Int. J. Aquat. Biol. (2023) 11(4): 328-337
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Assessment of growth and mortality parameters and exploitation rate to monitor the population status of wild catfish, *Pangasius nasutus* (Bleeker, 1863) in Pahang River, Malaysia

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Abstract: *Pangasius nasutus* is one of the popular freshwater fish species in Pahang River, Malaysia because of its economic value, however, the high exploitation rate, occurrence of invasive alien species in the same ecosystem, and habitat modification threatened its population sustainability. This study aimed to enhance the existing information database of a species that has limited data availability and to monitor its population status. The monthly samplings were conducted from the upstream to the downstream of the Pahang River for 12 consecutive months from May 2021 to April 2022. The FiSAT II software was used to analyse population parameters from the length frequency data. The results revealed the asymptotic length (L_∞) = 661.50 mm, growth coefficient (K) = 0.18 year^{-1}, growth performance index (Ø') = 4.90, the maximum age (T_{max}) = 16.67, total mortality (Z) = 0.61 year^{-1}, natural mortality (M) = 0.25 year^{-1}, fishing mortality (F) = 0.36 year^{-1} and exploitation rate (E) = 0.59 year^{-1}. The results also showed that *P. nasutus* exhibits a slow growth rate, rendering it more susceptible to overfishing. This study also indicated that the current level of exploitation of *P. nasutus* population in the Pahang River appears to be appropriate. However, it is recommended that a precautionary strategy be adopted to mitigate the risk of overexploitation.

Article history:
Received 25 June 2023
Accepted 3 August 2023
Available online 25 August 2023

Keywords:
Growth pattern
Conservation
Population dynamic
Length frequency data

Introduction

There are numerous species of catfish in the family Pangasiidae, and they have a significant role in Southeast Asia's inland fisheries (Hung et al., 1999). Three species of Pangasiidae have been identified in Peninsular Malaysia (Tweedie, 1936; Herre and Myers, 1937; Roberts and Vidthayanon, 1991; Lim and Zakaria-Ismail, 1995) including *Pangasius nasutus*, *Phalacronotus micronemus,* and *Helicophagus waandersii*. According to Fowler (1938), *P. polyuranodon* was discovered in Peninsular Malaysia, but its existence needs documentation by specimen (Lim and Zakaria-Ismail, 1995). *Pangasius nasutus* is a popular freshwater fish recognized as one of the prized native freshwater fish with significant economic value in the Pahang River, Malaysia. The catch of this species still depends on the wild which can lead to the decline of the natural resources (Hassan et al., 2011).

The population of *P. nasutus* in the Pahang River has been declining as reported by the Department of Fisheries (2017). Overfishing and habitat degradation have been identified as the primary causes contributing to the population reduction of this species (Chong et al., 2010). Despite a reported decline in the landing of this species and a concurrent increase in market price, the demand for *P. nasutus* has remained steadfast. In order to ensure sustainability and promote the long-term viability of its population, it is crucial to promptly adopt contingency plans. One

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DOI: https://doi.org/10.22034/ijab.v11i4.1997
DOR: https://dorl.net/dor/20.1001.1.23830956.2023.11.4.8.4

