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Ecological Study on the Population Dynamics of the Armatus Barb (*Cyclocheilichthys armatus*) in Huai Kho Reservoir, Northeastern Thailand

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ABSTRACT

This research focused on understanding the population behavior of the Armatus Barb (*Cyclocheilichthys armatus*) in Huai Kho Reservoir, northeastern Thailand. Over the course of 2022, a total of 520 fish were sampled. Sampling was conducted monthly. Fish sizes varied from 90 to 205 millimeter in fork length, and weights ranged from 16 to 135 grams. The species showed a mean fork length of 128.42±17.05 millimeter and an average weight of 26.38±13.20 gram. Growth modeling indicated a maximum potential length of 194.25 millimeter, with a growth rate (K) of 0.44 per year. The species' length–weight relationship (LWR) showed a strong correlation ($W = 0.011343L^{1.94526}$; $r^2 = 0.95$). Estimated mortality rates included a natural mortality (M) of 0.65 $year^{-1}$, fishing mortality (F) of 1.18 $year^{-1}$, and total mortality (Z) of 1.83 $year^{-1}$. Recruitment occurred throughout the year, peaking between July and October, with a maximum in September (21.51%). The estimated length at first capture was 14.56 millimeter. The exploitation rate (E) was 0.65, surpassing the sustainability threshold of 0.50 and indicating considerable fishing pressure on the population. These findings suggest that the *C. armatus* population in the Huai Kho Reservoir is currently overexploited and experiencing overfishing. Therefore, management measures and harvesting regulations are urgently needed to ensure the sustainability of this species in the reservoir.

INTRODUCTION

Cyclocheilichthys is a freshwater cyprinid (family Cyprinidae); it is an indigenous species that inhabits lentic or sluggishly flowing waters, for instance, swamps, marshes, canals, and rivers **(Rainboth, 1996)**. It characteristically forms schools, foraging on macrophytes, filamentous algae, organic detritus, and small benthic fauna; it is native to and widely distributed in freshwater habitats across Southeast Asia. Worldwide, nine additional species within this genus are recognized, each with distinct country-level distributions. *Cyclocheilichthys apogon* and *Cyclocheilichthys repasson* are distributed widely across Southeast Asia. *Cyclocheilichthys armatus* is found in Brunei Darussalam, Cambodia, Indonesia, the Lao PDR, Malaysia, Myanmar, Thailand, and Viet Nam. *Cyclocheilichthys enoplus* and *Cyclocheilichthys heteronema* occur in Cambodia, Indonesia, the Lao PDR, Peninsular Malaysia, Thailand, and Viet Nam. *Cyclocheilichthys furcatus* has been recorded in Cambodia, the Lao PDR, and Thailand. The species *Cyclocheilichthys lagleri* and *Cyclocheilichthys schoppeae* are found only in the Philippines. Finally, *Cyclocheilichthys janthochir* is known from Indonesia, according to previous studies **(Pasco-Viel *et al.*, 2012; Thinh *et al.*, 2020)**.

C. armatus is not yet recognized as an economically significant species in Thailand; nevertheless, as a naturally occurring member of the native freshwater ichthyofauna, it enriches the dietary diversity of communities living around reservoirs and rivers. Moreover, the species is regarded as ecologically significant; it enriches biodiversity and plays a pivotal role in freshwater ecosystems, especially within natural water bodies **(Fish Base, 2025)**. *C. armatus* functions as a primary/secondary consumer, subsisting on zooplankton, algae, suspended organic detritus, aquatic insects, and small benthic invertebrates. *C. armatus* helps regulate plankton and aquatic-insect populations; unchecked blooms of these organisms could destabilize the ecosystem. By exerting this control, the species channels energy from the food-chain base (e.g., algae and plankton) to higher-order consumers. *C. armatus* functions as a pivotal trophic intermediary, transferring energy generated by aquatic plants and minute organisms to principal piscivorous predators—specifically *Hampala dispar*, *Channa striata*, *Clarias batrachus*, *Notopterus notopterus*, and *Oxyeleotris marmorata*—within the Huai Kho Reservoir ecosystem **(Wilkinson *et al.*, 2022; Fish Base, 2025)**. At present, the genus *Cyclocheilichthys* in the Huai Kho Reservoir comprises three species—*C. armatus*, *C. apogon*, and *C. repasson*; each is esteemed for its year-round availability and is commonly consumed fresh or processed into diverse products, including fermented fish paste (*Pla ra*), dried fish, and fish sauce **(Khowhit *et al*., 2023)**. This research is the first to explore the population ecology of *C. armatus* in Southeast Asia. It aimed to estimate key biological parameters, including population structure and growth, to evaluate the stock status in Huai Kho Reservoir, northeastern Thailand. These findings offer valuable baseline data that can inform long-term conservation efforts and sustainable fisheries management.

