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Population Dynamics and Exploitation Rate of Bronze Featherback (*Notopterus notopterus*, Pallas, 1769) for Sustainable Management in Huai Kho Reservoir, Na Chueak District, Maha Sarakham Province, Thailand

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ABSTRACT

The study on Bronze Featherback in Huai Kho Reservoir examined 273 specimens, with fork lengths ranging from 105 to 295mm and an average length of 185.80 ± 27.05mm. The fish exhibited a strong length-weight correlation, with an allometric coefficient (b) greater than 3.00, indicating a positive allometric growth. Growth parameters included an asymptotic length (L∞) of 309.75mm and a growth coefficient (K) of 0.10. Capture probabilities were 108.99 (L25%), 186.52 (L50%), and 191.44mm (L75%). Mortality rates were measured with a total mortality rate (Z) of 1.07 per year, natural mortality (M) at 0.22 per year, and fishing mortality (F) at 0.86 per year. Recruitment peaks occurred from June to August, and replacement rates were the highest from July to September. The current exploitation rate (E) of 0.80 exceeds the maximum sustainable rate (Emax) of 0.724. The total steady-state biomass was 10.57 tons. To promote sustainable management, it is recommended to regulate fishing gear and enforce a fishing ban during the spawning season.

INTRODUCTION

The bronze featherback, a species belonging to the genus Notopterus, is known for its distinctive features. It inhabits flood plains and is available in still-water bodies like reservoirs and rivers. Its distribution is limitedly found to South and Southeast Asia, including countries such as India, Pakistan, Bangladesh, Myanmar, Laos, Thailand, Cambodia, Malaysia, Vietnam, the Philippines, Brunei, and Indonesia. It can grow up to 40cm in length, whereas they are commonly found to be between 20-25cm **(Wibowo & Sunarno, 2006)**; This suggests the need to regulate harvesting. The results indicated that the bronze featherback stock in Huai Kho Reservoir is overexploited, with fishing pressure surpassing the reservoir's natural production capacity. Currently, the population of the bronze featherback in Thailand shows a declining trend. In 2021, the quantity was

1,025 tons, valued at 60,225 baht. In 2022, the quantity was 753.97 tons, valued at 47,900 baht. In 2023, the quantity was 712 tons, valued at 41,889 baht **(Department of Fisheries, 2021; Department of Fisheries, 2022; Department of Fisheries, 2023)**. Therefore, it is recommended to implement fishing gear regulations and impose a fishing ban during the spawning season. Females ready for breeding typically measure 21-25cm in length and can lay between 1,200 to 3,000 eggs. The bronze featherbacks are predatory fish exhibiting crepuscular or nocturnal behavior, actively foraging during transitions between light and darkness and throughout the night. Their diet comprises insects, fish, crustaceans, and small organisms inhabiting aquatic vegetation. Furthermore, there have been reports suggesting that consuming soup made from this fish might potentially prevent humans from contracting muscles. As a result, these factors contribute to the significance of this fish as a valuable food and economic resource in South and Southeast Asia. Bronze Featherback cannot be cultivated and is found only in natural water bodies, making it highly valuable and economically significant in South and Southeast Asia **(Roberts, 1992; Fishbase, 2024)**

Huai Kho Reservoir, constructed in 1968, is the largest reservoir in Maha Sarakham Province. Multipurpose reservoirs offer a multitude of benefits, including tourism, fisheries, agricultural water storage during dry seasons, and flood control during rainy seasons. The bronze featherback is a key species in Huai Kho Reservoir, valued for its economic importance and culinary versatility. It is prized for its delicious taste and can be prepared in various dishes, including fried fish-paste balls, sizzling stir-fried fish balls, green curry with fish balls, fish balls in red curry mousse, and stir-fried fish balls with red curry **(CMARE, 2020)**. Currently, the population of the bronze featherback in Huai Kho Reservoir is declining due to continuous fishing activities, overexploitation of resources, and insufficient knowledge of sustainable resource management. Understanding the population parameters and exploitation rate (E) of this valuable fish species is crucial for effective conservation and management. FiSAT_II, a widely used software program for studying the population dynamics of aquatic animals such as fish, shrimp, mollusks, and crabs, provides essential data for developing conservation strategies and measures to ensure the sustainable use of aquatic resources **(Azmi *et al.*, 2022; Ginzel *et al.*, 2022; Ernaningsih *et al.*, 2024; Ghosh *et al.*, 2024 Mahmoud *et al.*, 2024)**. The studies on fish population dynamics in reservoirs are relatively few **(Alkan Uckun & Gokce, 2015; Fazli *et al.*, 2019)**. Research specifically focusing on the population dynamics of Bronze Featherback in reservoirs is notably scarce, with the most recent study conducted in Bangladesh in 2014 **(Mustafa *et al.*, 2014)**. This study represents the first of its kind in Thailand and Southeast Asia, marking a significant advancement in international distribution research for the region. The objectives are to examine the population dynamics and exploitation rate of the Bronze Featherback, assess the stock status of the species in Huai Kho Reservoir, and provide foundational data for the sustainable

management of the bronze featherback resources. This aims to ensure that population levels remain adequate to meet the needs of local communities surrounding the reservoir.

MATERIALS AND METHODS

1. Sample collection and laboratory analysis

Fishermen collected the bronze featherback samples monthly over the course of a year (January to December 2022) from six different locations, each sampled six times using gill nets with mesh sizes of 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, and 6.0cm. All collected fish were weighed in grams (g) and measured in millimeters (mm) (Fig. 1).