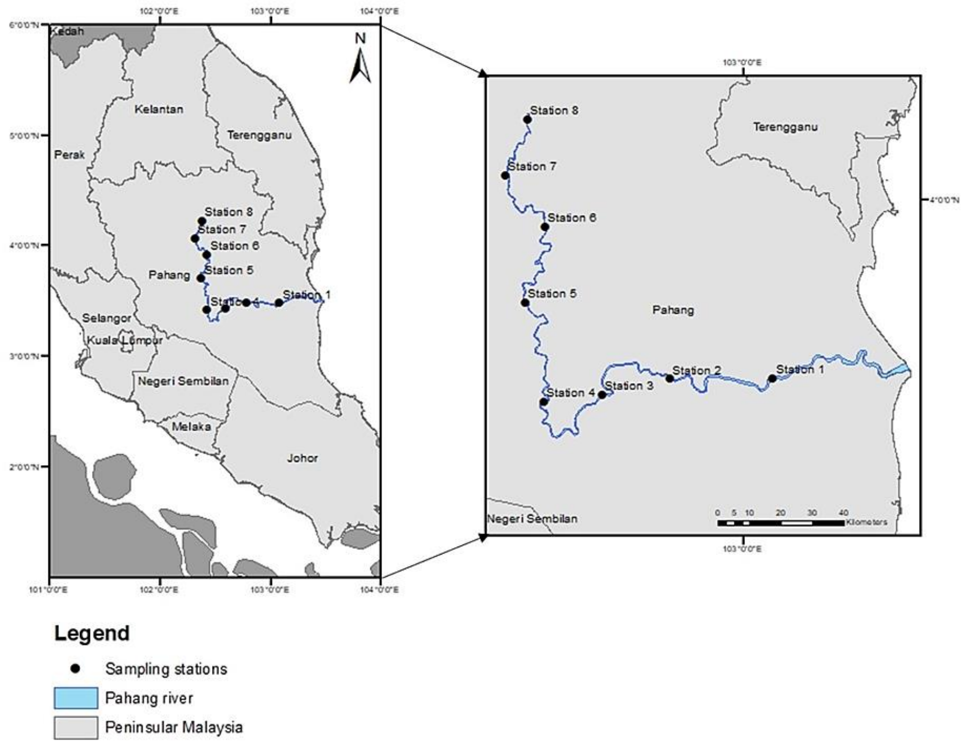

Figure 1. The Pahang River sampling locations are shown on a map of the Pahang River in Malaysia.

effective approach for achieving this objective is the implementation of natural restocking measures, namely reintroducing the fish into the Pahang River. The implementation of this alternative, in conjunction with consistent and effective resource management, will guarantee the preservation of this species as a significant aquatic heritage of the Pahang River.

According to Gulland (1971), an effective management strategy can be constructed by leveraging a strong scientific foundation. Understanding the key drivers that impact the overall fish population of a particular species is of utmost importance in order to effectively manage and regulate it. The assessment of population dynamics, encompassing factors such as population structure, current population status, and projected changes, holds significance for the understanding and management of fish populations (Pope et al., 2010). Currently, the only information available on this species is its complete mitochondrial genomes (Abdul Halim et al., 2023). This study was undertaken to address the lack of information regarding the population status of *P. nasutus* in the Pahang River. The primary objective was to acquire valuable insights into the current state of this species' population. The findings of this study will serve as a valuable resource for the formulation of effective conservation strategies aimed at maintaining the population of *P. nasutus* in a sustainable manner.

Materials and Methods

Study area: The study was undertaken along the Pahang River, in the State of Pahang, Malaysia. Eight sampling locations covering upstream to the downstream of Pahang River as shown in Figure 1 were selected. Each sampling site is between 30 and 40 km between each site.

Sampling design: Monthly sampling was carried out at regular intervals for a period of 12 months, from May 2021 to April 2022. Due to the COVID-19 epidemic, where all travel was restricted, the study was conducted with the help of local fishermen who operate in this area. The Malaysian government established a movement control order during this time to prevent the epidemic, however, fishing was one of the permitted economic activities. In this study,