MATERIALS AND METHODS

1. Sample collection and laboratory analysis

Monthly collections were conducted from January to December 2022 at six sites (ST1–ST6) within Huai Kho Reservoir (Fig. 2 & Table 1). Six gill nets (1.0- 1.5m depth, 3.0-6.0cm mesh) were set per station in randomized replicates. Nets were deployed from 16:00 to 04:00h. *C. armatus* specimens were weighed to 0.01g (Cascade, 5,000g) and measured for fork length to 0.1cm. Identification was confirmed via taxonomic keys **(Rainboth, 1996; FishBase, 2025)** (Fig. 1).

Fig. 1. Armatus Barb (*Cyclocheilichthys armatus*)

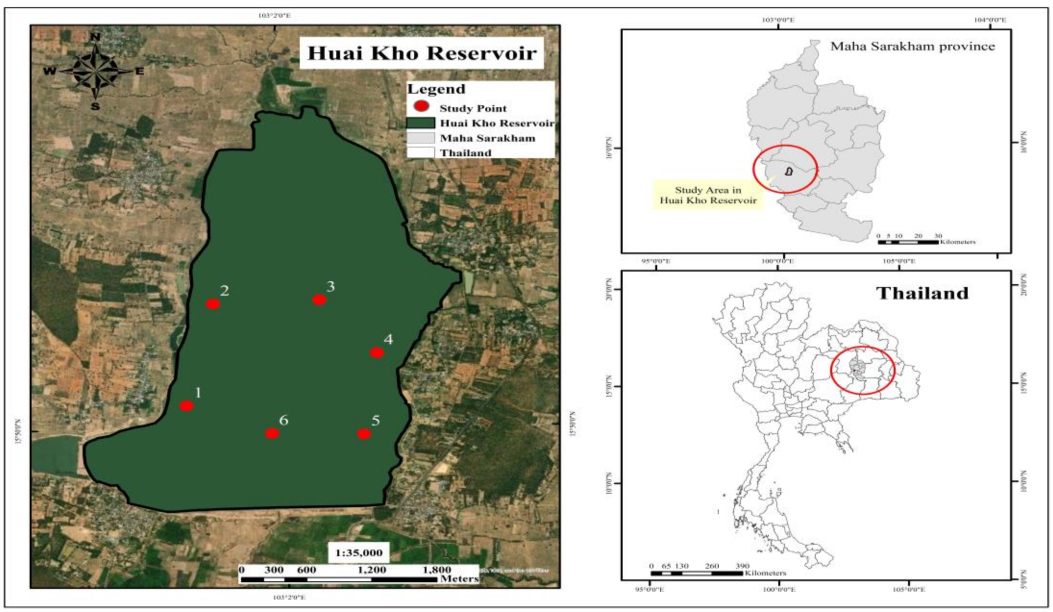

Fig. 2. Map showing the locations of the sampling stations (ST1–ST6) in the Huai Kho Reservoir, northeastern Thailand

Table 1. Sampling stations in the Huai Kho reservoir

Sampling stations	Site code	Latitude	Longitude
Ban Kao Kwang	ST1	15°83'59.38"N,	103°02'47.81"E.
Ban Sumsang	ST2	15°84'72.21"N	103°02'72.71"E
Koh Nonkha	ST3	15°84'75.05"N	103°03'64.11"E
Pattaya Na Chauk 2	ST4	15°84'15.43"N	103°04'12. 46"E
Pattaya Na Chauk 1	ST5	15°83'25.43"N	103°03'99.59"E
Huai Kho reservoir	ST6	15°83'26.98"N	103°03'26.62"E

2. Parameters calculation

A total of 520 *C. armatus* individuals were sampled. The data, aggregated monthly across all six sampling locations, were classified into 0.5mm length classes for analysis (Table 2). Length- frequency analysis was subsequently conducted using the FiSAT II program. **(Gayanilo *et al.*, 1996; Mustakim *et al.*, 2018; Ernaningsih *et al.*, 2024)**. The methodology is outlined as follows:

2.1. Length-weight relationship (LWR)

The LWR was determined using the formula $W = aL^b$ **(Quinn & Deriso, 1999)**, where W is total weight (g), L is total length (mm), *a* is the body form coefficient, and b is the growth exponent (with b = 3 indicating isometric growth; **Pauly, 1984**). To linearize the data, the logarithmic form was applied:

$$\log_{10}W = \log_{10}a + b\cdot\log_{10}L$$

This transformation enabled linear regression analysis to estimate the r^2 value and assess statistical significance **(Scherrer, 1984)**.

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

To estimate the theoretical age at birth (t_0), the following empirical formula developed by **Pauly (1979)** was applied: $\log_{10}(-t_0) = -0.3922 - 0.275 \times \log_{10}L_\infty - 1.038 \times \log_{10}K$

Where, t_0 is the theoretical age at zero length (in years); L_∞ is the asymptotic length (in millimeters), and *K* is the growth constant (year^{-1}).

To assess the growth performance of the population, the growth performance index (ϕ) was calculated following the formula by **Munro and Pauly (1983)**:

$$\phi = 2 \times \log_{10}L\infty + \log_{10}K$$

In this formula, ϕ stands for the growth performance index, L_∞ indicates the asymptotic length (in mm), and K is the von Bertalanffy Growth Function (VBGF) parameter that reflects how quickly the fish grows toward its maximum size.