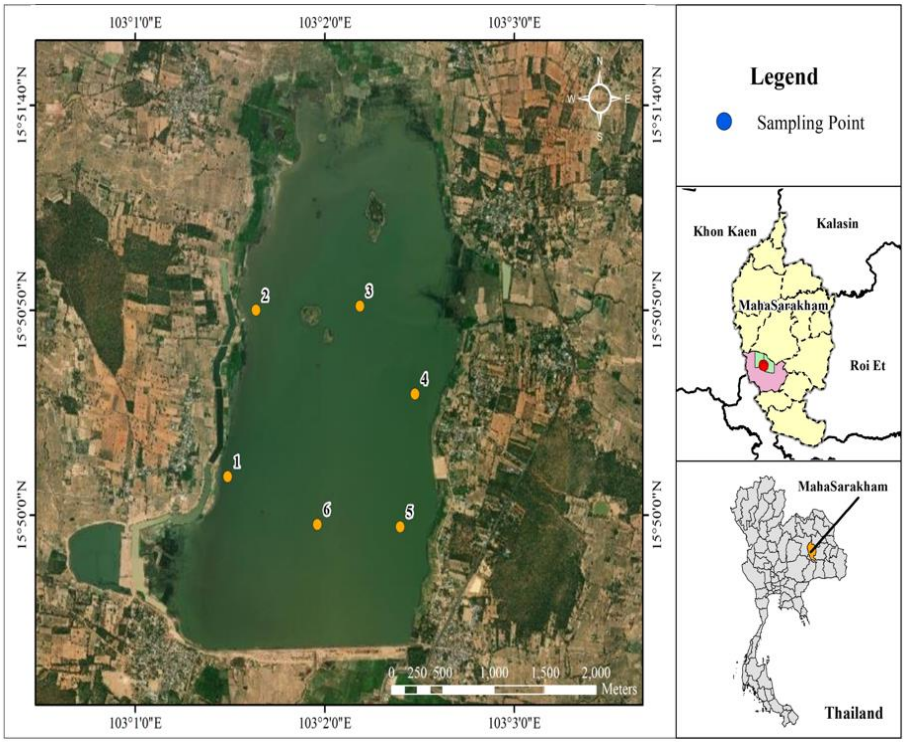

Fig. 1. Sampling stations in Huai Kho Reservoir where the bronze featherback samples were collected

2. Population dynamics parameters of calculation

A total of 273 bronze featherback *(Notopterus notopterus*) 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. 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)**.

2.1 Length-weight relationship (LWR)

The mathematical expression was used to compute the LWR **(Le Cren, 1951)**: $LWR = aL^b$

Where, W= Weight (gram; g); L= Length (millimeters; mm); a= Intercept, and b= Growth pattern estimator of length-weight.

To test the value of $b = 3$ or $b \neq 3$, a t-test (partial test) is carried out, with the hypothesis:

H_0: $b = 3$, The pattern of the relationship between length and weight is isometric.

H_1: $b \neq 3$, The pattern of the relationship between length and weight is allometric.

a. Allometric positive occurs if $b > 3$, meaning the weight growth is faster than the length growth.

b. Allometric negative occurs if $b < 3$, meaning the length growth is faster than the weight growth.

Its mathematical expression was computed using the formula **(Scherrer, 1984)**:

Log10 LWR = log10 a+b log10 L

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 formula: $\log_{10}(-t_0) = -0.3922-0.275\times\log10\ L_\infty\ -1.038\ \times\log10K$ **(Pauly, 1984a)**

Where, 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 is given below **(Munro & Pauly, 1983)**:

$\phi = 2\ \log10\ L\infty + \log10K$

Where, ϕ represents the growth performance index; L_∞ is the asymptotic length (in millimeters), and K is the von Bertalanffy growth function (VBGF) curvature parameter.

The values for L_∞ and K were derived from the corrected length-frequency data and fitted to the classical von Bertalanffy growth function (VBGF). The VBGF parameters were computed using the ELEFANT-I routine of the FiSAT_II software, following the formula by **Pauly (1984)**: $Lt = L\infty\ (1-e-K(t-to))$

Where, L_t is the mean length at age t; t is the age of the bronze featherback, and t0 is the hypothetical age at which the length is zero.

2.3 Age

The Bhattacharya method **(Bhattacharya, 1967)** was used for age analysis. This technique divides fish into different length classes, converting the frequency of each length class into a logarithm, and calculating the difference between the logarithms of successive classes.

2.4 Mortality rates (M)

The annual total mortality rate (Z) was calculated through length-converted catch curve analysis, while the natural mortality rate (M) was estimated using **Pauly**'s **(1980)**

empirical formula, adhering to standard ichthyological methods **(Pauly, 1984b):** log10 M = -0.0066-0.279 log10 L_∞ +0.6543 log10 K+0.4634 log10 T, where the annual average surface water temperature in the Huai Kho Reservoir was used to determine the fishing mortality rate (F), F=Z-M. The level of exploitation (E) was estimated with E = F /Z

The annual average surface water temperature in Huai Kho Reservoir was used to estimate the fishing mortality rate (F), calculated as F=Z−M. The exploitation rate (E) was determined using E= Z-F

2.5 Probability of capture and recruitment pattern

The probability of capture was determined using the length-converted catch curve method, which estimates the lengths at which 25, 50, and 75% of the population are captured (L25, L50, and L75, respectively) **(Sparre & Venema, 1998)**. Recruitment patterns over a year were assessed based on monthly length measurements of the bronze featherback and analyzed using the von Bertalanffy growth function to evaluate the consistency of length distribution, as outlined by **Moreau and Cuende (1991)**.

2.6 Virtual population analysis (VPA)

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

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

Y'/R and B'/R were approximated in FiSAT_II software applying the Beverton and Holt model **(Beverton & Holt 1966)**, as per the following equation:

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

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)

A frequency distribution analysis of the size of Bronze Featherback 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 273 individuals of the bronze featherback were sampled, ranging in weight from 8 to 226 grams, with an average weight of 53.19± 26.25 grams. The size frequency distribution of the total length at intervals of 0.50 millimeters ranged from 105 to 295 millimeters (Fig. 2). The mean total length was 185.51±27.05 millimeters, with the prominent size class

occurring between 185-205 millimeters, as shown in Figs. (2, 3). Length-weight relationship (LWR) of the bronze featherback is detailed as follows: LWR = $0.000158L^{3.80214}$ (r^2= 0.92); Lt = 309.75 *(1-e $^{-0.1}$($^{t+0.75}$)) (Fig. 3).

Age and growth parameters

The maximum length (L_{max}) of the bronze featherback was estimated to be 297.45 millimeters. The sizes observed in the population were 52, 102, 152, 202, 252, and 302 millimeters, which correspond to ages of 2, 4, 7, 11, 17, and 37 months, respectively (Fig. 5)

From the analysis of monthly length frequency distributions, the growth parameters for the bronze featherback in the study area were determined as follows: a growth performance index (ϕ) of 3.87 per year (Fig. 3), an asymptotic length (L∞) of 309.75 millimeters, a growth coefficient (K) of 0.10 per year, and a t0 of -0.75 months (Fig. 4).

