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Assessment of Population Dynamics and Exploitation Rate of the Climbing Perch (*Anabas testudineus*, Bloch, 1792) for Fishery Resource Management in Huai Kho Reservoir, Na Chueak District, Maha Sarakham Province, Thailand

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ABSTRACT

This research focused on assessing the population dynamics and exploitation rate of the climbing perch in Huai Kho Reservoir to inform fishery management. A total of 336 climbing perch were sampled, with fork lengths ranging from 90 to 185mm (average: 130.82 ± 18.46mm) and weights ranging from 19.0 to 126.0g (average: 49.78 ± 21.69g). The growth performance index (ϕ) was calculated as 3.87 per year, with an asymptotic length ($L\infty$) of 194.25mm and a growth coefficient (K) of 0.25. Capture probabilities were estimated as L25% = 107.18mm, L50% = 101.99mm, and L75% = 114.80mm. The length-weight relationship equation, $W = 0.026938L^{1.56963}$ ($r^2 = 0.95$), indicated a strong correlation between length and weight, with a b-value of less than 3.00, demonstrating negative allometric growth. Mortality rates included total mortality (Z) of 0.84 per year, natural mortality (M) of 0.45 per year, and fishing mortality (F) of 0.40 per year. Recruitment peaked from November to January. The exploitation rate (E) was found to be 0.47, lower than the maximum exploitation rate (Emax) of 0.702. The study estimated a total biomass of 1.90 tons of the climbing perch, suggesting the species is currently underexploited, with a higher natural mortality than fishing mortality, likely due to fish behavior and biology. To ensure sustainable fishery management, it is recommended that fishermen shift from using pelagic gillnet fishing to demersal gillnet fishing.

INTRODUCTION

Anabas testudineus (the climbing perch), described by Bloch in 1972, is a freshwater fish highly regarded across its extensive range in South and Southeast Asia.

The species is prevalent in numerous countries, including Pakistan, India, Bangladesh, Nepal, Bhutan, Sri Lanka, Myanmar, Thailand, Cambodia, Laos, Vietnam, southern China, Malaysia, Indonesia, Brunei, and Singapore **(De Silva *et al.*, 2015; Froese & Pauly, 2019)**. In Thailand, the climbing perch has different names in each region; in the North, it is variously called *pla sadet*; in the Northeast, *pla kheng*; and in the South, *i-kae pu-yu*. The Thai climbing perch inhabits a range of freshwater environments, including rivers, ponds, and marshes. It is highly resilient, capable of rapid growth, and well-adapted to different environments **(Rodjanapitak, 2019)**. It can withstand environments with relatively low water or even the absence of water for more extended periods compared to other fish species. This ability is due to its specialized labyrinth organ. The organ is located in the gill chamber beneath the eyes and allows it to take in atmospheric oxygen directly. Furthermore, it has the ability to bury itself in mud for longer periods. Its hard scales protect it and allow it to survive in low-oxygen water or even on land for 6 to 10 hours **(Hughes & Singh, 1970)**. Regarding its diet and current challenges, the climbing perch's diet includes protozoans, rotifers, crustaceans, insects, algae, diatoms, and small quantities of other organisms **(Roy *et al.*, 2013)**. In recent years, however, the number of the Thai climbing perch caught from natural water sources has been steadily decreasing, while consumer demand continues to rise. This has led to an insufficient supply of climbing perch for both domestic and international markets **(Rodjanapitak, 2019; Slamat *et al*., 2019; Ansyari & Slamat, 2020)**.

Previously, the climbing perch spp. were abundant in natural water sources throughout Thailand, which enabled it to harvest them for consumption across all regions of the country. This supply sufficiently met the needs of the general population. The climbing perch is a native freshwater fish of Thailand, widely known for its good taste, firm texture, and rich, flavorful meat, distinct from other fish due to having fewer bones. It is commonly used in a variety of dishes, such as tom yum, curry, and fried preparations, and can also be processed into different products. The climbing perch has long been popular among consumers, and its popularity remains high today. It is consumed mainly in fresh form (approximately 84%), fermented fish as *pla ra* (about 12%), and processed into salted, dried, smoked, and other forms (around 4%) **(Rodjanapitak, 2019)**. Currently, the number of climbing perches in natural water sources is progressively diminishing as a result of the degradation of their habitats caused by human activities. This has brought about changes in the environment and habitat of the climbing perch, which made it unsuitable for their growth. The population of climbing perch in Thailand shows a declining trend. In 2021, the quantity was 4.2 tons, valued at 289.6 million Baht. In 2022, it was 3.8 tons, valued at 254.3 million Baht, and in 2023, the quantity decreased to 3.7 tons, valued at 240.4 million Baht **(Department of Fisheries, 2023)**. In Thailand, research specifically examining the population dynamics of climbing perch in the Chi River is relatively limited, with notable studies dating back to 2019 **(Satrawaha & Pilasamorn, 2009)**. As the first known study on climbing perch population dynamics within a reservoir setting in Thailand, this research aimed to analyze the species' population trends, exploitation rate, and stock status specifically in Huai Kho Reservoir. It also seeked to generate foundational data for sustainable management practices, ensuring that climbing perch populations remain adequate to support the surrounding local communities that rely on these fisheries from reservoirs, lakes, and wetlands.

MATERIALS AND METHODS

1. Sample collection and laboratory analysis

Climbing perch samples were collected by fishermen each month from January to December 2022, across six locations with six sampling events per location. Samples were obtained using gill nets with mesh sizes ranging from 3.0 to 6.0cm. All fish were weighed (g) and measured (mm). The Bronze featherback species was subsequently identified in 2024 using a modified comparison method, with reference to **Kottelat (2013)** and **Fishbase (2024)**.

2. Population dynamics parameter calculations

A total of 336 climbing perch (*Anabas testudineus)* specimens were measured for length and weight as part of biometric analysis. The length data were categorized into 0.5mm intervals for detailed statistical examination, as illustrated in Table (1) **(Mustakim *et al.*, 2018; Ernaningsih *et al.*, 2024)**. FiSAT_II software, in combination with Microsoft Excel 2021, was used for analysis following the methodology set by **Gayanilo *et al.* (2005)**.

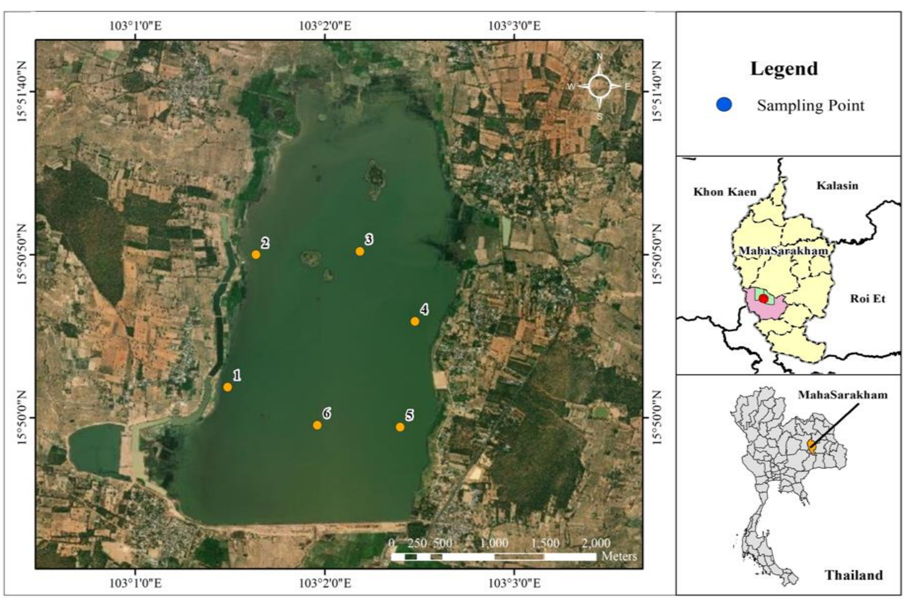

Fig. 1. Sampling stations in Huai Kho Reservoir where the climbing perch samples were collected