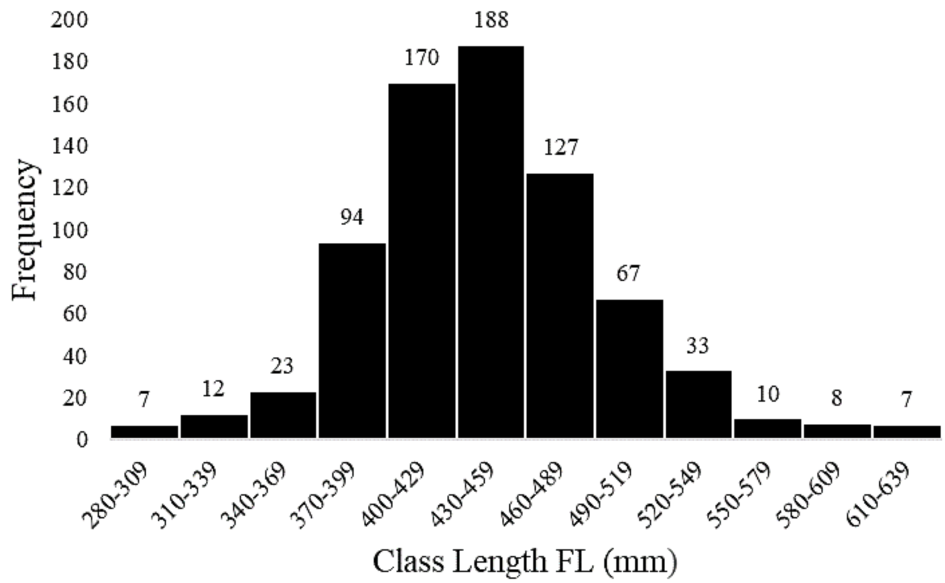

Figure 2. Distribution of the fish samples based on length classes (N = 746).

samples of *P. nasutus* were caught using gill nets, cast nets, and hooks. In accordance with the descriptions provided by Roberts and Vidthayanon (1991) and Kottelat et al. (1993), fish samples were classified taxonomically. The samples that were brought back to the laboratory were deliberate to the nearest 0.01 mm in Total length (TL), Fork length (FL), Standard length (SL), and 0.01 kg in body weight.

Data analysis

Growth parameters: In this study, ELEFAN-I (Pauly and David, 1981; Saeger and Gayanilo, 1986), which is integrated into FiSAT II Software, was used to estimate the Asymptotic length (L) and growth coefficient (K) of the von Bertalanffy equation for growth parameters. Pauly and Munro (1984) provided the equation to estimate the growth performance index which is $Ø' = \log10\ K + 2\log10\ L_\infty$. The formula from Froese and Binohlan (2000) was used to calculate the optimum length of samples (L_{opt}) as follows: $L_{opt} = 3*L_\infty/(3+M/K)$. Pauly's (1979) formula was used to calculate the estimated maximum age as follows: $T_{max}=3/K$. Input parameters are L_∞, K, and M where M is the natural mortality rate, L_∞ is infinity or asymptotic length, and K is the growth coefficient. The values of K and L_∞ were obtained from the von Bertalanffy Growth Function (VBGF).

Estimation of mortality, relative yield per recruit (Y/R) and biomass per recruit (B/R): The total mortality (Z) was estimated by length converted catch curve method provided by Beverton and Holt (1956) where the mortality rate was calculated using the FiSAT II software and the Natural mortality rate (M) was calculated using Pauly's empirical relationship (Pauly, 1980). In this calculation, the mean water temperature was 28.6°C as suggested by Zulkafli et al. (2018). The equation was $\text{Log}\ M = 0.0066–0.279\ \text{Log10}\ L_\infty + 0.6543\ \text{Log10}\ K + 0.4634\ \text{Log10}T$ (Pauly, 1980).

Fishing mortality (F) was calculated by subtracting M (natural mortality) from Z (total mortality): F = Z-M and exploitation rate (E) = F/Z (Gulland, 1965). Modified Beverton and Holt Yield Per Recruit Model (Pauly and Soriono, 1986) were used to calculate the relative yield per recruit and relative biomass per recruit. In this analysis, input parameters incorporated into the FAO FiSAT II (Gayanilo et al., 2005) were L_c/L_∞ ratio (from 0.05 to 0.95) and M/K ratio (from 0.10 to 9.99).

The length at first capture (L_c) and length at first maturity (L_m): Probabilities of capture by length are computed from the extended catch curve analysis implemented into the FiSAT II (Gayanilo et al., 2005) to estimate the selection parameters which are L-25, L-50, and L-75. The length at first capture (L_c) is the