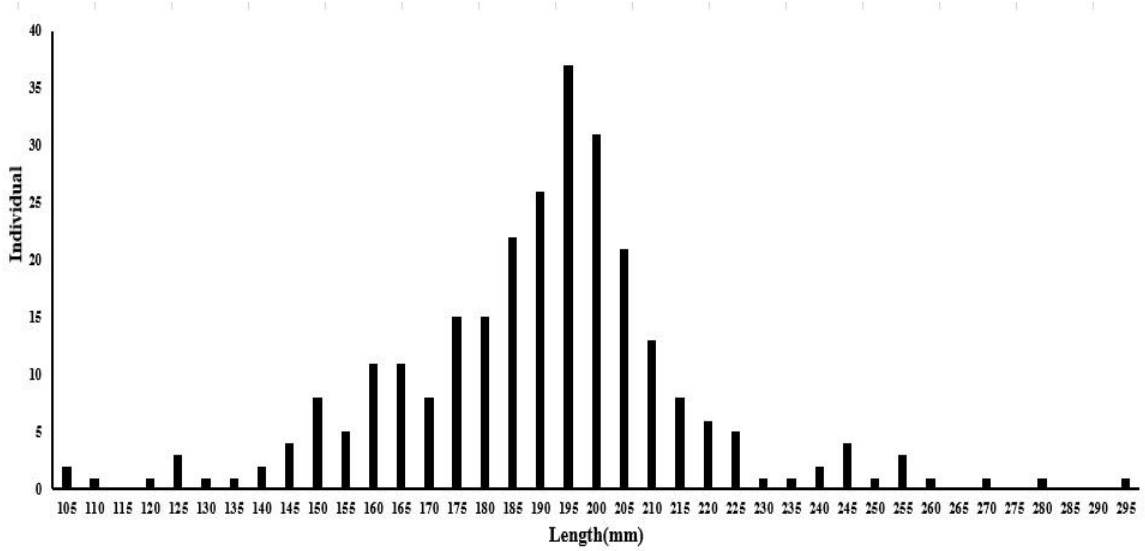

Fig. 2. Length frequency distribution ranging between 105-295 millimeters (TL) for both sexes of the bronze featherback (n=273) using the landing data from Huai Kho Reservoir during January-December 2022

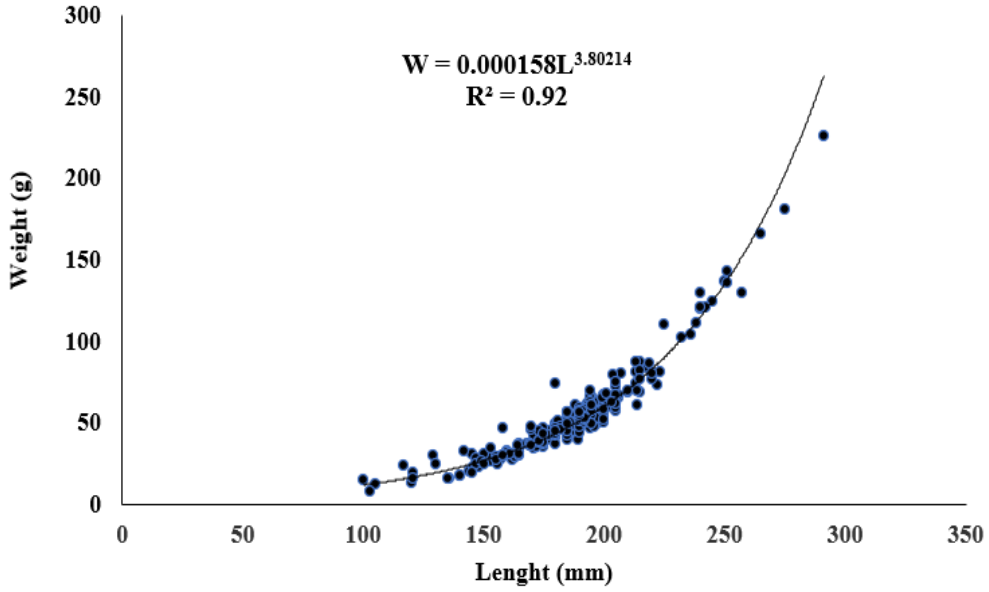

Fig. 3. Length-weight relationship (LWR) of the bronze featherback (n=273) in the Huai Kho Reservoir

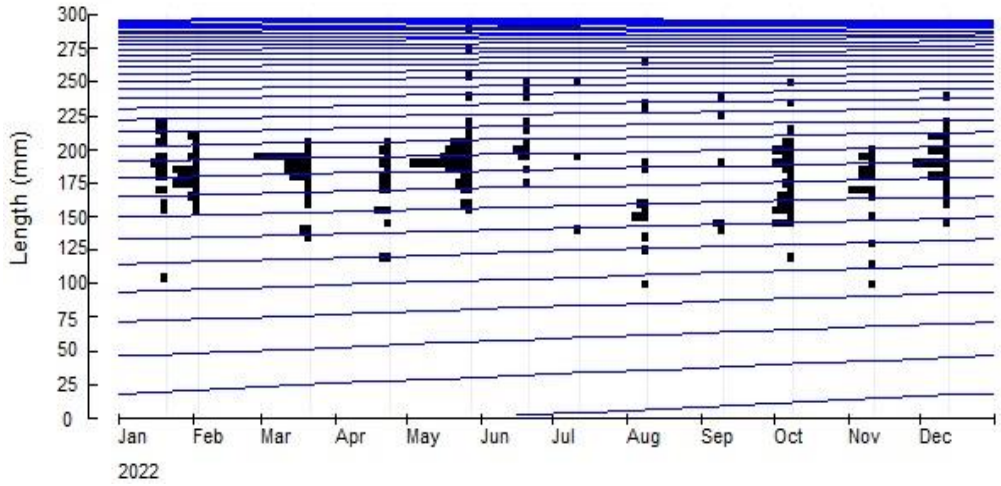

Fig. 4. Restructured length-frequency distribution of samples of the bronze featherback (n=273) from gill nets catches in the Huai Kho Reservoir superimposed with growth curves. Analyzed using ELEFAN-1 from the K-scan of FiSAT_II.

