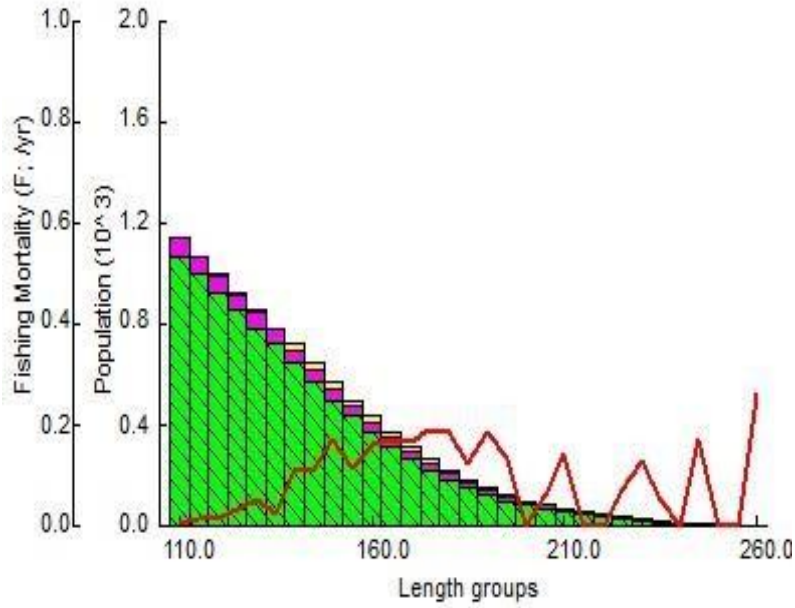

Fig. 10. Population size and mortality characteristics for the marble goby (n=284) in the Huai Kho Reservoir based on length-structured VPA

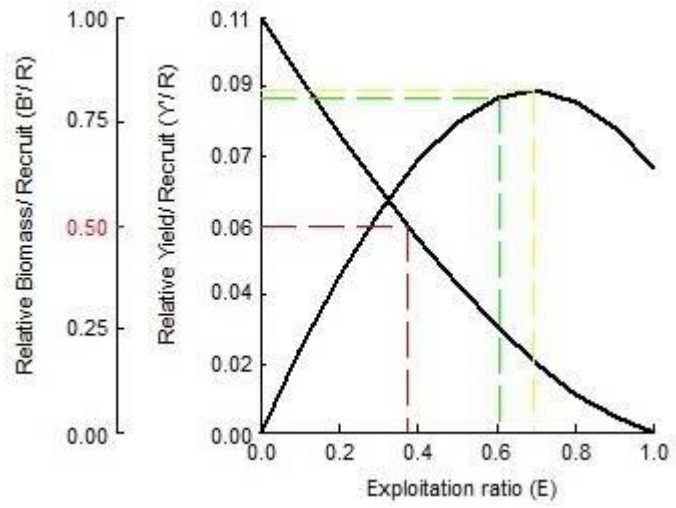

Fig. 11. Relative yield per recruit and biomass per recruit for the marble goby (n=284) in the Huai Kho Reservoir. Note: The dash-lines: red (--) green (--) and yellow (--) show the exploitation rates at $E_{0.1}$, $E_{0.5}$, and E_{max}, respectively

DISCUSSION

According to the study, a total of 284 marble goby specimens were collected, with weights ranging from 24 to 236g, and an average weight of 60.87± 31.00g. The size frequency distribution spanned from 115 to 262mm. The mean total length was 162.97± 24.60mm. When compared to the reference baseline, it was found that the weight and length of the marble goby in the study area were lower than those in Serma Reservoir, where weights ranged from 21.0 to 704.8g, and lengths ranged from 120 to 445mm **(Aini *et al.*, 2020)**. In contrast, in Tandano Lake, the marble goby were found to have weights ranging from 16 to 30g and sizes from 21.6 to 260mm **(Sipayung *et al.*, 2023)**. Regarding the length-weight relationship (LWR) analysis, it was found that LWR = $0.02443L^{1.61202}$ (r^2 = 0.92). This preliminary study on the marble goby from Huai Kho Reservoir shows that the growth pattern is negatively allometric, as evidenced by a coefficient 'b' value lower than 3 (b<3). In the present case, the estimated b value (1.61202) is lower than the isometric value (3). This suggests that the growth pattern in terms of the weight of the fish is faster than its length **(Oussellam *et al.*, 2023)**. Upon comparing with the reference area, it was found that the Huai Kho Reservoir has a lower b value than Sermo Reservoir (b=3.3005), indicating that the growth pattern in terms of the length of the fish is more rapid than its weight growth **(Aini *et al.*, 2020)**. The differences in the length-weight relationship (LWR) of the marble goby are influenced by sex (male and female), habitat, diet, stomach contents, and water quality, including temperature, pH, and dissolved oxygen (DO) levels **(Herawatia *et al.*, 2016; Idris *et al.*,**

2016; Ing & Chew, 2017; Lim *et al.*, 2018; Teoh *et al.*, 2019; Sipayung *et al.*, 2023). Huai Kho Reservoir has changed significantly from the past. At present, the population has increased, and the area around Huai Kho Reservoir is densely populated with communities and villages. Wastewater from community activities, rich in nitrogen and phosphorus, flows directly into the reservoir. This nutrient influx benefits aquatic plants, leading to a high density and an abundance of species such as *Hydrilla verticillata*, *Utricularia aurea*, *Spirogyra* sp., *Typha angustifolia*, and *Nelumbo nucifera*. These plants serve as hiding spots for the juvenile marble goby and as ambush sites for prey. Furthermore, aquatic plants provide habitats for small organisms such as juvenile fish, shrimp, snails, and aquatic insects. These small organisms become food for the marble goby **(Khowhit *et al.*, 2023; Fishbase, 2024)**. As a result, the marble goby in Huai Kho Reservoir has an abundant food supply, resulting in their unique characteristic of having a weight that exceeds their length.