Table 1. Length frequency data of climbing perch from the Huai Kho Reservoir

ML (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
90	3												**3**
95	1											1	**2**
100	4										1	1	**6**
105	9	1								3	1	1	**15**
110	15	1								2	1	2	**21**
115	30	1								2	2	2	**37**
120	17	1								3	7	11	**39**
125	18	2								2	2	10	**34**
130	10	1	1				2			2	5	12	**33**
135	19	1					2			2	10	3	**37**
140	19	1		1	1	2	1	2	1	2	2	3	**35**
145	3			1	2	1	1		3	1	2	3	**18**
150	5		1				1			1	1	5	**14**
155	3						1			1	1	4	**10**
160	8	2					1				1	3	**15**
165	1		1				1				2	1	**6**
170	1		1				1					1	**4**
175			2				1		1				**4**
180			2				1						**3**
185							1						**1**
	166	**11**	**8**	**2**	**3**	**3**	**14**	**2**	**5**	**21**	**38**	**63**	**336**

2.1. Length-weight relationship (LWR)

The length-weight relationship (LWR) for the fish was calculated using **Le Cren's (1951)** formula:

$$LWR = aL^b$$

Where, W is the weight in grams (g); L is the length in millimeters (mm); a is the intercept; and b is the growth pattern estimator for the relationship between length and weight.

To determine if b=3 (suggesting isometric growth) or b≠3 (indicating allometric growth), a t-test was conducted with the following hypotheses:

H_0: b=3, suggesting isometric growth where length and weight grow proportionately.

H_0: b≠3, indicating allometric growth with differing growth rates for length and weight.

If b>3, positive allometric growth occurs, meaning weight grows faster than length. If b<3, negative allometric growth occurs, meaning length grows faster than weight. The log-transformed length-weight relationship (LWR) formula, as described by **Scherrer (1984)**, is:

$$\text{Log10 LWR} = \log 10\ a + b \log 10\ L$$

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

To estimate the theoretical age at birth (t_0), **Pauly**'s **(1984a)** empirical formula 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_∞ denotes the asymptotic length (in centimeters); and K is the annual growth coefficient. The growth performance index (ϕ) was then determined following **Munro and Pauly**'s **(1983)** formula:

$$\phi = 2 \log 10\ L_\infty + \log 10 K$$

Where, ϕ indicates growth performance; L_∞ is in millimeters; and K is the von Bertalanffy Growth Function (VBGF) parameter indicating growth curvature

The values for $L\infty$ and K were obtained from adjusted length-frequency data and fitted to the VBGF model. Calculations were carried out using the ELEFANT-I routine in FiSAT_II software according to **Pauly (1984a)**, using the formula:

$$Lt = L_\infty (1-^{e-K(t-to)})$$

Where, L_t represents the mean length at age t, with t as the climbing perch's age, and t_0 the hypothetical age at zero length.

2.3. Age

Age analysis was conducted using the method of **Bhattacharya (1967)**, which divides the fish population into different length classes. The frequency of each length class is converted to a logarithmic scale, and differences between logarithms of consecutive classes are calculated to determine age structure.

2.4. Mortality rates (M)

The length-converted catch curve analysis was employed to calculate the total annual mortality rate (Z). Natural mortality (M) was estimated using **Pauly**'s **(1980)** empirical formula :

$$\log 10\ M = -0.0066 - 0.279 \log 10\ L_\infty + 0.6543 \log 10\ K + 0.4634 \log 10\ T$$

Where, T is the annual average surface water temperature of the Huai Kho Reservoir. Fishing mortality (F) was then derived from $F=Z-M$, and the exploitation rate was (E) calculated as $E=F/Z$.

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

The probability of capture was determined using the length-converted catch curve, estimating lengths at which 25, 50, and 75% of the population are captured (L25, L50, and L75), as described by **Sparre and Venema (1998)**.

2.6. Virtual population analysis (VPA)

Length-structured VPA was used to assess population sizes and fishing mortality rates across length groups. Inputs included a, b, M, F, L_∞, and K, processed using FiSAT_II software **(Pauly, 1984a).**

2.7. 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 relative yield per recruit (Y//R) and biomass per recruit (Y//R):

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

Where, U=1-(Lc/ L_∞); m=(1-E)/(M/K)=K/Z; and E=F/Z. Moreover, B/R was estimated using the relationship: (Y/R)/F.

RESULTS

Length-weight relationship (LWR)

Frequency distribution analysis of the climbing perch was performed based on samples collected monthly from Huai Kho Reservoir throughout 2022. A total of 336 individuals were collected, with weights varying between 19 and 126 grams and an average weight of 49.78 ± 21.69 grams. The specimens measured between 90 and 185 millimeters in total length, with measurements taken in 0.50-millimeter intervals (Table 1 & Fig. 2). The mean total length was found to be 130.82 ± 18.46 millimeters, with the predominant size class ranging from 115 to 140 millimeters (Figs. 2, 3**)**. Details on the length-weight relationship (LWR) of the climbing perch are presented below:

LWR = $0.026938L^{1.56963}$ (r^2= 0.95); Lt = 194.25 *(1-$^{e\ -0.1}$($^{t+40}$)) (Fig. 3)

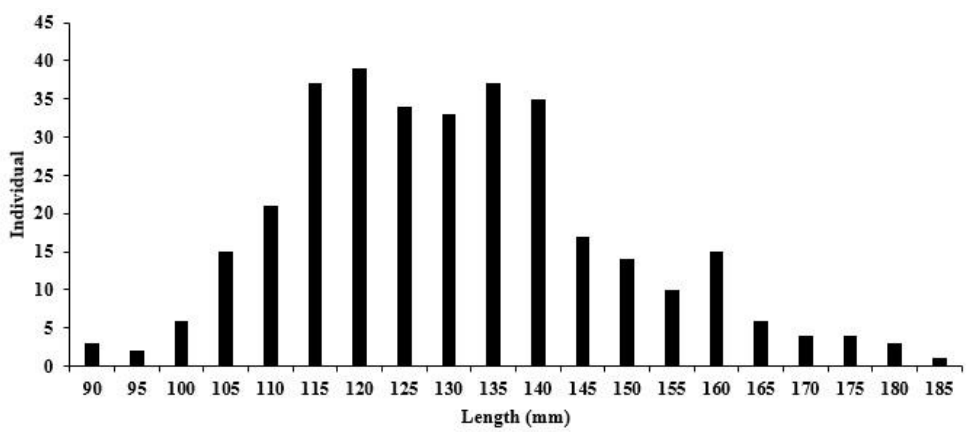

Fig. 2. The length frequency distribution of the climbing perch (n = 336), ranging from 90 to 185 millimeters in total length (TL), was analyzed for both sexes using landing data collected from Huai Kho Reservoir from January to December 2022