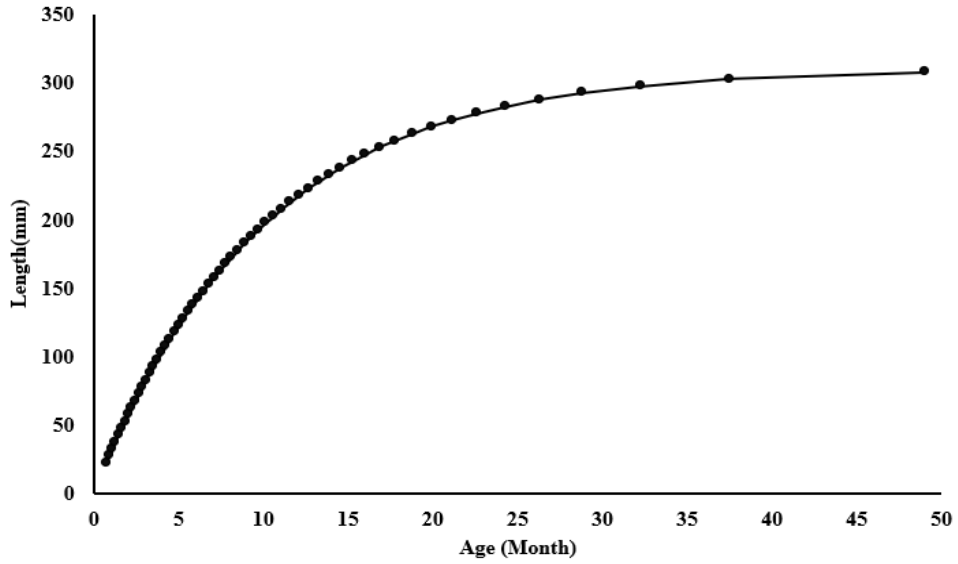

Fig. 5. The correlation between age (in months) and length (in millimeters) of the bronze featherback (n=273) in the Huai Kho Reservoir can be calculated using growth parameters

Total mortality (Z)

Based on the von Bertalanffy growth function (VBGF) parameters (L_∞ and K) in the length-converted catch curve model, the total mortality rate (Z) was estimated at 1.07 per year, with a 95% confidence interval between 0.98 and 1.17 ($r^2 = 0.975$). The natural mortality rate (M) was 0.22 per year. Therefore, the fishing mortality rate (F), calculated as $F = Z - M$, was determined to be 0.86 per year (Fig. 7).

Probability of capture

The probability of capture for the bronze featherback was determined as follows: L25% = 180.99 millimeters, L50% = 186.52 millimeters, and L75% = 191.44 millimeters (Fig. 7).

Recruitment pattern

The recruitment pattern indicates a single annual peak for the bronze featherback, with a replacement rate ranging from 0.00 to 17.71%. The highest replacement rates occured between July and September, peaking at 17.71% in September, while the lowest replacement rates were recorded in December, reaching 0.00% (Fig. 8).

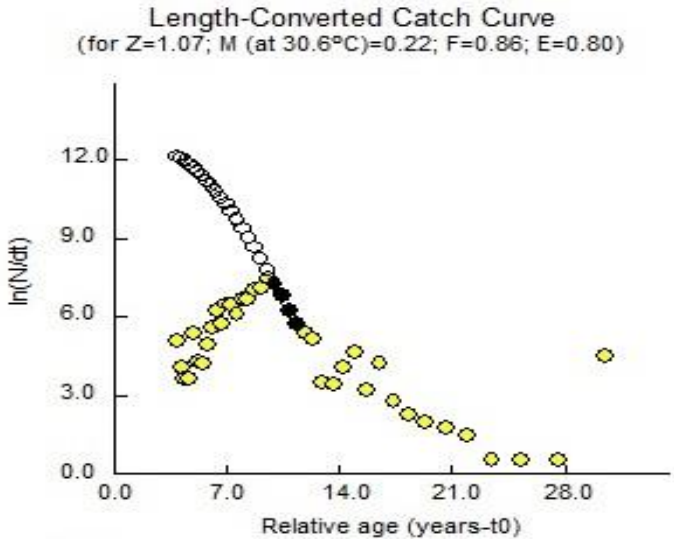

Fig. 6. The length-converted catch curve for the bronze featherback (n=273) in Huai Kho Reservoir was used to estimate various mortality rates and the exploitation rate

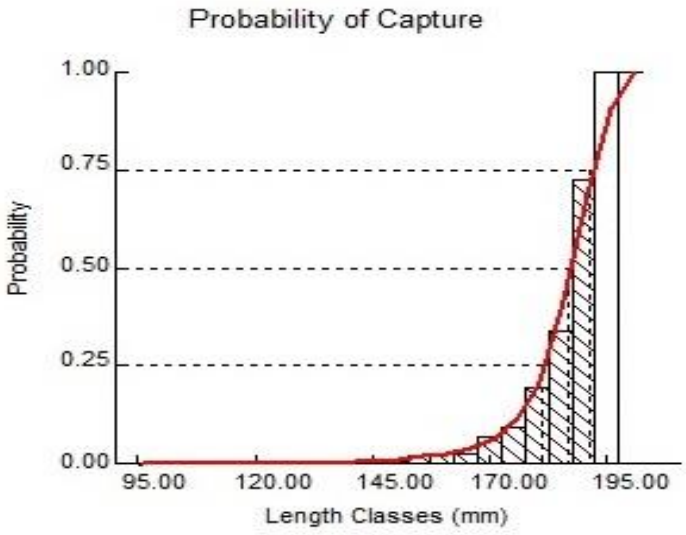

Fig. 7. The selectivity curve of the bronze featherback (n=273) in the Huai Kho Reservoir

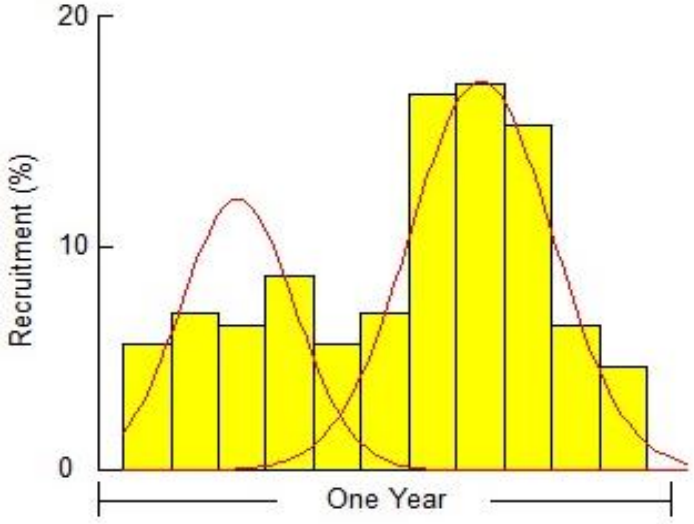

Fig. 8. Recruitment pattern of the bronze featherback (n=273) in the Huai Kho Reservoir

Virtual population analysis (VPA)

VPA for the bronze featherback in Huai Kho Reservoir was performed using FiSAT_II software. In 2022, a total of 17,346.03 bronze featherback individuals were recorded. The smallest size at which individuals began to be replaced was 100 millimeters, with 14,123.23 individuals observed. Mortality rates were higher in the length range of 180 to 220 millimeters, peaking at 195 millimeters with 257.14 individuals. The total steady-state biomass was 0.37 tons, reflecting high fishing mortality on the juvenile bronze featherback. Annual total mortality rates ranged from 0.1021 to 0.3098, while fishing gear-induced mortality (F) varied from 0.000 to 0.3098 per year. The total steady-state biomass of the bronze featherback was calculated to be 10.57 tons (Fig. 9).