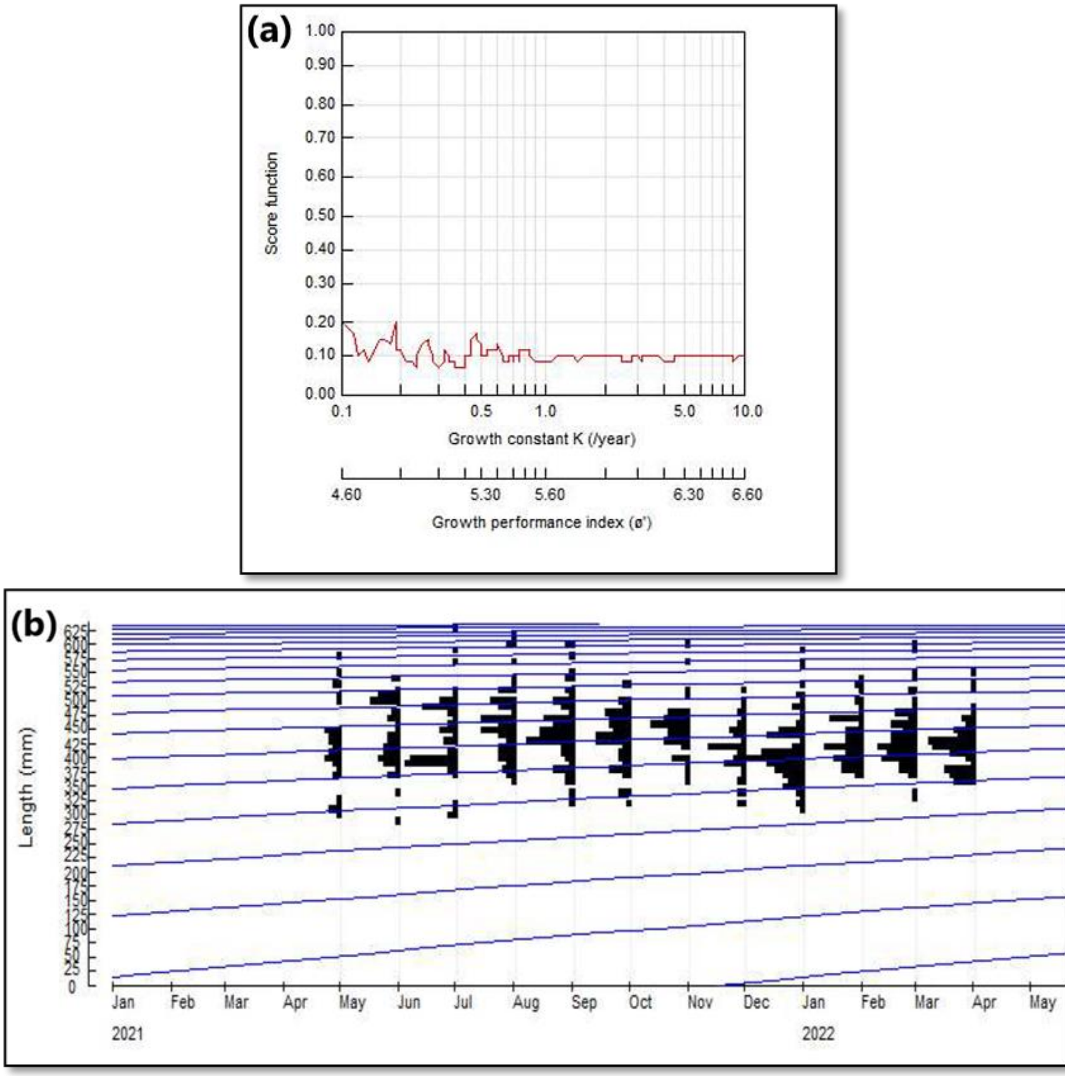

Figure 3. (a) The ELEFAN 1; Growth coefficient (K) was 0.18 $year^{-1}$ and growth performance index (Ø) was 4.9 $year^{-1}$. (b) Von Bertallanfy Growth Function Plot and Length Frequencies of *Pangasius nasutus*.

length of 50% of the fish vulnerable to the gear which is L-50 (Gayanilo et al., 2005). The length at first maturity (L_m) is estimated based on the calculation: $L_m = L_\infty * 2/3$ (Hoggarth et al., 2006).

Recruitment pattern and length-structured virtual population (VPA): The recruitment pattern followed the user's manual of FiSAT II (Gayanilo et al., 2005) based on the principal model of Moreau and Cuende (1991) and Pauly (1983). The input parameters used from VGBF which is L_∞, K, and t_0 (t_0 =0). The plot showed the number of pulses per year and the relative strength of the recruitment into the fishery. The length structure Virtual Population Analysis (VPA) followed the modified method of Jones and van Zalinge (1981) fitted in the FiSAT II (Gayanilo et al., 2005). The input parameters for this model are L_∞, K, M, F, and the least square regression coefficients (a and b).