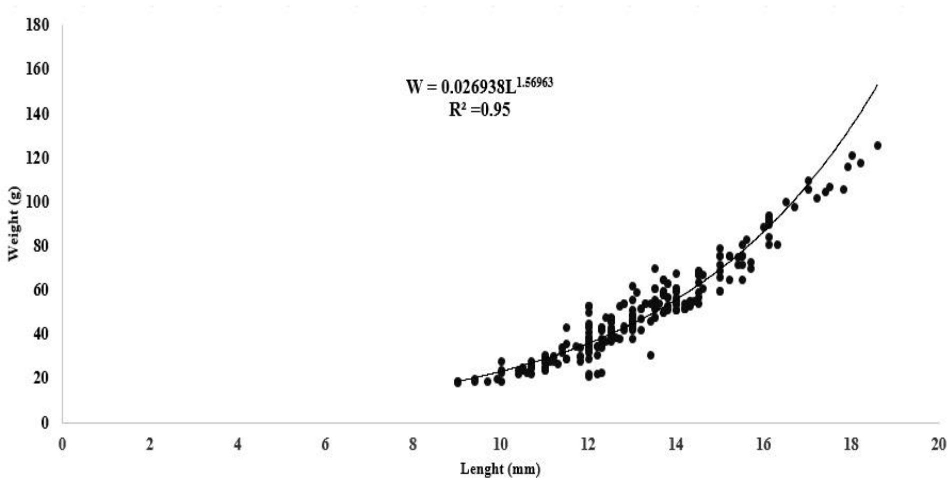

Fig. 3. An analysis of the length-weight relationship (LWR) for the climbing perch (n = 336) was conducted using samples collected from Huai Kho Reservoir

Age and growth parameters

The climbing perch population exhibited an estimated maximum length (L_{max}) of 192.45 millimeters, with observed sizes of 42, 97, 132, 157, 177, and 187 millimeters, corresponding to ages of 1, 3, 5, 7, 10, and 15 months, respectively (Fig. 6).

Through analysis of monthly length frequency data, the growth parameters for the climbing perch in this study area were established as follows: an observed extreme length of 185 millimeters and a predicted extreme length of 191.28 millimeters, with a 95% confidence interval spanning 177.82 to 204.74 millimeters. The growth performance index (ϕ) was determined to be 3.97 per year, with an asymptotic length (L_∞) of 194.25 millimeters, a growth coefficient (K) of 0.25 per year, and a t_0 value of -0.40 months (Figs. 4a, 5).

Total mortality (Z)

The total mortality rate (Z) for climbing perch was calculated at 0.84 per year using the von Bertalanffy Growth Function (VBGF) parameters (L_∞ and K) in the length-converted catch curve model, with a 95% confidence interval of 0.07 to 1.74 ($r^2 = 0.99$). The natural mortality rate (M) was 0.45 per year, leading to a fishing mortality rate (F) of 0.40 per year, calculated as $F=Z-M$. The exploitation rate (E) was estimated at 0.47 (Fig. 7).

Probability of capture

The specific lengths at which 25, 50, and 75% of the population are captured were calculated as follows: L25% = 107.18 millimeters, L50% = 101.99 millimeters, and L75% = 114.80 millimeters. These values indicate the length classes at which the climbing perch reaches the respective capture probabilities of 25, 50, and 75%. The data suggest that individuals within the population of the climbing perch are predominantly captured once they reach lengths around 101.99 to 107.18 millimeters, with larger individuals being increasingly captured up to 114.80 millimeters. These findings provide valuable information for understanding the fishing dynamics and the size structure of the population in the Huai Kho Reservoir (Fig. 8).

Virtual population analysis (VPA)

VPA for climbing perch in Huai Kho Reservoir was performed using FiSAT_II software. In 2022, a total of 9,074.73 climbing perch individuals were recorded. The smallest size at which individuals began to be replaced was 90 millimeters, with 1294.28 individuals observed. Mortality rates were higher in the length range of 160 to 180 millimeters, peaking at 160 millimeters with 78.6 individuals. The total steady-state biomass of climbing perch was calculated to be 1.90 tons, while steady-state biomass ranged from 0.010 to 0.142 tons. The overall mortality rate ranged from 0.0088 to 0.4832 $year^{-1}$, while the maximum value occurred at 160 millimeters, totaling 78.6 individuals, repeatedly indicating high fishing mortality in juvenile climbing perch (Fig. 9).

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

Using FiSAT_II software's knife-edge procedure, the relative yield per recruit ($Y^{/}/R$) and biomass per recruit ($B^{/}/R$) were analyzed for the climbing perch. The identified exploitation rates were as follows: E_{10}, which maximizes yield per recruit, was 0.607; E_{50}, the rate at which 50% of the maximum yield is achieved, was 0.351; and E_{max}, the rate that yields the maximum yield, was 0.702 (Fig. 10).

(a) **(b)**

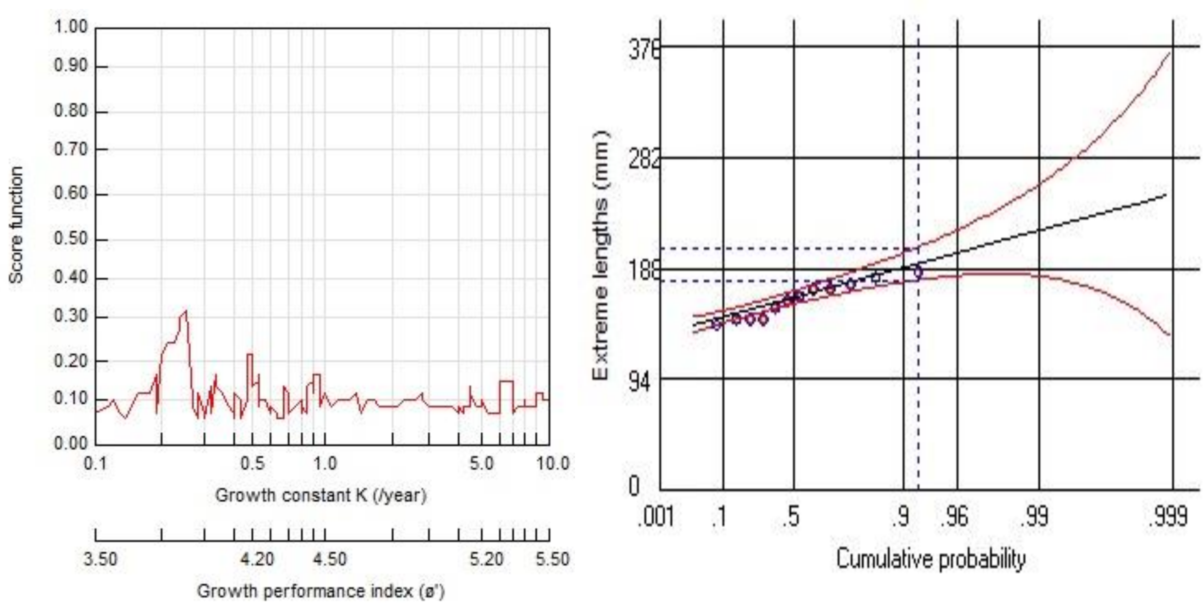

Fig. 4. a) The FiSAT II software's ELEFAN-I K-scan routine was utilized to analyze the growth patterns of climbing perch (n=336) in the Huai Kho Reservoir

b) Using extreme value theory, the maximum length of climbing perch (n=336) in the Huai Kho Reservoir was predicted with a high degree of confidence