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

Using the knife-edge procedure in FiSAT_II software, the Y'/R and B'/R analyses for the bronze featherback were performed. The findings revealed these exploitation rates: E10, the rate that maximizes yield per recruit, was 0.601; E50, the rate that achieves 50% of the maximum yield, was 0.382; and Emax, the rate that provides the maximum yield, was 0.724 (Fig. 10).

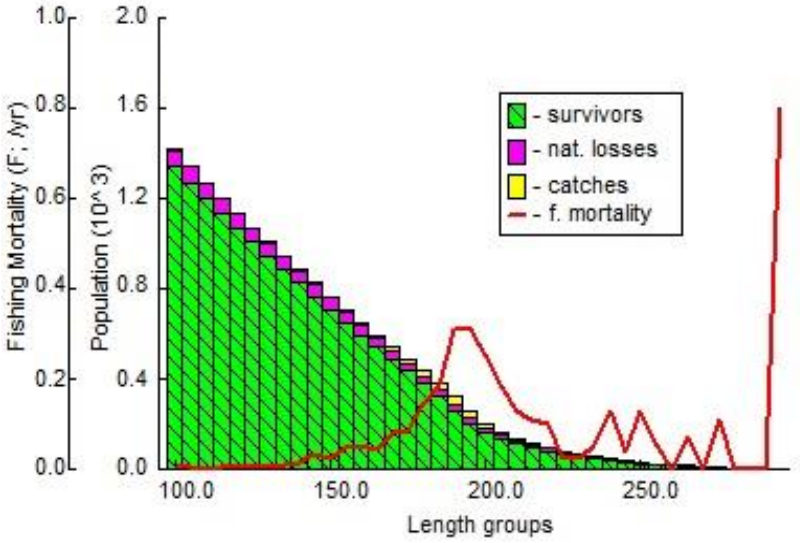

Fig. 9. Population size and mortality characteristics for the bronze featherback (n=273) in Huai Kho Reservoir, as determined through length-structured virtual population analysis (VPA)

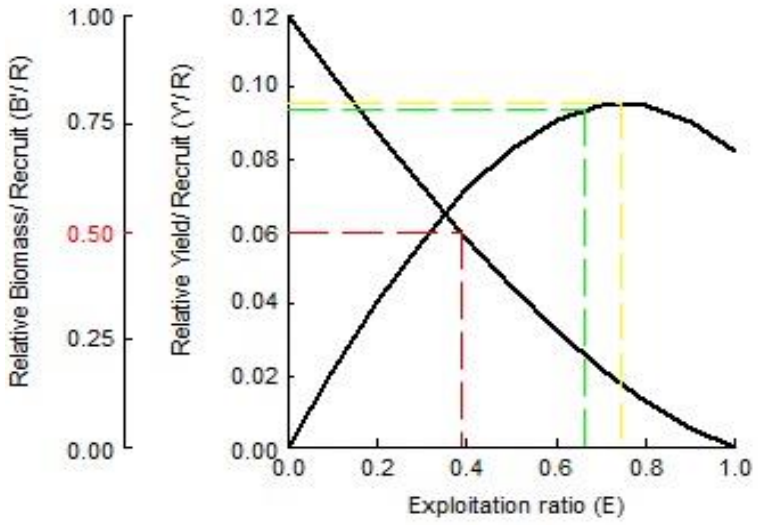

Fig. 10. Relative yield per recruit and biomass per recruit for the bronze featherback (n=273) in the Huai Kho Reservoir. Note: The dash-lines: red (--) green (--) and yellow (--) indicate the exploitation rates at $E_{0.1}$, $E_{0.5}$, and E_{max}, respectively

DISCUSSION

The size frequency distribution of the total length at intervals of 0.50 millimeters ranged from 105 to 295 millimeters (Fig. 2). The mean total length was 185.51± 27.05 millimeters, with the prominent size class occurring between 185-205 millimeters, as shown in Figs. (2, 3). The variation in fish size is influenced by differences in water quality, temperature, habitat, food abundance, watershed characteristics, and geographical environmental conditions **(Narwariya & Gupta, 2009; Sukendi *et al.*, 2020; Damchoo *et al.*, 2021)**. The variations among reported lengths and weights of fishes are due to the species type, seasonal fluctuations of environmental parameters, physiological conditions, sizes and differences in fishing gear **(Shankar & Kulkarni, 2006; Kaur & Rawal, 2017; N'Dri *et al.*, 2020; Dereli *et al.*, 2022; Santos *et al.*, 2022; Bam *et al.*, 2024)**. The bronze featherback is a type of carnivorous fish and predatory fish that is hunting for food **(Shillewar & Nanware, 2009; Sukendi *et al.*, 2024)**. According to the study of the stomach contents of the bronze featherback, it was found that the quantities of different food items vary, including arthropods and fish (100%), fish (90.04%) **(Burnawi & Pamungkas, 2016)** fish (52.93%) **(Rapita *et al.*, 2021)**. Therefore, the variation in food availability or the abundance of food for the Bronze Featherback each month is directly correlated with the size, length, and weight of the fish. In months with abundant food, the bronze featherback grows rapidly, whereas in months with less food, the growth of this species is slower, accordingly.

Length-weight relationship (LWR) = $0.000158L^{3.80214}$ (r^2= 0.92); Lt = 309.75 *(1-$e^{-0.1(t+0.75)}$)) (Fig. 3). This preliminary study on the bronze featherback from Huai Kho Reservoir shows that the growth pattern is positively allometric, as evidenced by a coefficient 'b' value exceeding 3 (b > 3). In the present case, estimated b (3.80214) is higher than the isometric value (3) **(Oussellam *et al.*, 2023)**. This suggests that the growth pattern in terms of length of the fish is more rapid than its weight growth. The high 'b' value, greater than 3.00, in the length-weight relationship (LWR) of the bronze featherback may result from several factors, including geographical area, age, gonadal maturity, habitat conditions, seasonal effects, and fish diseases. These factors can influence the growth patterns and overall health of the fish, leading to variations in the relationship between length and weight **(Minoungou *et al.*, 2020; Mughul *et al.*, 2022; Muslim *et al.*, 2023; Roy *et al.*, 2023)**. Understanding the LWR of the bronze featherback will offer insights into the current status of the fish, the environmental conditions, the water reservoir depth level, the specific habitat for the species, and the vegetation in Huai Kho Reservoir.