Growth parameters L_∞ (the maximum length a fish can reach) and K (the growth rate) were estimated by applying the ELEFAN-I method in FiSAT II v1.2.2 **(Gayanilo *et***

***al*., 2005**) to corrected length-frequency data. This method fits the data to the von Bertalanffy Growth Function (VBGF), defined by **Pauly (1984)** as: $L_t = L_\infty(1 - e^{-K(t-t_0)})$.

Where, L_t is the length at age t, t_0 represents the hypothetical age when length is zero, and L_∞ and K describe the fish's growth characteristics **(Newman, 2002)**.

Table 2. Length frequency data of Armatus Barb (*Cyclocheilichthys armatus*)

ML (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
90				1								
95				1		2				1		
100	1	3			2		3		2	1	3	1
105	2	2	2		2	2	4	2	1	2	1	2
110	1	7	15	7	8	3	4	3	2	4	7	5
115	1	6	11	7	11	2	3	4	1	1	6	6
120	1	11	10	9	21	1	3	3	1	2	9	6
125	2	7	5	5	10	1	2	1	2	1	1	3
130	3	9	6	7	5	3	1	5	3	2	1	3
135	1	7	5	7	10	3	1	4	1			2
140	3	6	3	4	17	2	3	3	1		2	1
145	3	4	2	5	10	1	2	3	2	1		1
150	1	1	1	2	14		4	2	1		1	1
155	1	1	1	3	5		3	1	1			1
160		1	1	2	3			1		1		1
165				1	2							
170				1	2							
175			1		1		1					
180					1							
185					1							
190					1							
195					1							

2.3 Mortality rates

Total mortality (Z) was derived from the length-converted catch curve. Natural mortality (M) was estimated using **Pauly**'s **(1980)** formula:

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

with T representing the mean annual temperature (30.55 °C). Fishing mortality (F) was calculated as F = Z − M, based on **Gulland (1971)**. Moreover, the exploitation rate (E) was computed as E = F / Z, following **Beverton and Holt (1966)**.

2.4 Probability of capture and recruitment pattern

Capture probability was assessed via the length-converted catch curve approach, enabling estimation of the lengths at which 25, 50, and 75% of the population are susceptible to capture (L25, L50, and L75, respectively) **(Sparre & Venema, 1998)**. Recruitment patterns throughout the year were determined from monthly length-frequency data of *C. armatus* and analyzed using the von Bertalanffy Growth Function, as described by **Moreau and Cuende (1991)**, to evaluate temporal consistency in size distribution.

2.5 Virtual population analysis (VPA)

A length-structured virtual population analysis (VPA) was conducted to evaluate population abundance and fishing mortality by size class. The analysis incorporated parameters a, b, natural mortality (M), fishing mortality (F), asymptotic length (L_∞), and growth coefficient (K), processed using FiSAT II software **(Pauly, 1984)**.

2.6 Relative yield per recruit (Y/ /R) and biomass per recruit (Y/ /R)

The **Beverton and Holt (1966)** model within FiSAT_II software was applied to estimate.

$$Y'/R = EU^{M/K}\left\{1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right\}$$

Where, U=1-(Lc/ L_∞), m=(1-E)/(M/K)=K/Z and E=F/Z

B/ /R is estimated using the relationship: (Y/ /R)/F.

RESULTS

Length-weight relationship (LWR)

During 2022, a total of 520 *C. armatus* specimens were collected monthly from Huai Kho Reservoir for frequency distribution analysis. Weights ranged from 16– 135g (mean: 26.38 ± 13.20g), and total lengths ranged from 90– 205mm, analyzed at 0.5-mm intervals. The mean total length was 128.42 ± 17.05mm, with the dominant size class being 110– 120mm. The length–weight relationship followed $W = 0.011343L^{1.94526}$ (r^2 = 0.95), and the von Bertalanffy growth function was $L_t = 194.25 \times (1 - e^{(-0.44(t + 0.651)})$ (Figs. 3, 4).

Growth parameters

An analysis of monthly length-frequency data revealed the growth characteristics of *C. armatus* in the Huai Kho Reservoir. The species reached a maximum observed length of 190.00mm, while the model estimated the asymptotic length (L_∞) at 194.24mm. The projected maximum size was 193.27mm, with a 95% confidence interval ranging from 178.91 to 207.62mm. The growth coefficient (K) was found to be 0.25 $year^{-1}$, and the theoretical age at zero length (t_0) was -0.651 months. The growth performance index (ϕ) was calculated at 4.22, indicating that the species grows at a moderate rate (Figs. 5, 6).

Total mortality (Z)

Analysis of *C. armatus* mortality revealed a total death rate (Z) of 1.83 per year, based on length-frequency data and VBGF parameters. This value was supported by a high degree of confidence (CI: 9.399–11.520; $r^2 = 0.99$). Natural causes accounted for a mortality rate (M) of 0.65, while fishing activities were responsible for a rate (F) of 1.18. With an exploitation rate (E) of 0.65, the species is clearly subject to significant fishing pressure in the Huai Kho Reservoir (Fig. 7).