Results

Throughout this 12-month study, a total of 746 samples of *P. nasutus* were collected (Fig. 2). The smallest individual collected was 287 mm, while the maximum size of the specimen was 637 mm with an average length of 443.12 mm. The *P. nasutus* in the Pahang River was mostly individual within the 370 to 520 mm length class (Fig. 2) with the dominant sizes ranging from 400 to 460 mm.

Growth parameters: The values L_∞ and K of the Von Bertalanffy growth equation (VBGF) were estimated (Fig. 3), as L_∞ = 661.50 mm and K = 0.18. The results

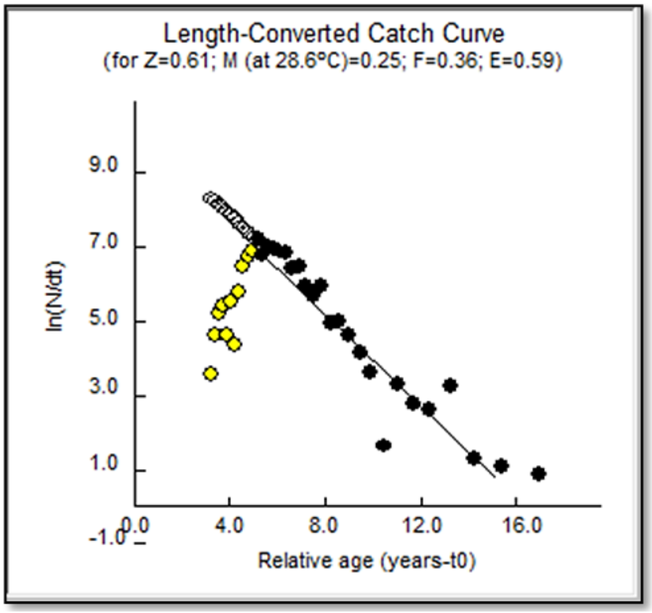

Figure 4. The length-converted catch curve of *Pangasius nasutus*.

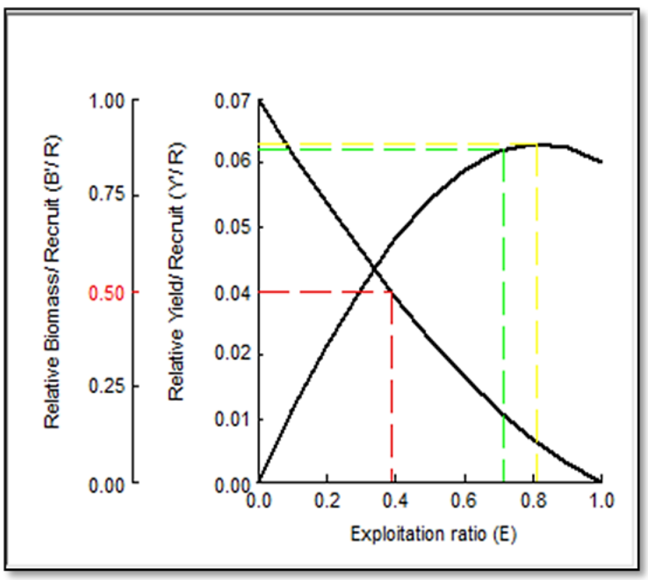

Figure 5. The relative yield per recruit (Y'/R) and biomass per recruit (B'/R) of *Pangasius nasutus*.

showed the growth performance index (Ø) as 4.9 year^{-1} and the optimum length size fishing (L_{opt}) as 452.05 mm. The calculated estimated maximum age (T_{max}) was 16.67 years.