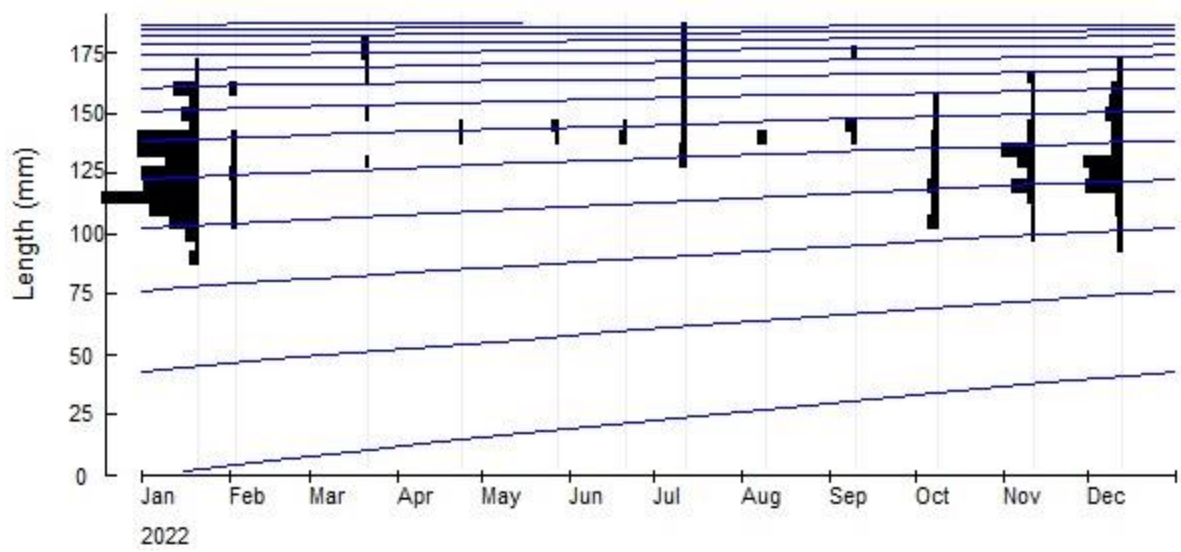

Fig. 5. The length-frequency distribution of climbing perch (n=336) sampled from gill net catches in the Huai Kho Reservoir was restructured and superimposed with growth curves. The analysis was conducted using the ELEFAN-I routine from the K-scan in FiSAT_II software

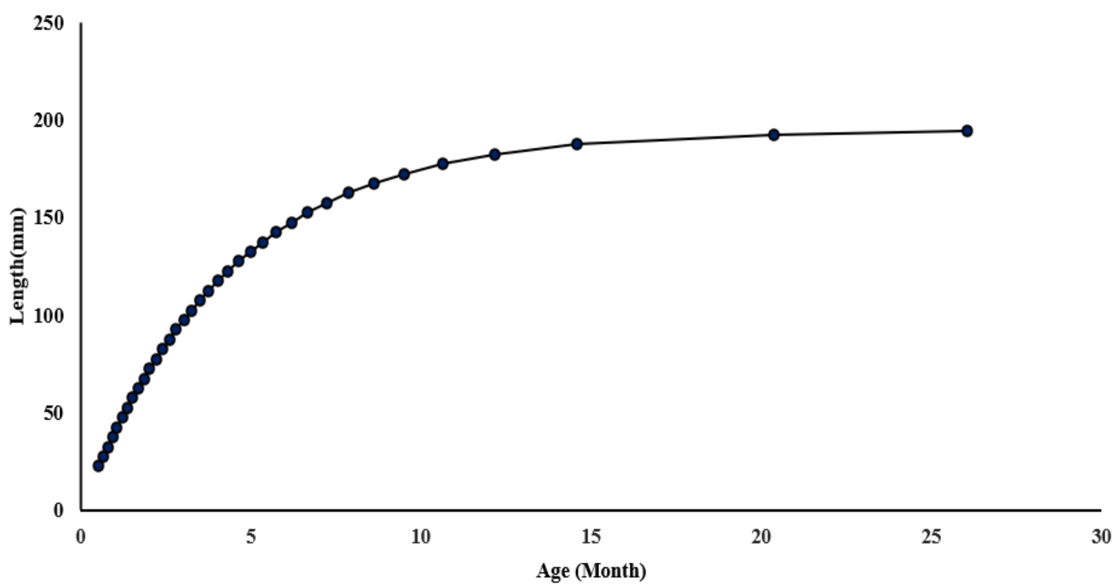

Fig. 6. The relationship between age (in months) and length (in millimeters) of climbing perch (n=336) in the Huai Kho Reservoir can be determined through the application of growth parameters

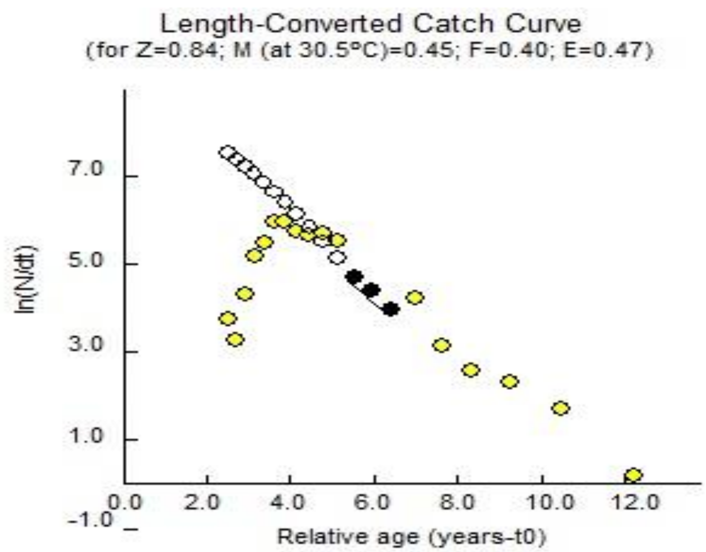

Fig. 7. The length-converted catch curve for climbing perch (n=336) in the Huai Kho Reservoir was utilized to estimate different mortality rates, including total mortality, natural mortality, and fishing mortality, as well as the exploitation rate

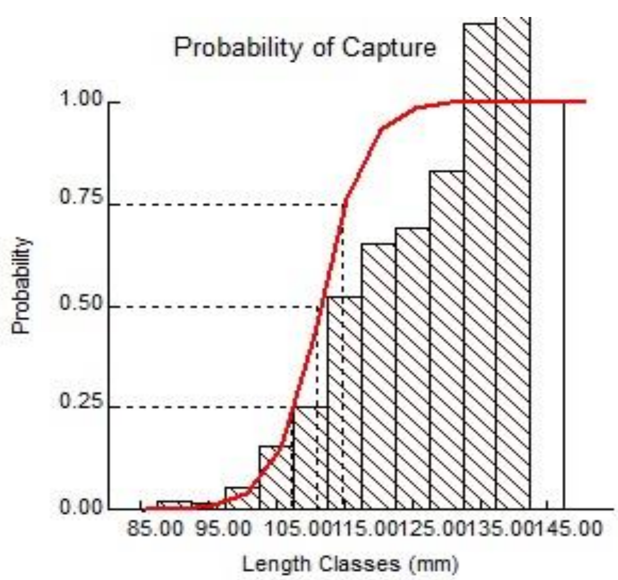

Fig. 8. The selectivity curve of climbing perch (n=336) in the Huai Kho Reservoir was developed to understand the relationship between fish size and the probability of capture