Probability of capture

The lengths at which 25, 50, and 75% of the *C. armatus* population were captured were determined to be 104.19 mm (L25%), 121.61 mm (L50%), and 130.96 mm (L75%), respectively (Fig. 8).

Recruitment pattern

The recruitment pattern indicates a single annual peak for *C. armatus*, with a replacement rate ranging from 0.00% to 21.51%. The highest replacement rates occur between July and October, peaking at 21.51% in September, while the lowest replacement rates are recorded in December, reaching 0.00% (Fig. 9).

Virtual population analysis (VPA)

VPA for *C. armatus* in Huai Kho Reservoir was performed using FiSAT_II software. In 2022, a total of 8,572.88 *C. armatus* individuals were recorded. The smallest size at which individuals began to be replaced was 90 millimeters, with 1279.12 individuals observed. The total steady-state biomass of *C. armatus* was calculated to be 0.98 tons, while steady-state biomass ranged from 0.001 to 0.007 tons. Mortality rates were higher in the length range of 135 to 150 millimeters, peaking at 145 millimeters with 305.53 individuals repeatedly indicating high fishing mortality in juvenile *C. armatus* (Fig. 10).

Relative yield per recruit ($Y^/$/R) and biomass per recruit ($B^/$/R)

The relative yield-per-recruit and biomass-per-recruit analyses for *C. armatus* were conducted using FiSAT II software, applying the knife-edge selection approach. The results indicated that the exploitation rate for maximizing yield (E_{10}) was 0.559, while the rate corresponding to 50% of the maximum yield (E_{50}) was 0.366. The exploitation level yielding the absolute maximum production (E_{max}) was calculated at 0.664. These findings provide insight into how current fishing pressure compares with optimal harvest levels (Fig. 11).

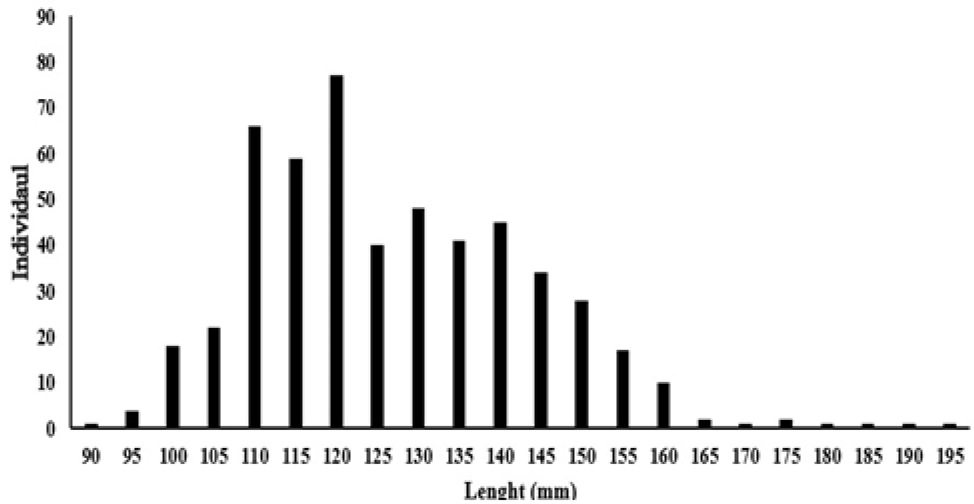

Fig. 3. Length frequency distribution ranging between 90-195 millimeters (TL) for both sexes of *C. armatus* (n=520) using the landing data from Huai Kho Reservoir

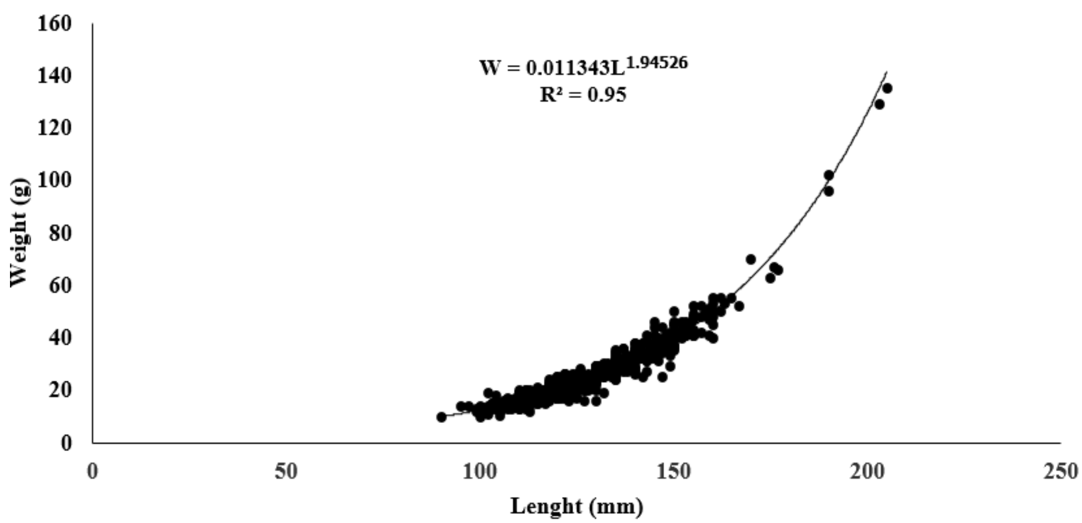

Fig. 4. Length-weight relationship (LWR) of *C. armatus* (n=520) in the Huai Kho Reservoir