Estimation of mortality, relative yield per recruit (Y/R), and biomass per recruit (B/R): Based on the results, total mortality (Z) was 0.61, natural mortality (M) = 0.25, fishing mortality (F) = 0.36, and exploitation rate (E) = 0.59 (Fig. 4). The values $L_c/L\infty$ and M/K were 0.58 and 1.39, respectively, and were used to obtain the graph of the relative yield per recruit

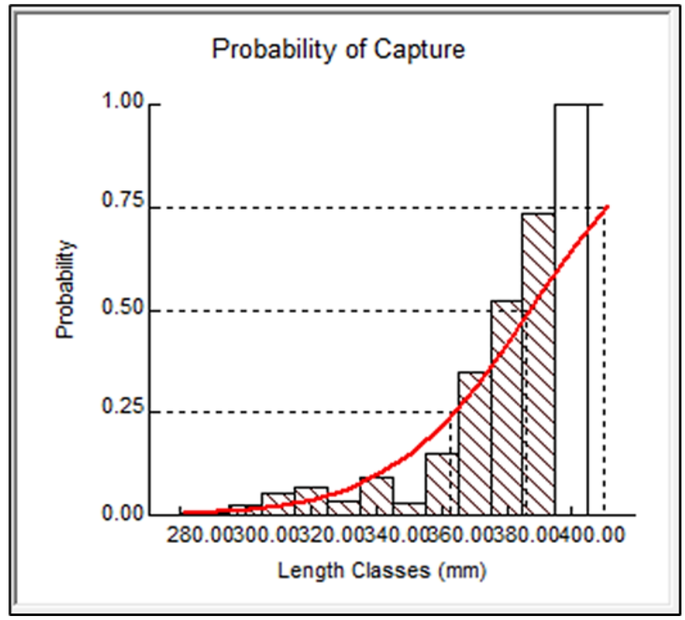

Figure 6. The probability capture of *Pangasius nasutus*.

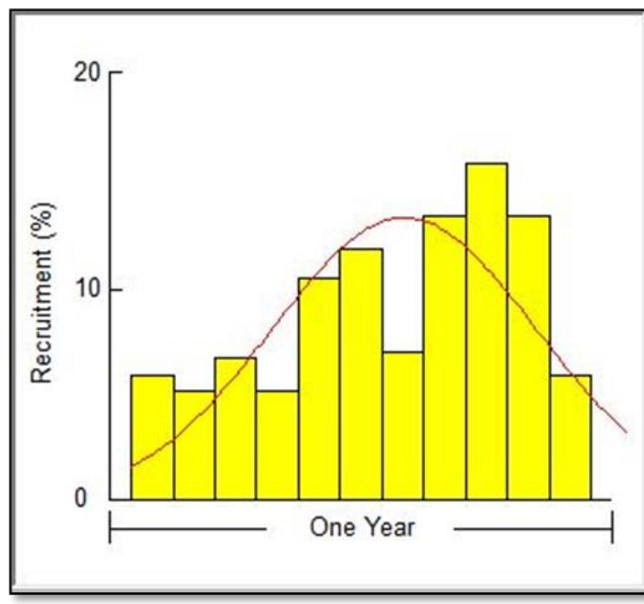

Figure 7. Monthly pulse percentage recruitment for one year of *Pangasius nasutus*.

(Y'/R) and biomass per recruit (B'/R) (Fig. 5). The maximum relative yield-per-recruit represented as the maximum exploitation rate (E_{max}) found 0.812. The E-10 is the exploitation rate responsible, and the E-50 is the reduction in the new stock estimated as 0.714 and 0.386, respectively.

Length at first capture (*L_c*) and length at first maturity (*L_m*): The values of the probability of capture of the *P. nasutus* at 25%, 50%, and 75% are shown in Figure 6. The estimated value at the L-25