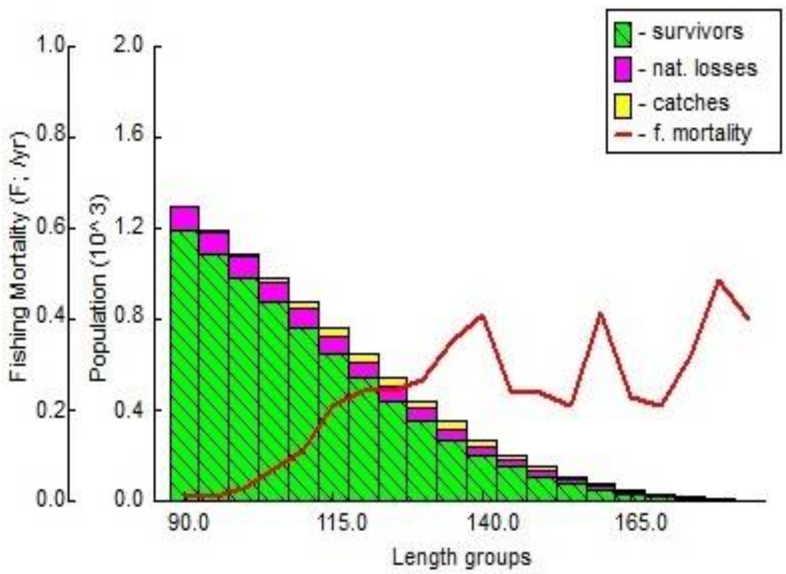

Fig. 9. The length-structured virtual population analysis (VPA) was employed to estimate the population size and mortality characteristics of climbing perch (n=336) in Huai Kho Reservoir

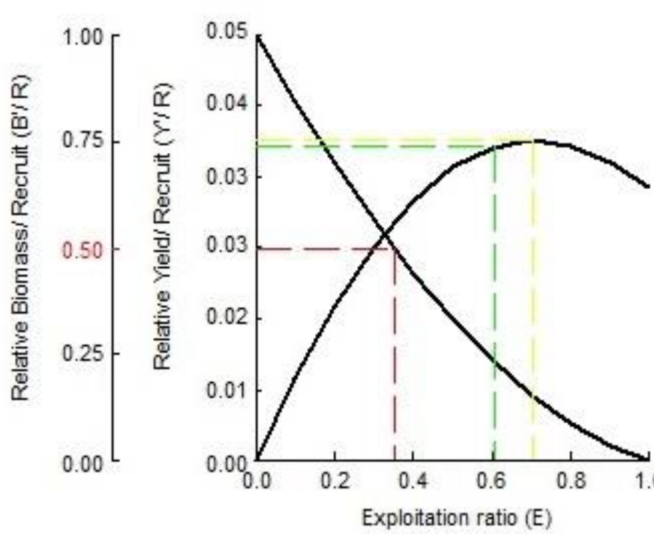

Fig. 10. Relative yield per recruit ($Y^{/}/R$) and biomass per recruit ($B^{/}/R$) for the climbing perch (n=336) in the Huai Kho Reservoir were assessed using the FiSAT_II software. Note: The dash-lines: red (--) green (--) and yellow (--) indicate the exploitation rates at $E_{0.1}$, $E_{0.5}$, and E_{max}, respectively

DISCUSSION

The climbing perch total length measurements at 0.50-millimeter intervals ranged from 90 to 185 millimeters, with a mean total length of 130.82 ± 18.46 millimeters. The primary size class fell between 115–140 millimeters (Table 1 & Figs. 2, 3). When comparing size class distribution to other studies, variations were noted. For instance, the climbing perch lengths in Lake Lubuk Siam ranged from 115 to 200mm **(Felni *et al.*, 2019)**, while Danau Tempe Lake lengths ranged from 115 to 135mm **(Srioktoviana *et al.*, 2022).** Such differences can be attributed to geographic location, local food availability, and fishing methods, factors known to impact fish growth patterns within a population **(Roy *et al.*, 2013; Zworkin, 2018; Mawa *et al.*, 2021; Hasnidar *et al.*, 2022; Srioktoviana *et al.*, 2022)**. Stomach content analysis showed that animal matter comprised 40-95% of the diet (including fish, shrimp, insects, snails, and worms), plant matter made up 15-48%, and 0.38-5% was unidentifiable **(Mustakim *et al.*, 2020)**. This study demonstrates that food availability directly affects growth rates in climbing perch: during months with abundant food, the species grows faster, whereas growth slows during leaner periods.

Length-weight relationship (LWR) = $0.026938L^{1.56963}$ (r^2= 0.95); Lt = 194.25 *(1-$e^{-0.1}$($^{t+40}$)) is depicted in Fig. (3). This preliminary study on the climbing perch 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 (1.56963) 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. When compared to reference areas, such as other reservoirs or artificial wetlands, no differences in growth patterns were observed. The climbing perch exhibits a negative allometric growth (b < 3). **(Garcia, 2010; Kumary & Raj, 2016**; **Mustakim *et al.*, 2018; Ndobe *et al.*, 2019; Maurya *et al.*, 2020; Ndobe *et al.*, 2020; Hasnidar *et al.*, 2022)**. There is also a difference in growth patterns, with the climbing perch in some environments showing a positively allometric growth (b > 3) **(Khatun *et al.*, 2019)**. The high 'b' value, less than or higher than the isometric value (3), in the LWR may result from several factors such as age, sex (The b value is higher in females than in males), geographical area, water quality, water level, habitat, gonadal maturity, seasonal effects, preservation process, variation in the physiology, and food abundance **(Hossain *et al.*, 2015; Ernawati *et al.*, 2019; Slamat *et al.*, 2019; Mawa *et al.*, 2021; Pavlova *et al.*, 2021; Salam *et al.*, 2021; Zworkin, 2021; Priyatha & Chitra, 2022a; Manon *et al.*, 2023; Pandit *et al.*, 2023)** Understanding the LWR of climbing perch will offer insights into the current status of the fish, the environmental conditions (flowing water with aquatic plant), food abundance, good water quality and the aquatic plant (*Hydrilla verticillate*, *Utricularia aurea*, *Spirogyra* sp., and *Azolla pinnata*) in Huai Kho Reservoir.