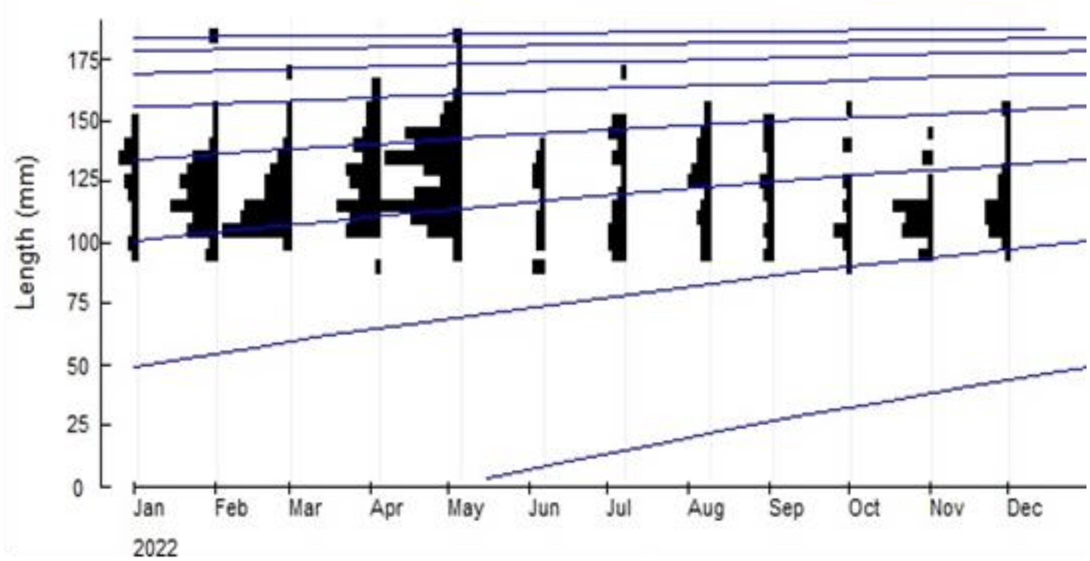

Fig. 5. Restructured length-frequency distribution of samples of *C. armatus* (n=520) from trawl catches in the Huai Kho reservoir superimposed with growth curves. analyzed using ELEFAN-1 of FiSAT_II

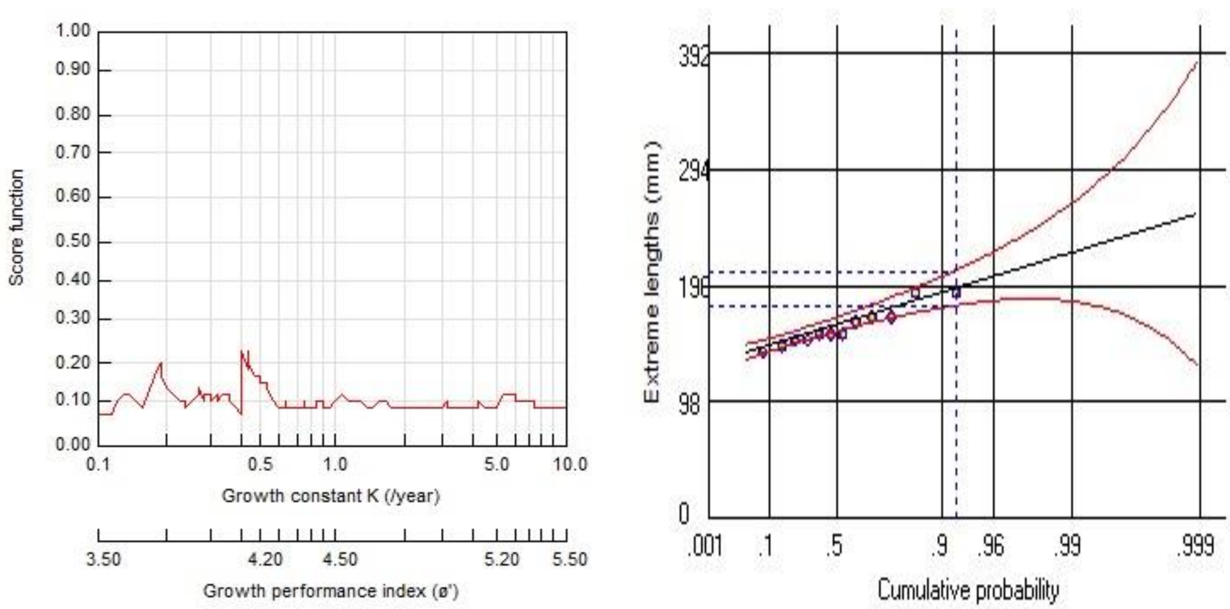

Fig. 6. ELEFAN I K-scan routine FiSAT II output for *C. armatus* (n=520) in the Huai Kho Reservoir