The bronze featherback exhibits a growth performance index (ϕ) of 3.87 per year (Fig. 3), an asymptotic length (L_∞) of 309.75 millimeters, a growth coefficient (K) of 0.10 per year, and a t0 of -0.75 months (Fig. 4). 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 **(Shalloof *et al.*, 2024)**. These values indicate lower growth rates compared to those observed in other regions. Specifically, the growth parameters in the reference area showed an asymptotic length (L_∞) of 349.10 millimeters and a growth coefficient (K) of 0.38 per year **(Mustafa *et al.*, 2014)**, highlighting that the bronze featherback in Huai Kho Reservoir experiences slower growth compared to those in other locations. The growth pattern of aquatic organisms is influenced by various factors, including changes in body shape at different life stages, species-specific characteristics, growth phases, seasonal variations in food availability, physiological conditions of digestion, breeding seasons, and the length range of analyzed fish **(Kaur & Rawal, 2017; Rapita *et al.*, 2021)**. The bronze featherback population in Huai Kho Reservoir is experiencing slow growth, a common trait among species that allocate more energy to maintenance and reproduction rather than rapid growth, particularly in environments with varying food availability. The total mortality rate (Z) was estimated at 1.07 per year, with natural mortality (M) at 0.22 per year and fishing mortality (F) at 0.86 per year. This suggests that fishing mortality is the primary factor affecting the bronze featherback population in the reservoir. This aligns with findings by **Chueabandit and Surakate (2023)**, which indicated that water quality in the Huai Kho Reservoir is good and does not harm aquatic life. Comparison with reference values shows that in similar studies, the total mortality (Z), natural mortality (M), and fishing mortality (F) were 1.91 per year, 0.91 per year, and 0.28 per year, respectively **(Mustafa *et al.*, 2014)**. This comparison highlights that fishing mortality in the Huai Kho Reservoir is significantly higher than in other areas, suggesting substantial fishing pressure. The exploitation rate (E) of 0.80 in the reservoir exceeds the maximum sustainable exploitation rate (Emax) of 0.724, indicating that current fishing practices are surpassing the species' sustainable production capacity. Ideally, the exploitation rate should be at or below 0.50 to ensure long-term sustainability. The observed high exploitation rate suggests heavy exploitation of the bronze featherback in Huai Kho Reservoir, contrasting with a lower exploitation rate of 0.24 found in other studies **(Mustafa *et al.*, 2014)**. This underscores the need for more sustainable fishing practices to ensure the long-term viability of the bronze featherback population.

The probability of capture for the bronze featherback in Huai Kho Reservoir is estimated as follows: L25% = 180.99 millimeters, L50% = 186.52 millimeters, and L75% = 191.44 millimeters. These values suggest that the fishing gear in use is highly effective, especially at capturing juvenile fish. Approximately 50% of the Bronze Featherback population is captured at a length of 186.52 millimeters, which is close to the mean total length of 185.51 ± 27.05 millimeters. The most common size class of captured fish ranges between 185 and 205 millimeters. When compared to reference values, the captured lengths in Huai Kho Reservoir are smaller. In the reference area, the estimated capture lengths for the 25 (L25), 50 (L50), and 75% (L75) probabilities were 168.30,

183.30, and 198.30 millimeters, respectively **(Mustafa *et al.*, 2014)**. The total steady-state biomass of the bronze featherback in Huai Kho Reservoir was calculated to be 10.57 tons, significantly lower than the 664.5 tons reported in the reference area, where the maximum fishing mortality occurred between 105 and 305 millimeters, peaking at 332.5 millimeters **(Mustafa *et al.*, 2014)**. This indicates that factors such as gill net dimensions—twine size, mesh size, and net dimensions—significantly impact capture probabilities. The highest replacement rates for Bronze Featherback occur between July and September, peaking at 17.71% in September, consistent with findings that spawning occurs from April to September **(Taruwan *et al.*, 2009)**. This pattern aligns with studies identifying the peak breeding season from May to July and a subsequent increase in recruitment from September onward **(Narwariya & Gupta, 1991; Srivastava *et al.*, 2012)**. Compared to the reference area, which exhibits bimodal recruitment peaks from March to April and May to June **(Mustafa *et al.*, 2014)**, the Huai Kho Reservoir's recruitment patterns align with tropical aquatic species' continuous reproduction, often varying with seasons and water levels **(Yanwirsal *et al.*, 2017)**.

The exploitation rates of the bronze featherback in Huai Kho Reservoir are as follows: E0.1, the rate maximizing yield per recruit, was 0.601; E50, the rate achieving 50% of maximum yield, was 0.382; and Emax, the rate providing maximum yield, was 0.724. The current exploitation rate (E) of 0.80 per year exceeds these thresholds, indicating over-exploitation and unsustainable fishing practices. The exploitation rate surpasses E0.1, E0.5, and Emax, which suggests that local fishing activities are exerting excessive pressure on the bronze featherback population. This high exploitation rate reflects an over-exploitation, negatively impacting stock health. The total annual mortality rate (TAMR) ranges from 0.1021 to 0.3098, and the fishing gear-induced mortality rate (FGMR) ranges from 0.000 to 0.3098 **(Tirtadanu *et al.*, 2018)**. Compared to reference values, the exploitation rates of the bronze featherback at E0.1, E0.5, and Emax were 0.707, 0.364, and 0.828, respectively **(Mustafa *et al.*, 2014)**. This suggests that the current fishing pressure in Huai Kho Reservoir is unsustainable, exceeding the fish population's production capacity and impacting its long-term viability.

CONCLUSION

The exploitation rate (E) of 0.80 in Huai Kho Reservoir exceeds the maximum sustainable exploitation rate (Emax) of 0.724, indicating excessive fishing pressure. This level of exploitation, which surpasses the threshold of $E > 0.50$, highlights the urgent need for regulatory measures. To address this issue, it is recommended to implement controls on harvesting, enforce a fishing ban during the spawning season, and educate fishermen about avoiding fishing during critical reproductive periods. These measures are

crucial for ensuring the sustainable management and conservation of the bronze featherback population.

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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.