The growth performance index (ϕ) of the climbing perch is 3.97 per year (Fig. 3), with an asymptotic length (L_∞) of 194.25 millimeters, a growth coefficient (K) of 0.25

per year, and an initial age (t_0) of -0.40 months (Fig. 4). The K value can be influenced by factors such as sex, fish size, season, and stages of gonadal development **(Wootton, 1998)**. Fulton's condition factor, ranging from 1.25 to 1.84, indicates that the climbing perch is in generally good health. However, the low K value of 0.25 suggests suboptimal growth rates, potentially due to health rather than habitat conditions **(Maurya *et al.*, 2018)**. The growth coefficient (K) serves as a growth rate indicator for aquatic organisms, with higher K values reflecting favorable, faster growth, and lower values indicating slower, less favorable growth (**Shalloof *et al.*, 2024)**. Comparing the asymptotic length (L_∞) and growth coefficient (K) in the study area with reference values, the growth parameters in the reference area showed a growth performance index (ϕ) of 4.56 per year, an asymptotic length (L_∞) of 202.13mm and a growth coefficient (K) of 0.70 per year in the Semayang Lake **(Mustakim *et al.*, 2018)**. While, the growth parameters in the reference area showed a growth performance index (ϕ) of 4.56 per year, an asymptotic length (L_∞) of 216.25mm and a growth coefficient (K) of 0.78 per year in the Rudrasagar Lake **(Maurya *et al.*, 2020)**. The growth parameters in the reference area showed a growth performance index (ϕ) of 4.56 per year, an asymptotic length (L_∞) of 263.0mm and a growth coefficient (K) of 0.50 per year, and a t_0 of -0.33 months in the Danau Tempe Lake **(Srioktoviana *et al.*, 2022**). This in turn highlights that the climbing perch in Huai Kho Reservoir experiences slower and lower 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, fishing gears, seasonal variations in food availability, reproductive cycle, and the length range of analyzed fish **(Mostafa *et al.*, 2008; Maurya *et al.*, 2018; Maw *et al.*, 2020; Ndobe *et al*, 2020; Hasnidar *et al.*, 2022; Priyatha & Chitra, 2022a; Zworkin, 2023)**

As a result, the climbing perch in Huai Kho Reservoir are experiencing a slow growth, which may indicate poor health of the fish rather than issues with the habitat. The total mortality rate (Z) was estimated at 0.84 per year, with the natural mortality rate (M) at 0.45 per year and the fishing mortality rate (F) at 0.40 per year (Fig. 7). This suggests that in Huai Kho Reservoir, the climbing perch are predominantly affected by natural mortality. Studies have shown that the climbing perch cannot tolerate or survive in environments with high concentrations of herbicides, such as triclosan and paraquat, which are among the causes of natural mortality in this species **(Norhan *et al.*, 2019; Norhan *et al.*, 2022; Priyatha & Chitra, 2022b; Mandal *et al.*, 2024; Sudhakaran & Suja, 2024)**. This aligns with the findings of **Khowhit *et al*. (2024)**, who confirmed that the water quality in Huai Kho Reservoir is good and does not negatively affect aquatic life.

The relatively high rate of natural mortality in the climbing perch is attributed to their biology, which allows them to survive in low-water or even dry conditions for extended periods, thanks to their specialized labyrinth organ. This organ enables them to breathe air directly, and during the summer, they often burrow into mud **(Pererera *et al.*,**

2013; Ahmad *et al.*, 2019). Consequently, during the summer months (February to June), fishermen in the Huai Kho Reservoir are unable to catch the climbing perch. However, when the rainy season arrives, the climbing perch emerge to breed (Table 1).

A comparison of total mortality rates in the study area with values from other regions reveals differences in the mortality rates of the climbing perch. In Semayang Lake, the total mortality rate (Z) for the climbing perch was 1.63 per year, with a natural mortality (M) of 0.76 per year and a fishing mortality (F) of 0.87 per year **(Mustakim *et al*., 2018)**. In Rudrasagar Lake, the rates were higher: total mortality (Z) was 1.95 per year, natural mortality (M) was 1.54 per year, and fishing mortality (F) was 0.41 per year **(Maurya *et al.*, 2020)**. Danau Tempe Lake exhibited the highest rates, with a total mortality (Z) of 3.41 per year, natural mortality (M) of 1.22 per year, and fishing mortality (F) of 2.19 per year **(Srioktoviana *et al.*, 2022)**. The differences in natural mortality rates likely stem from factors such as food availability, predation, fish behavior, and environmental conditions like temperature. In contrast, variations in fishing mortality reflect differences in fishing pressure and gear selectivity **(Srioktoviana *et al.*, 2022)**. This comparison indicates that the natural mortality rate (M) is the primary factor affecting the climbing perch in the study area. The high observed natural mortality rate suggests significant fishing pressure, which may be due to the abundance of large individuals in the area. The climbing perch's labyrinth organ, which allows it to survive in low-oxygen conditions for extended periods, combined with its burrowing behavior during the summer months, make it difficult for fishermen to catch them.

The highest replacement rates of climbing perch occur between November and January (Table 1). Consistent with studies on the biological reproduction of climbing perch in Thailand, males and females tend to mate and spawn in shallow waters with fresh water conditions after rainfall, particularly when temperatures are slightly lower than usual. Spawning has been found to occur from May to October **(Radjanapitak, 2019)**. Therefore, the highest recruitment rates are observed from November to January. This observation aligns with findings from a study that identified the period from July to October as the peak breeding season for climbing perch. As a result, the replacement rate increases from November to January, reaching its maximum level.

In comparison with reference areas, climbing perch recruitment shows bimodal peaks. The highest recruitment in Rudrasagar Lake occurs once a year, typically in September **(Maurya *et al*., 2020)**. In Bararawa Swamp, peak recruitment occurs in June, aligning with the spawning season from May to August, with specific peaks in June and July **(Maw *et al.*, 2020)**. In Tungkaran Swamp, peak recruitment is observed in August, while in Pantai Harapan Swamp, peak recruitment occurs in May and again in July **(Rosadi & Budiarti, 2022)**. In general, most tropical aquatic species exhibit continuous recruitment throughout the year, with pronounced intensity during monsoon or transitional seasons.

The study found that the exploitation rate (E) of the climbing perch in Huai Kho Reservoir is 0.47, which is lower than the maximum sustainable exploitation rate (E_max) of 0.702. The exploitation rate should be at or below 0.50 to ensure long-term sustainability. The low exploitation rate observed suggests that the climbing perch are being exploited in low numbers in Huai Kho Reservoir. Therefore, the utilization of the climbing perch in the reservoir has not yet exceeded its production capacity, and fishermen can still engage in more fishing activities. In contrast, reference areas show higher exploitation rates, such as 0.47 in Semayang Lake **(Mustakim *et al.*, 2018)**, 0.21 in Rudrasagar Lake **(Maurya *et al.*, 2020)**, and 0.64 in Danau Tempe Lake **(Srioktoviana *et al.*, 2022)**. This indicates that the current exploitation rate in Huai Kho Reservoir is within sustainable levels. These exploitation rates are crucial for determining the best management strategies for climbing perch. By adjusting fishing efforts to stay within optimal exploitation rates, it is possible to maintain a balance between maximizing yield and ensuring the long-term health of the population.

CONCLUSION

The total mortality rate (Z) of climbing perch was estimated at 0.84 per year, with the natural mortality rate (M) at 0.45 per year and the fishing mortality rate (F) at 0.40 per year. The exploitation rate (E) was calculated to be 0.47, indicating a moderate level of fishing pressure ($E < 0.50$) on climbing perch in Huai Kho Reservoir. Despite this, the species has a relatively high natural mortality rate, which is not attributed to water pollution from community or agricultural activities around the reservoir. Instead, it is linked to the biology and behavior of the climbing perch.

The climbing perch possess a specialized labyrinth organ, located in the gill chamber beneath the eyes, allowing them to absorb atmospheric oxygen directly. Additionally, they exhibit behaviors such as burying or embedding themselves in mud for extended periods, which makes them difficult for fishermen to catch. As a result, during the months from March to October, it is recommended that fishermen switch from using surface gill nets to bottom-set nets to maximize the utilization of climbing perch resources.