The growth pattern of the marble goby is influenced by various factors, including changes in body shape at different life stages, seasonal variation, physiological conditions of digestion, breeding seasons, water levels in the reservoir, water quality, and the length range of the analyzed fish **(Suwanjarat *et al.*, 2004; Chewa *et al.*, 2009; Herawatia *et al.*, 2016; Lim *et al.*, 2020; Lim *et al.*, 2023)**. The marble goby in Huai Kho Reservoir has a growth performance index (ϕ) value of 3.986 per year, an asymptotic length (L_∞) of 273.00mm, and a growth coefficient (K) of 0.13 per year. When compared with the reference area, the growth parameters were found to be lower, with an asymptotic length (L_∞) of 339.1mm and a growth coefficient (K) of 0.64 per year **(Makmur *et al.*, 2023)**. The growth coefficient (K) serves as an indicator of the growth rate of aquatic organisms. A higher growth coefficient (K) signifies faster and more favorable growth, while a lower growth coefficient (K) reveals slower and less optimal growth. The growth coefficient (K) of 0.13 per year indicates that the marble goby in Huai Kho Reservoir has a low growth rate.

Total mortality (Z) was 0.97 per year. Natural mortality (M) was 0.26 per year, and fishing mortality (F) was 0.71 per year. This indicates a high level of mortality from fishing gear. Upon comparing the total mortality in the study area with the reference values, it was discovered that for the marble Goby, the total mortality (Z), natural mortality (M), and fishing mortality (F) were 2.63 per year, 1.32 per year, and 0.50 per year, respectively **(Makmur *et al.*, 2023)**. Huai Kho Reservoir has a unique ecological environment, characterized by a large number of aquatic plants that provide hiding places for the marble goby. This makes it difficult to catch them using fishing nets. Consequently, fishermen have shifted to using fish traps, which has resulted in a higher catch of the marble goby and a subsequent decline in their population.

The study determined that the exploitation rate (E) of the marble goby fish in the Huai Kho Reservoir is 0.73, surpassing the maximum sustainable exploitation rate (E_{max}) of 0.693. This finding underscores that the current utilization of the marble goby fish

exceeds its sustainable production capacity. Typically, the exploitation rate (E) should be maintained at or below 0.50 to ensure sustainability. An E value above 0.5 indicates a high level of exploitation of the marble goby in the Huai Kho Reservoir. The utilization of aquatic organisms has exceeded the sustainable production capacity. When compared with the reference values, the exploitation rate (E) of the marble goby was determined to be E = 0.50 **(Makmur *et al.*, 2023)**. The exploitation rates suggest that the utilization of aquatic resources in Huai Kho Reservoir exceeds the sustainable production threshold.

The probability of capture for the marble goby was calculated in fork length as L25%= 137.18mm, L50%= 144.90mm, and L75%= 163.02mm. The findings indicate a high efficiency of fishing gear in capturing the marble goby, with the highest catch rates in the Huai Kho Reservoir occurring among the juvenile fish. The length of 175mm was found to have F_{max} = 0.1917 per year. From the probability of capture analysis, it was found that about 50% of fish are caught at the length of 144.90mm for the marble goby, which correlates with the mean total length of 162.97± 24.60mm and the prominent size class occurring between 144- 150mm. This finding suggests that the fishing gear dimensions, such as the twine size of gill nets, mesh size of gill nets, and the width, length, and depth of gill nets, significantly affect the probability of capture for the marble goby **(Warsa *et al.*, 2019; Dereli *et al.*, 2022)**. The recruitment pattern indicates a single annual peak for the marble goby, with the highest replacement rates occurring between March and June, peaking at 18.82% in May. For most tropical aquatic species, recruitment occurs continuously throughout the year but may vary seasonally, with a pronounced recruitment intensity during monsoon periods or transitional seasons.

CONCLUSION

The study on the population dynamics of the marble goby in Huai Kho Reservoir revealed that the current exploitation rate (E=0.73) exceeds the optimal level (E=0.5) and surpasses the predicted maximum exploitation rate (E_{max}=0.693). Therefore, urgent conservation and management measures for the marble goby are necessary and should include: a) controlling and collaborating with fishermen to prevent the use of illegal fishing gear, such as fish traps; b) establishing conservation zones for the marble goby by designating the area along the rim of Huai Kho Reservoir, extending 1 kilometer inland and 100 meters into the water, as a protected area; c) providing habitats or artificial shelters for the marble goby using local materials around the reservoir, such as bamboo, branches, and tree stumps; d) enacting regulations to impose penalties on fishermen or others who violate conservation rules within Huai Kho Reservoir; e) educating fishermen to refrain from fishing during the spawning season of the species; f) conducting training programs to instill a sense of responsibility and appreciation for the marble goby among fishermen; and g) improving and expanding the reservoir's capacity, given that Huai Kho Reservoir, built in 1968, has experienced siltation over 56 years.

ACKNOWLEDGEMENTS

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ETHICS STATEMENT

This research project has been approved by the Ethical Principles and Guidelines for the Use of Animals No. 17/2023 of Mahasarakham University, Thailand.

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