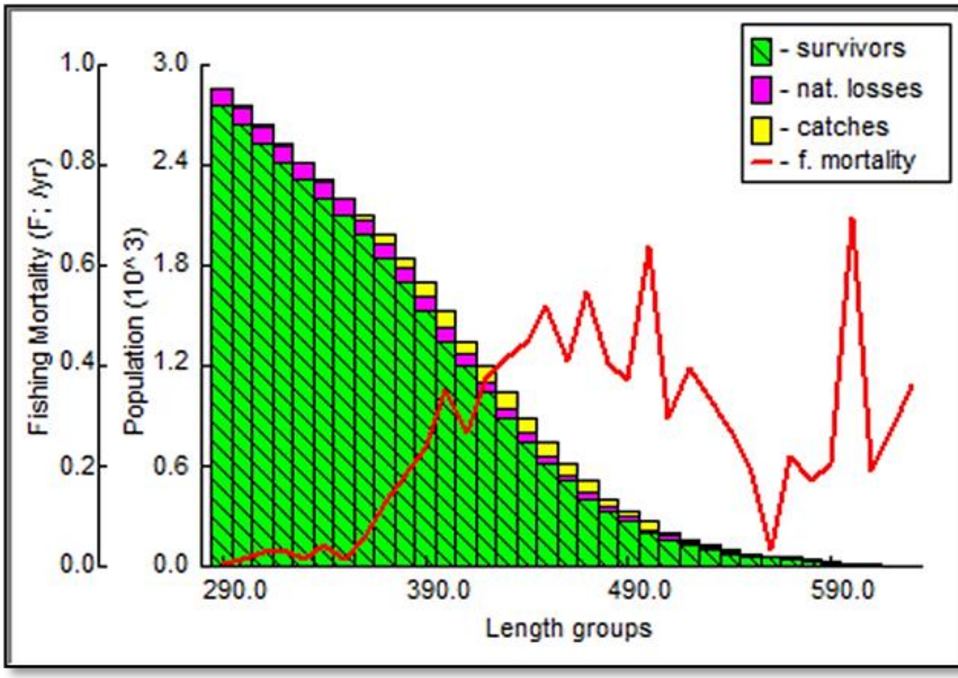

Figure 8. The virtual population analysis of *Pangasius nasutus*.

was 362.98 mm, L-50 = 386.29 mm, and L-75 = 409.60 mm. Accordingly, the L-50 was conjectured to the length at first capture (L_c) as 386.29 mm. The length at first maturity (L_m) was estimated at 441.00 mm.

Recruitment pattern and length-structured virtual population (VPA): The monthly percentage of recruitment of *P. nasutus* in Pahang River, Malaysia is shown in Figure 7. This species has a continuous recruitment cycle with a significant peak every year. Over the course of a year, the percentage of recruitment ranged from 0 to 15.61% (Fig. 7). The results of the VPA revealed the minimum fishing mortalities as 0.0047 year^{-1} for the mid-lengths of 290 mm and maximum fishing mortalities as 0.6955 year^{-1} for the mid-lengths of 600 mm (Fig. 8). The average fishing mortality in the VPA analysis was at 0.4103 year^{-1} with mid-lengths of 460 mm. At the mid-lengths 490 mm and 590 mm, the fishing mortality rate (F) was higher than other mid-lengths.

Discussions

Estimating the growth and mortality of the exploited species is important because stock assessment and management depend on these parameters. The value of Rn obtained from the analysis is between 0 and 1, which means that the method used is the best fit and the estimated parameters obtained are reliable (Pauly, 1987).

This study revealed that the asymptotic length (L_m) at 661.50 mm and growth coefficient (K) was 0.18 year^{-1}. The value of K = 0.18 year^{-1} in the present study indicates that *P. nasutus* grows slowly towards asymptotic length. The growth coefficient (K) for *P. nasutus* was 0.18 year^{-1}, indicating that this species is slow-growing as suggested by Sparre and Venema (1992) where K = 1.0 means fast growth, K = 0.5 means medium growth, and K = 0.2 means slow growth. This is also confirmed by its long lifespan of T_{max} = 16.67 years. Murua et al. (2017) suggested that the population of slow-growing species will decline faster, hence a higher probability of being overfished. The slow-growing fish also provide smaller estimates of sustainable yields (MSY) than fast-growing ones so only a small yield can be exploited from this population. Overfishing will occur when the yield harvest is larger than the estimated MSY of the slow-growing fish. The growth performance index (Ø) of *P. nasutus* was 4.9 year^{-1}, higher than the value of 3.27 year^{-1} for Pangasiidae fishes as reported by Preecha et al. (2011) and Ramakrishniah (1986) which indicated that this species in Pahang River, Malaysia grows slightly better than the population in Thailand and India, respectively.