From November to January, which corresponds to the post-spawning period, climbing perch change their behavior by moving to shallow areas or the edges of the reservoir, where they no longer bury themselves in mud. During this period, fishermen are advised to use floating nets.

Furthermore, efforts should be made to prevent the use of illegal fishing gear, such as Sai Sing (fish traps), which are often placed around the edges of the reservoir. Collaboration with local fishermen to control and monitor fishing practices is crucial to ensuring sustainable fishing 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.

REFERENCES

Ahmad, A. B.; Hadiaty, R. K.; De Alwis Goonatilake, S.; Fernado, M. and Kotagama, O. (2019). *Anabas testudineus* (errata version published in 2020). The IUCN Red List of Threatened Species 2019: e.T166543A174787197.

Ansyari, P. and Slamat, S. (2020). Comparison of the performance of Climbing Perch (*Anabas testudineus* Bloch) filial 2 fry and natural fry treated in acidic swamp waters, Jejangkit Village, South Kalimantan. Jurnal Lahan Suboptimal: Journal of Suboptimal Lands, 9 (1): 23-30. DOI:10.33230/JLSO.9.1.2020.442

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.

De Silva, M.; Hapuarachchi, N. and Jayaratne, T. (2015). Sri Lankan freshwater fishes. Wildlife Conservation Society - Galle. 391 p.

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]

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. Egyptian Journal of Aquatic Biology and Fisheries, 28(3): 285-298. DOI:10.21 608/ EJABF.2024.355856

Felni, A. N.; Fauzi, M. and Fajri, N. E. (2020). Populasi ikan climbing perch (*Anabas testudineus*) di Danau Lubuk Siam Desa Lubuk Siam Kecamatan Siak Hulu Provinsi Riau. Universitas Riau. Pekanbaru.

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

Froese, R. and Pauly, D. (2019). FishBase, The Global Database of Fish.

Garcia, L. M. B. (2010). Species composition and length-weight relationship of fishes in the Candaba wetland on Luzon Island, Philippines. Journal of Applied Ichthyology, 26: 946-948. DOI:10. 1111/j.1439-0426.2010.01516.x

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.

Hasnidar, Tamsil, A.; Ernaningsih.; Hasrun. and Akram A. M. (2022). Reproductive biology climbing perch *Anabas testudineus* (Bloch 1792) at Danau Tempe Kabupaten Wajo South Sulawesi. Jurnal Iktiologi Indonesia, 22(1): 17-34. DOI: 10.32491/jii.v22i1.567

Hossain, Y. M.; Hossen, M. A.; Pramani, M. N. U.; Ahmed, F.; Yahya, K.; Rahman, M. M. and Ohtomi, M. (2015). Threatened fishes of the world: *Anabas testudineus* (Bloch. 1792) (Perciformes: Anabantidae). Croatian Journal of Fisheries, 73: 128-131. DOI:10.14798/73.3.838

Hughes, G. M. and Singh B. N. (1970). Respiration in an air-breathing fish,the climbing perch *Anabas Testudineus* Bloch. Journal of Experimental Biology, 53 (2): 265-280. DOI:10.1242/jeb.53.2.265.

Khowhit, S.; Tanee, T.; Khowhit, D.; Pumipuntu, N.; Muangmai, N. and Musiri, P. (2024). Population dynamics and exploitation rate of BronzeFeatherback (*Notopterus notopterus*, Pallas, 1769) for sustainable management in Huai Kho Reservoir, Na Chueak District, Maha Sarakham Province, Thailand. Egyptian Journal of Aquatic Biology and Fisheries, 28(5): 219-237. DOI: 10.21608/ejabf.2024.377650

Khatun, D.; Hossain, M. Y.; Rahman, M. A.; Islam, M. A.; Rahman, O.; Azad, M. A. K.; Sarmin, M. S.; Parvin, M. F.; Haque, A. T. U.; Mawa, Z. and Hossain, M. A. (2019). Life-history traits of the climbing perch *Anabas testudineus* (Bloch, 1792) in a wetland ecosystem. Jordan Journal of Biological Sciences, 12 (2): 175-182.

Kumary, K. S. A. and Raj, S. (2016). Length-weight relationship and condition of climbing perch *Anabas testudineus* Bloch population in Kuttanad, Kerala. International Journal of Advanced Research in Biological Sciences, 3(9): 21-26. DOI:10.22192/ijarbs. 2016.03.09.00

Kottelat, M. (2013). The fishes of the inland waters of southeast Asia: a catalogue and core bibiography of the fishes known to occur in freshwaters, mangroves and estuaries. Raffles Bulletin of Zoology, 27: 1-663.

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.

Mandal, G.; Mandal, S. and Mandal, B. (2024). Study on the effect of paraquat dichloride's (PD) acute toxicity on *Anabas testudineus* (Bloch, 1792). Journal of Stress Physiology and Biochemistry, 20(3): 49-63.

Manon, M. R. K.; Md. Sufian, A., Alam, A.; Ullah, M. R.; Hossain, M. A. Hossen, M. B.; Iqbal, M. M. and Rahman, M. A. (2023). Intraspecific phenotypic differences in climbing perch *Anabas testudineus* (Bloch, 1792) populations may be linked to habitat adaptations. Heliyon, 9: e17685. DOI:10.1016/j.heliyon. 2023.e17685

Maurya, A. K.; Radhakrishnan, K. V.; Sahu, P.; Prasad, L.; Khan, S. and Kumar, R. (2018). Length weight relationship and condition factor of *Anabas testudineus* (Bloch, 1792) from Rudrasagar Lake (A Ramsar site), Tripura. Journal of Pharmacognosy and Phytochemistry, 7(2): 1395-1398.

Maurya, A. K.; Radhakrishnan, K. V. and Kumar, R. (2020). Population characteristics and level of exploitation of *Anabas testudineus* (Bloch, 1792) in Rudrasagar Lake, a Ramsar site in North-eastern India. Indian Journal of Marine Science, 49 (02): 298-302.

Maw, Z.; Hossain, M. Y.; Hasan, M. R. and Asaduzzaman, M. (2022). Reproductive aspects of *Anabas testudineus* collected from the Gajner Beel wetland in Bangladesh: implications for its conservation under changing eco-climatic conditions and suggestions for best aquaculture practice. Environmental Science and Pollution Research, 29(44): 66277-66294. DOI:10.1007/s 11356-022-20423-7.

Mawa, Z.; Tanjin, S.; Hossain, M. Y.; Hasan, M. R.; Rahman, M. A.; Sabbir, W.; Azad, M. A. K.; Islam, M. A.; Rahman, M. A.; Jasmine, S.; Basir, Z.; Sarmin, M. S. and Ohtomi, J. (2021). Estimation of relative growth of *Anabas testudineus* through multiple linear dimensions. Egyptian Journal of Aquatic Biology and Fisheries, 25(1): 935-952. DOI:10.21608/ejabf.2021. 153232

Mostafa, Z. B.; Tareque, A. M. H. B.; Rasel, M. S. E. and Rahman, S. M. M. (2008). Length-weight relationship and condition factor of climbing perch (*Anabas Testudineus*, Bloch). Khulna University Studies, 9(2): 211-214.