REFERENCES

Alkan Uckun, A. and Gokce, D. (2015). Assessing age, growth, and reproduction of *Alburnus mossulensis* and *Acanthobrama marmid* (Cyprinidae) populations in karakaya dam lake (Turkey). Turk. J. Zool., 39(1): 1-14. DOI:10.3906/zoo-1211-13

Azmi, F.; Maward, A. L.; Singga, S.; Nurdin, M. S.; Febri S. P. and Hasser, T. F. (2022). Population dynamics of *Anadara antiquata* of east coast of aceh, Indonesia. B I O D I V E R S I T A S, 23 (1): 436-442. DOI: 10.13057/biodiv/d230145

Bam, Gh. R.; Kamrani, E.; Kaymaram, F.; Jamili, Sh. and Fatemi; M.R. (2022). Population dynamic parameters of the malabar trevally *Carangoides malabaricus* (Bloch and Schneider, 1801) in the persian gulf and Oman sea. Iran. J. Fish. Sci., 21(2): 516-525. DOI:10.22092/ ijfs.2022.126511

Beverton, R. J. H. and Holt, S. J. (1966). Manual of methods for fish stock assessment, Part 2: Table of yield functions. FAO Fisheries Technical Paper No. 38 (Rev. 1). FAO, Rome.

Bhattacharya, C. G. (1967). A simple method of resolution of a distribution into Gaussian components. Biometrics., 23: 115-135.

Burnawi and Pamungkas, Y. P. (2016). Contents of the intestine putak (*Notopterus Notoptrtus*) catches of fishermen in lubuk lampam waters of ogan kemuning ilir regency, South Sumatra. Litkayasa Engineering Bulletin, 14:19-21.

Chueabandit, S. and Surakate, S. (2023). The Study of raw water quality for supply water production in Huai Kho Reservoir, Na Chueak District, Maha Sarakha Province, Thailand. Special Problem, Degree Bachelor of Science Program in Environmental and Natural Resource Management, Faculty of Environment and Resource Studies, Mahasarakham University, Thailand. [Thailand]

Climate Changes Mitigation and Adaptation Research Unit (CMARE). (2020). Climate Change Adaptation for Nachueakpittayasan School. Nachueak subdistrict, Nachueak district, Mahasakham Province. Climate Change Mitigation and

Adaptation Research Unit; CMARE, Faculty of Environment and Resources Studies, Mahasakham University, Thailand. 239 pp.[Thailand]

Damchoo, S.; Grudpan, C.; Jutagate, A.; Grudpan, J. and Jutagate, T. (2021). Morphological investigation and length-weight relationships of long-snouted pipefish *Doryichthys boaja* (Syngnathidae) from two different environments. Agr. Nat. Resour., 55(4): 664-673.

Department of Fisheries. (2021). Statistics of the freshwater animals captured from natural sources in 2020. Fishery Statistics Group, Fisheries Development Policy and Planning Division, Technical Paper No. 17/2021. Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand. 45 pp. [Thailand]

Department of Fisheries. (2022). Statistics of the freshwater animals captured from natural sources in 2021. Fishery Statistics Group, Fisheries Development Policy and Planning Division, Technical Paper No. 12/2022. Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand. 46 pp. [Thailand]

Department of Fisheries. (2023). Statistics of the freshwater animals captured from natural sources in 2022. Fishery Statistics Group, Fisheries Development Policy and Planning Division, Technical Paper No. 6/2023. Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand. 47 pp. [Thailand]

Dereli, H.; Şen, Y.; Kebapçıoğlu, T.; Erdoğuş, M.; Ölçek, Z. S.; Özdemir, M. and Ulman, A. (2022). Management recommendations for common carp fisheries in Turkey in light of their reproductivity and gear selectivity. J. Fish. Environ., 46(1): 141-156.

Ernaningsih, Danial, Syahrul, Umar M. T. and Nursyahran. (2024). Population Parameters and Exploitation Ratio of Blue Swimming Crab, *Portunus pelagicus* (Linnaeus, 1758) from the Bawasalo Waters Pangkep Regency, South Sulawesi. Egypt. Aquat. Biol. Fish., 28(3): 285-298.

Fazli, H.; Daryanabard, G. R.; Janbaz, A.; Naderi, M.; Mirzaei, R.; Hosseinpour, H. and Vahedi, N. (2019). Age and growth of *Alburnus mossulensis* Heckel, 1843 in Azad dam Reservoir and Komasi River in Kordestan Province, Iran. Iran. J. Fish. Sci. 18(4): 672-683. DOI: 10.22092/ijfs.2018.117745

Fishbase. (2024). Scientific name. http://www. Fishbase.org., Cited 1 August 2024.

Gayanilo, F.C.; Sparre, P. and Pauly, P. (2005). The FAO-ICLARM Stock Assessment Tools (FiSAT). Revised version. User's manual. FAO Computerized Information Series (Fisheries), No. 7 Rome: World fish Center, FAO. 168 pp.

Ginzel, F. I.; Wijayanti, D. P.; Subagiyo and Sabdono, A. (2022). Growth and Mortality, Recruitment and Exploitation Rate of Fringescale Sardinella *Sardinella fimbriata* (Valenciennes 1847) in rote island in the savu sea. Croat. J. Fish., 80(4): 189-196. DOI: 10.2478/cjf-2022-0019

Ghosh, M.; Dutta, S.; Dutta, M. and Homechaudhur, S. (2024). Assessing the population dynamics of *Cirrhinus reba* (Hamilton, 1822) in River Atrai, India, for its conservation and sustainability as natural stock. J. Fish. Environ., 48 (1): 51-67.

Kaur, V. and Rawal. Y. K. (2017). Length-weight relationship (LWR) in *Notopterus notopterus* (Pallas) from Sukhna Lake, Chandigarh. IOSR J. Pharm Bio. Sci., (IOSR-JPBS) 12(4): 63-65.

Le Cren, E. D. (1951). The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal Animal Ecology 20: 201-219.

Mehanna, S. F.; Baker, T. S.; Soliman, F. M. and Soliman, H. A. (2017). Some biological aspects and population dynamics of the five-lined snapper, *Lutjanus quinquelineatus* (family: lutjanidae) from Red Sea off Hurghada, Egypt. Int. J. Fish. Aqua. Studies. 5(5): 321-326.

Moreau, J. and Cuende, F. X. (1991). On improving the resolution of the recruitment patterns of fishes. Fishbyte, 9(1): 45-46.

Minoungou, M.; Ouedraogo, R; Da, N. and Oueda, A. (2020). Length-weight relationship and condition factor of seven fish species from Samandeni Reservoir prior to its opening to fishing (Burkina Faso). J. App. Biosci., 151: 15559-15572.