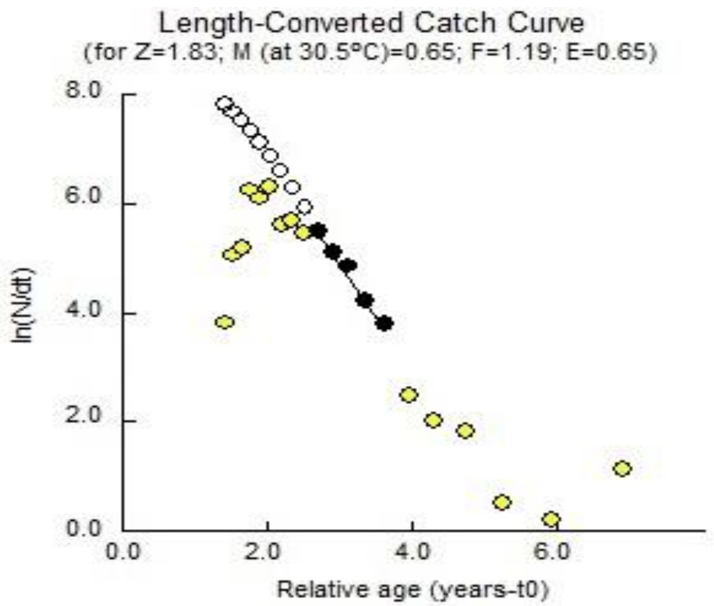

Fig. 7. Length-converted catch curve for *C. armatus* (n=520) in Huai Kho Reservoir, applied to calculate mortality and exploitation rates