The results showed that the total mortality (Z) of *P. nasutus* in the Pahang River, Malaysia was 0.61 $year^{-1}$ with the fishing mortality (F) of 0.36 $year^{-1}$. The ratio of M/K was 1.39 indicating that the population of *P. nasutus* is threatened by intensive fishing practices and habitat destruction (Batubara et al., 2019). Beverton and Holt (1959) and Al-Marzouqi et al. (2012) suggested that the M/K ratio of normal fish is between 1.0 to 2.5 (Beverton and Holt, 1959; Al-Marzouqi et al., 2012).

Beverton and Holt (1966) and Pauly and Soriano (1986) defined E_{max} as the maximum allowable limit of exploitation rate and can be described as the maximum relative yield-per-recruit. Gulland (1971) suggested that E = 0.50 can be considered as the optimal exploitation rate. In the present study, the value of E = 0.59, lower than E_{max} of 0.812, but exceeded the level of optimal exploitation rate. This may suggest that the exploitation of *P. nasutus* population in the Pahang River is acceptable, however, precautions should be taken to minimize the risk of over-exploitation of the population. Fish stocks are at risk of depletion if the value of (E) is higher than E_{max} (Mohd Azim et al., 2017).

The recruitment of the population of *P. nasutus* in the Pahang River occurred throughout the year. Allen and Hightower (2010) explained that the recruitment is coordinated with the spawning of adult stock fish where increasing spawning stock results in higher recruitment and sustainable long-term yield. This species spawns at the beginning of the rainy season and coincides with the Southwest monsoon (Chew and Zulkafli, 2007), where both female and male *P. nasutus* are actively reproducing. This species migrates from the lower to the upper stream to spawn in the rainy season and mainly inhabits the main river in the dry season (Kottelat and Widjanarti, 2005). Additionally, *P. nasutus* is known as a batch spawner and has shown a single-modal spawning pattern throughout the years (Mohd-Zafri, 2006).

The L_c value is the length at first capture and corresponds to L-50, which is the length at which 50% of the fish could be caught (Gayanilo et al., 2005). The results of this study showed that the length at first capture (L_c) was 386.29 mm while the length at first maturity (L_m) was 441 mm indicating that the fish may be caught before the maturity stage (Amponsah et al., 2016). Manangkalangi et al. (2022) suggested that overfishing in the form of growth and recruitment occurs when the value of L_c is lower than that of L_m and the catch is more than 50% immature. Fish should have a chance to recruit to the stock before being caught by fishing gear (Mohamed and Al-Hassani, 2021). This will allow more young recruits to grow and reproduce to ensure resource availability and sustainability (Udoh and Ukpatu, 2017). According to Wehye et al. (2017), growth overfishing is where more small-size fish are caught. This study however found that more than 50% of individuals captured throughout this study are larger than the size at first maturity.

Virtual Population Analysis (VPA) also revealed that the main loss of *P. nasutus* stocks due to fishing activities occurred at the mean lengths between 370 and 500 mm with the highest peak of fishing mortality was 600 mm mean length at 0.6955 $year^{-1}$ fishing mortality. This shows that this species has moderate fishing mortality in the juvenile stage (Haihua and Yanping, 2017). These results may suggest that, currently there are still many adults in the environment and the catch of young individuals is acceptable, but the regulations on fishing gear used need to be formulated to avoid future overexploitation of the stock.

Conclusion

The present work provided useful information for the management and sustainability of the economically important *P. nasutus* in the Pahang River, Malaysia. This study concludes that *P. nasutus* in the Pahang River faces a higher risk of population decline because of its slow-growing characteristics. The optimum level of exploitation is E = 0.50 but the exploitation rate was higher (E = 0.59) but lower than the E_{max}. Even though the length at first capture (L_c) estimated was smaller than the length at first maturity (L_m), more individuals larger than the size at first maturity were captured through this study. This study concludes that the current exploitation of *P. nasutus* population in the Pahang River is acceptable, however, the precaution should be taken seriously to prevent over-exploitation. Management measures can be formulated, for example by catching fish exceeding the size of the first capture by increasing the mesh size. Therefore, regular monitoring programs for this species should be implemented to monitor the status of the population and prevent the population from declining.

Acknowledgments

This study was funded through the Long-Term Research Grant Scheme (LRGS), provided by the Ministry of Higher Education, Malaysia (LRGS/1/2019/UPM/01/1/4). Also, thanks to the Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu for providing laboratory and logistics support.

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