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

Mustakim, M.; Anggoro, S.; Purwanti, F. and Haeruddin. (2018). Population dynamics of the climbing perch *Anabas testudineus* in the Semayang Lake, East Kalimantan Province, Indonesia. Aquaculture, Aquarium, Conservation and Legislation (AACL Bioflux), 11 (4): 1038-1046.

Mustakim, M.; Anggoro, S.; Purwanti, F. and Haeruddin. (2020). Food habits and trophic level of *Anabas testudineus* in floodplain lake, Lake Semayang, East Kalimantan. E3S Web of Conferences, 147: 02024: 1-10. DOI:10.1051/e3sconf/ 2020147020243

Ndobe, S.; Rusaini.; Masyahoro, A.; Serdiati, N.; Madinawati and Moore, A. M. (2019). Meristic characters and length-weight relation of climbing perch (*Anabas testudineus*) from wetlands in Sigi District, Central Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science, 370 01200

Ndobe, S.; Rusaini.; Masyahoro, A.; Serdiati,N.; Madinawati. and Moore, A. M. (2020). Reproductive and morphometric characteristics of climbing perch *Anabas testudineus* in Sigi, Central Sulawesi, Indonesia. Aquaculture, Aquarium, Conservation and Legislation (AACL Bioflux), 13 (1): 167-182.

Norhan, N. A. S.; Karim, N. U.; Daud, H. M.; Melad, A. A. N.; Zakariah, M. I. and Hassan, M. (2019). Behavioural effects of *Anabas testudineus* (Bloch, 1792) towards sublethal paraquat expoue. International Journal of Advanced Research, 7(11):1-7. DOI:10.21474/IJAR01/9967

Norhan, N. A.; Zakariah, M. I.; Karim, N. U.; Daud, H. M.; Melad, A. A. N.; Yusoff, N. A. H. and Hassan, M. (2022). Paraquat-induced histopathological changes on the gills, kidney and liver tissues of *Anabas testudineus* (Bloch 1792). Journal of Sustainability Science and Management, 17(8): 165-174.

Oussellam, M.; Selfati, M.; Ouamari, N. E. and Bazairi, H. (2023). Length-weight parameters for 32 species from the marchica lagoon (Mediterranean, Morocco). Egyptian Journal of Aquatic Biology and Fisheries, 27(3): 223-229. DOI:10.21 608/ejabf. 2023.300857

Pandit, D. N.; Kumari, M. and Garhwal, N. (2023). Length-weight relationship and condition factor of a threatened climbing perch (*Anabas testudineus*) from Arrah (Bihar), India during non-breeding season. Journal of Survey in Fisheries Sciences, 10(1): 2847-2854.

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.

Pererera, P. A. C. T.; Kodithuwakku, K. A. T.; Sundarabarathy, T. V. V. and Edirisinghe, U. (2013). Captive breeding of *Anabas testudineus* (Climbing Perch) under semi-artificial conditions for the mass production of fish seed for conservation and aquaculture. Insight Ecology, 8-14. DOI:10.5567/ECOLOGY-IK.2013.8.14

Pavlova, E. D.; Pavlova, D. S.; Ganzhaa, E. V.; Kostina, V. V. and Dien, T. D. (2021). Influence of water level on the exit of Climbing Perch *Anabas testudineus* out of the water and specific features of its movements. Journal of Ichthyology, 5 (61): 752-757. DOI:10.1134/S003294 522105012X

Priyatha, C. V. and Chitra, K. C. (2022a). Evaluation of the reproductive cycle and gonadal development in the climbing perch, *Anabas testudineus* (Bloch, 1792) in captivity. Journal of Fisheries, 10(1): 101206. DOI:10.17017/j.fish.364

Priyatha, C. V. and Chitra, K. C. (2022b). Evaluation of oxidative stress and genotoxicity induced by triclosan in the freshwater fish, *Anabas testudineus* (Bloch, 1792). International Journal of Zoological Investigations, 8 (1):1-17. DOI: 10.33745/ijzi.2022.v08i01.001

Rodjanapitak, S. (2019). Cultivation of climbing perch (*Anabas testudineus*). Kasetsiam Publishing, Bangkok, Thailand. [Thailand]

Rosadi, E. and Budiarti, L. Y. (2022). Population dynamics of climbing perch (*Anabas testudineus*, Bloch 1792) fish resources in south Kalimantan, Indonesia. Aquaculture, Aquarium, Conservation and Legislation (AACL Bioflux), 15 (4): 2070-2077.

Roy, D.; Masud, A. A.; Bhouiyan, N. A. and Naser, M. N. (2013). Food and feeding habits of climbing perch *Anabas testudineus* (Bloch) and indigenous Cat Fish *Rita rita* (Hamilton). International Journal of Biological Research, 15(1):1-6.

Salam, M. A.; Bedajit, Y.; Irungbam, S.; Ramananda, H. and Oinam, G. (2021). Study on growth performance, production and return of Vietnamese koi (Anabas testudineus) for socio economic upliftment of rural youth in Manipur, India. Journal of Experimental Biology and Agricultural Sciences, 9 (Spl-3-NR MCSSA_2021): 349-352. DOI:10.18006/2021.9 (Spl-3-NRMCSSA_2021). S349. S352

Satrawaha, R. and Pilasamorn, C. (2009). Length-weight and length-lengt relationships of fish species from the Chi River, northeastern Thailand. Journal of Applied Ichthyology, 25: 787-788. DOI: 10.1111/j.1439-0426.2010.01516.x

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

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. Egyptian Journal of Aquatic Biology and Fisheries, 28(1):1221-1237. DOI:10.21 608/ejabf.2024.339931

Slamat.; Ansyari, P.; Ahmadi, Kartika R. (2019). The breeding of limbing Perch (*Anabas testudineus*) with meristic phylogenetic hybridization technique sampled from three types of swamp ecosystems. Tropical Wetland Journal, 5(2): 31-39. DOI:10.20527/twj.v5i2.72

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

Srioktoviana, S. K.; Mallawa, A. and Amir, F. (2022). Population dynamics of the climbing perch (*Anabas testudineus*) in the wateras of Tempe Lake, Wajo

Regency, South Sulawes. Jurnal IPTEKS Pemanfaatan Sumberdaya Perikanan, 9 (1): 29 -39.

Sudhakaran, B. V. and Suja, S. (2024). Ovarian histological analysis of *Anabas testudineus* as a marker for pesticide residue analysis in freshwater ecosystems. Toxicology International, 31(1) : 93-99. DOI:10.18311/ti/2024/v31i1/3572

Wootton, R. J. (1998). Ecology of teleost fishes, Netherlands, 2nd Edition, kluwer Academic Publishers.

Zworkin, D. D. (2018). The behavior of climbing perch, *Anabas testdines*, with novel food in individual and social conditions. Journal of Ichthyology, 58 (2): 260-264. DOI:10.1134/S003294521 8020169

Zworkin, D. D. (2021). First record of the spawning capable climbing perch *Anabas testudineus* (Teleostei: Anabantidae) during the dry season. Ichthyological Exploration of Freshwaters, 31: 15-20. DOI: 10.23788/IEF-1165

Zworkin, D. D. (2023). *Anabas testudineus* (Bloch, 1792), climbing perch (Anabantidae), and its discovery in India. Archives of Natural History, 50 (1):22-34. DOI:10. 3366/anh.2023.0825