Mughul, W. G.; Rajput, S.; Laghari, S.; Hussain, I.; Khan, P.; Bilal, Z.; Sheikh, M.; Gachal, G. S. and Laghari, M. Y. (2022). Length-weight relationship and condition factor of *Labeo bata* (Hamilton) (Cypriniformes: Cyprinidae) found in ranikot stream, Sindh-Pakistan. J. Surv. Fish. Sci., 8(2): 91-102. DOI: 10.18331/ SFS2022.8.2.8

Mahmoud, H. H.; Ebrashi, A. E.; Baderldin, M. and Fahim, R. M. (2024). Population dynamics and stock Aassessment of Deep-Water Red Shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* in the Southeastern Mediterranean Waters. Egypt. Aquat. Biol. Fish., 28(1): 1093-1100.

Munro, J. L. and Pauly, D. (1983). A simple method for comparing the growth of fishes and invertebrates. ICLARM Fishbyte 1(1): 5-6.

Muslim, M. (2023). Length-Weight relationship and condition factor of *Notopterus Notopterus* (Pallas, 1769) from east pedamaran floodplain, Ogan Komering Ilir, South Sumatra, Indonesia. Int. J. Adv. Multidisc. Res. Stud. 3(5): 1227-1231.

Mustafa, M.G.; Singha, S.; Islam, M. R.; Mallick. N. (2014). Population dynamics of *Notopterus notopterus* (Pallas, 1769) from the Kaptai Reservoir of Bangladesh. SAARC J Agri. 12(2): 112-122. DOI: 10.3329/ sja.v12i2.21923

Narwariya, U. and Gupta, O. P. (1991). Seasonal variations in the corpuscles of stannius in *Notopterus notopterus* (Pallas). Okajimas. Folia. Anat. Jpn. 68(2-3):111-134. DOI: 10.2535/ofaj1936.68.2-3111

N'Dri, R. O.; Konan, Y. A.; Bamba, M.; Monney, A. I. and Koné, T. (2020). Length-weight relationships and condition factor of twenty-four freshwater fish species from Lake Buyo, Côte d'Ivoire. J. Fish. Aquat. Sci., 15(1): 2734. DOI: 10.3923/jfas. 2020.27.34.

Oussellam, M.; Selfati M.; Ouamari, N. E. and Bazairi, H. (2023). Length-weight

parameters for 32 species from the marchica lagoon (Mediterranean, Morocco). Egypt. Aquat. Biol. Fish., 27(3): 223-229.

Pauly, D. (1984a). Fish population dynamics in tropical waters: A manual for use with programmable calculators. ICLARM Studies and Review No. 8, International Center for Living Aquatic Resources Management, Manila, Philippines. 325 pp.

Pauly D. (1984b). Length-converted catch curves. A powerful tool for fisheries research in the tropics, (part II). ICLARM Fishbyte, 2(1):17-19.

Rapita,; Susiana, S.; Kurniawan, D.; Lestari, F.; Sabriaty, D.; and Rianti, U. (2021). Food habits of belida fish (*Notopterus notopterus*, Pallas 1769) in sei gesek reservoir, Bintan Regency, Riau Island, Indonesia. IOP Conf. Series: Earth Environ. Sci. 919(1): 012003. DOI: 10.1088/1755-1315/919/1/012003

Roy, S.; Roy, S. and Saikia S. K. (2023). Seasonal variation of length-weight relationships and fulton's condition factor of five small indigenous freshwater fish species. Egypt. Aquat. Biol. Fish., 27(3): 655-662.

Roberts, T. R. (1992). Systematic revision of the old world freshwater fish family Notopteridae. Ich. Exp. Fresh. 2(4): 361-383.

Santos, R.; Peixoto, U. I.; Medeiros-Leal, W.; Novoa-Pabon, A. and Pinho, M. (2022). Growth parameters and mortality rates estimated for seven data-deficient fishes from the azores based on length-frequency data. Life, 12(6): 778. DOI: 10.3390/ life12060778.

Scherrer, B. (1984). Biostatistique. Morin, Montreal, Paris. SPSS Inc. 1999. Systat version 9. SPSS Inc., USA. 850 pp.

Shankar, D.S. and Kulkarni, R.S. (2006). Effect of cortisol on the condition factor in *Notopterus notopterus* (Pallas) during reproductive phases. Indian J Fish. 53(3): 321-326.

Shalloof K.; Fetouh, M. A.; El-Far, A.; Aly, W. and El-Betar, T. (2024). The length-weight relationship and condition factors of twelve fish species, with special reference to cichlid species from the mediterranean manzala lagoon, Egypt. Egypt. Aquat. Biol. Fish., 28(1): 1221-1237.

Shillewar, K. S. and Nanware, S. S. (2009). Food and feeding habit of fresh water fish *Notopterus notopterus* (Pallas) from Godavari River, Nanded, Maharashtra. Biomed. Pharm. J. 2(2): 489-490.

Sparre, P. and Venema, S. (1998). Introduction to tropical fish stock assessment. Part 1. Manual. FAO, Rome, Italy. 407 pp.

Srivastava, S. M.; Singh, S. P. and Pandey, A. K. (2012). Food and feeding habits of threatened *Notopterus notopterus* in Gomti River, Lucknow (INDIA). J. Exp. Zool. India., 15(2): 395-402.

Sukendi,; Thamrin; Putra, R. M. and Yulindra, A. (2020). Behavior and reproduction of belida fish (*Notopterus notopterus*, Pallas 1769) in different stocking density and nurtured with different types of feed. J. Anim. Behav. Biometeorol., 8(3): 181-189.

Taruwan, W.; Ruekaewma, P. and Leknoi, A. (2009). The biological reproductive of some economic fish in the chi river. Department of Fisheries, Ministry of Agriculture and Cooperatives. Thailand. [Thailand]

Tirtadanu, K.; Wagiyo and Sadhotomo, B. (2018). Growth, yield per recruit and spawning potential ratio of Red Snapper (*Lutjanus malabaricus* Schneider, 1801) in sinjai and adjacent waters. J. penelit. Perikanan. Indones. 24: 1-10. DOI:10.15578/jppi.1.1.2018.1-10

Wibowo, A. and Sunarno, M. T. D. (2006). Karakteristik habitat ikan belida (*Notopterus chitala*). BAWAL. 1(1): 9-24. DOI:10.15578/bawal.1.1.2006.19-24

Yanwirsal, H.; Bartsch, P. and Kirschbaum, F. (2017). Reproduction and development of the asian bronze featherback *Notopterus notopterus* (Pallas, 1769) (Osteoglossiformes, Notopteridae) in captivity. J. Zool. Syst. Evol. Res. 93(2): 299-324. DOI: 10.3897/zse.93. 13341