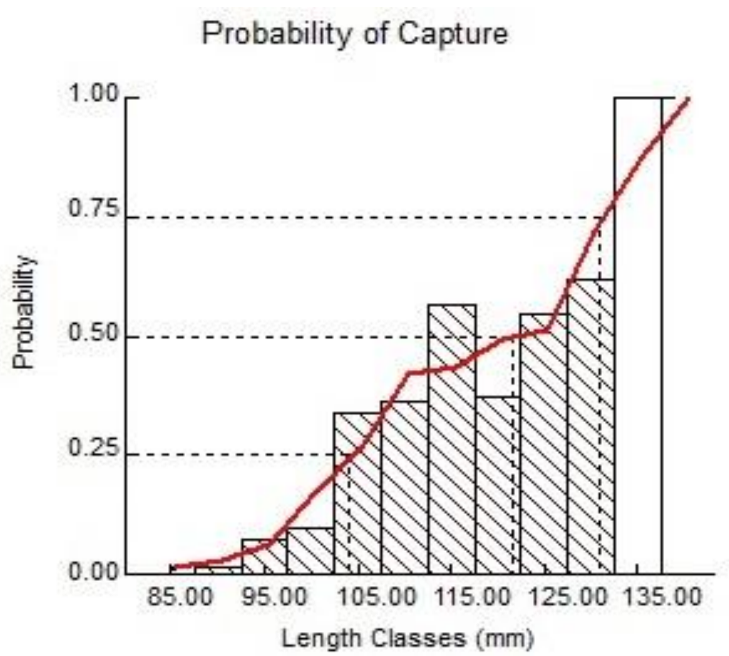

Fig. 8. The Selectivity curve of *C. armatus*(n=520) in the Huai Kho Reservoir

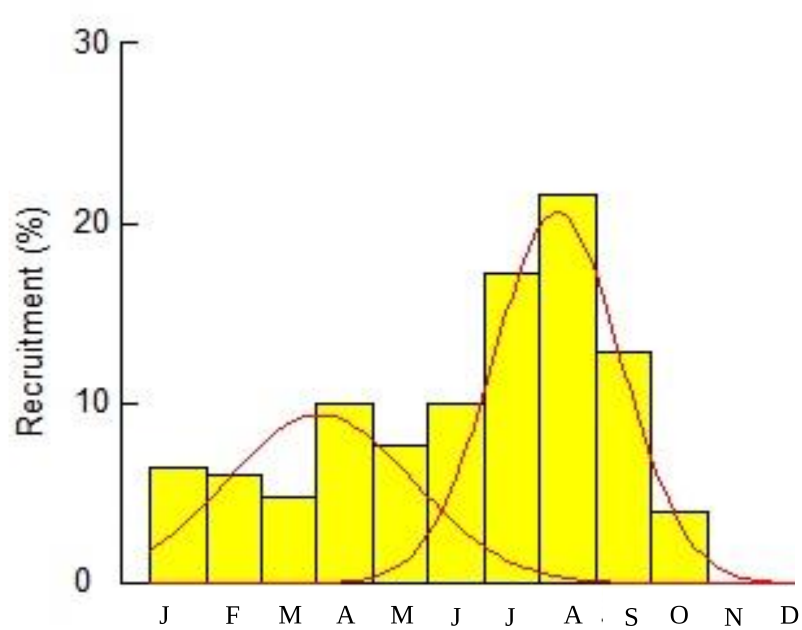

Fig. 9. Recruitment pattern of *C. armatus* (n=520) in the Huai Kho Reservoir

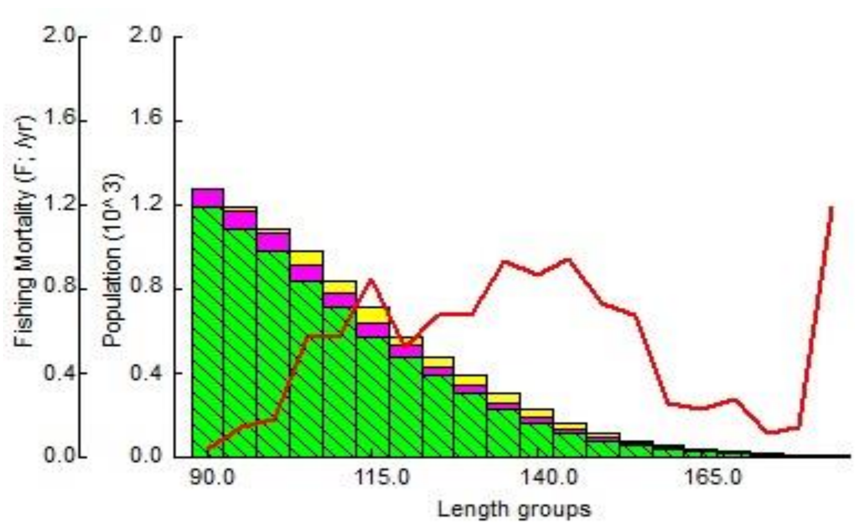

Fig. 10. Population size and mortality characteristics for *C. armatus* (n=520) in the Huai Kho Reservoir based on length structured VPA

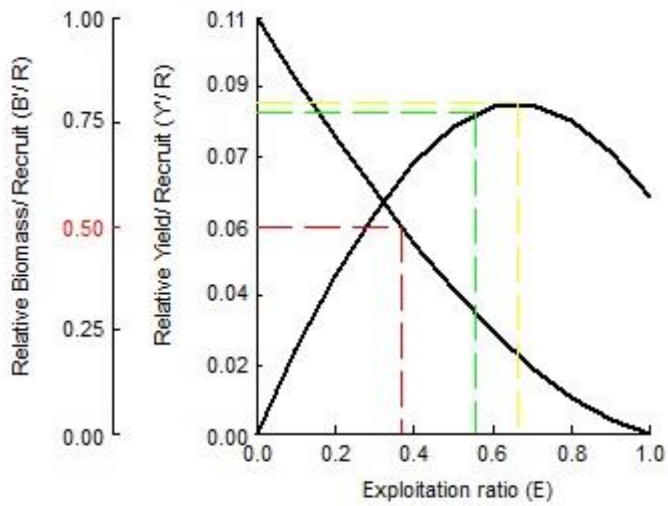

Fig. 11. Relative yield per recruit and biomass per recruit for *C. armatus* (n=520) in the Huai Kho Reservoir. Note: The dash-lines: red (--) green (--) and yellow (--) indicate the exploitation rates at $E_{0.1}$, $E_{0.5}$, and E_{max}, respectively

DISCUSSION

A total of 539 *C. armatus* individuals were collected, with weights varying between 16 and 135 grams and an average weight of 26.38±13.20 grams. The specimens measured between 90 and 205 millimeters in total length, analyzed in 0.50-millimeter intervals. The mean total length was found to be 128.42±17.05 millimeters, with the predominant size class ranging from 110 to 120 millimeters. Such differences can be attributed to geographic location, local food availability, and fishing methods (selectivity of the catching gear, sample size), factors known to impact fish growth patterns within a population **(Boudjadi & Rachedi, 2021; Rapita *et al.*, 2021; Roesma *et al.*, 2023)**.

From the analysis of the Length-weight relationship (LWR) equation of *C. armatus*, the equation LWR = 0.011343 $L^{1.94526}$ (r^2= 0.95) was obtained. This preliminary study on *C. armatus* from Huai Kho Reservoir shows that the growth pattern is negatively allometric, as evidenced by a coefficient 'b' value exceeding 3 (b < 3). In the present case, estimated b (1.94526) is lower than the isometric value (3) **(Oussellam *et al.*, 2023)**. This suggests that the growth pattern of the fish in terms of weight is more rapid than its growth in length. These variations ingrowth parameters may be due to food availability, changes in environmental factors, the ecological status of the habitats, fish sex, season and fishing gear used in sampling **(Olagbemide & Owolabi, 2023; Haslina *et al.*, 2024;**

Muslim *et al.*, 2024; Shuaib *et al.*, 2025). This suggests that the fish increased in length at a higher rate than in weight, possibly due to some actors (e.g., low food availability, environmental stress, early life stages, fish genetics, or season) **(Baihaqi *et al.*, 2025)**.

Based on an asymptotic length (L_∞) of 194.24 mm and a growth coefficient (K) of 0.25 per year, the growth performance index (ϕ) was calculated as 4.22 per year. According to **King (2013)**, a negative t_0 implies that juveniles exhibit faster initial growth compared to the projected adult growth curve. As defined by **Sparre and Venema (1998)**, a K value of 1.0 reflects rapid growth, 0.5 indicates moderate growth, and 0.2 denotes slow growth. In this study, the *K* value of 0.44 for *C. armatus* suggests relatively slow growth, potentially reflecting suboptimal habitat conditions. This low growth rate may be attributed to limited food availability in the oligotrophic conditions of the Huai Kho Reservoir **(Descloux & Cottet 2016; Fafioye & Ayodele, 2018)**. According to **Tessier *et al.* (2019)**, variability in the growth of freshwater fish populations is influenced by a range of factors, such as environmental parameters (e.g., water temperature and nutrient concentrations), human-induced stressors (e.g., exploitation and contamination), phenotypic adaptability, and pathogenic infections. Thus, 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) indicates slower and less optimal growth. As a result, the fish in Huai Kho Reservoir are experiencing slow growth, which is often characteristic of species and variations in food availability that grow slowly, tend to live longer, and have delayed reproduction. These species typically allocate more energy to maintenance and reproduction rather than rapid growth.

The total mortality rate (Z) for *C. armatus* in Huai Kho Reservoir was estimated at 1.83 $year^{-1}$, with natural mortality (M) calculated at 0.65 $year^{-1}$. Consequently, fishing mortality (F) was determined to be 1.18 $year^{-1}$, indicating that fishing is the dominant source of mortality for this species. This elevated fishing mortality may be associated with the high abundance and prevalence of large individuals in the sampling area. According to **Modou *et al.* (2013)**, a stock is considered stable when the ratio of total mortality to growth coefficient (Z/K) equals 1.0. Ratios exceeding 1.0 suggest stock depletion, while values greater than 2.0 indicate overexploitation. In this study, the Z/K ratio was 7.32, significantly above the overexploitation threshold, suggesting that the *C. armatus* population is under considerable harvesting pressure and is currently overexploited.

The exploitation rate (E) was 0.65. While this is slightly less than the maximum exploitation rate (E_{max}) of 0.664, it suggests that the fish population in Huai Kho Reservoir is over-exploited. In general, the study concludes that the current exploitation level is near the optimal value of E = 0.5, according to **Pauly (1982)**. **Gulland (1971)** stated that E value above 0.5 indicates the height level of exploitation rates of *C. armatus* from this Huai Kho reservoir. The utilization of aquatic organisms has exceeded the sustainable production capacity. The height exploitation rates suggest that the utilization of aquatic resources in this reservoir is high the sustainable production threshold. Therefore, the utilization of *C. armatus* in the Huai Kho Reservoir still exceeds the production capacity, and further labor input may not be sustainable.

The probability of capture analysis revealed that approximately 75% of *C. armatus* are captured at a length of 130.96mm, indicating a higher likelihood of catching juvenile fish before reaching reproductive maturity. This relationship correlates with the size of the fish and the gear's selectivity relative to the available fish size, as highlighted by **Rochet *et al.* (2011)**.

The recruitment pattern of *C. armatus* shows a single annual peak, with the highest replacement rates occurring between July and October, reaching 21.51% in September. This period also corresponds to an increase in the gonadosomatic index from May to July, peaking in September before declining in October. In contrast to the present findings, **Widiana *et al.* (2020)** documented peak spawning activity of *C. armatus* occurring at the end of the rainy season, notably in June and December. In tropical regions, most aquatic organisms reproduce continuously throughout the year, although reproductive activity can vary according to seasonal changes and water levels **(Yanwirsal *et al.*, 2017)**. Specifically, recruitment in many tropical aquatic species tends to occur year-round, with heightened intensity during monsoon seasons or transitional periods.

CONCLUSION

The analysis showed that the growth pattern of *Cyclocheilichthys armatus* is negatively allometric, with a regression coefficient (b) of 1.94526 that significantly differs from 3 (P> 0.05). This means that as the fish grow longer, their weight does not increase proportionally. Replacement rates were at their highest between July and October, peaking at 21.51% in September, which also matches the peak in reproductive activity measured by the gonadosomatic index. The exploitation rate was 0.65, indicating heavy fishing pressure since values above 0.50 suggest overfishing. Therefore, urgent management measures like setting minimum catch sizes and restricting fishing during spawning seasons are needed to protect the *C. armatus* population in Huai Kho Reservoir.

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ETHICS STATEMENT

This research project has been approved by the Ethical Principles and Guidelines for the Use of Animals No. 36/2023 of Mahasarakham University, Thailand.

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