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POPULATION DYNAMICS OF THE GRAY EEL CATFISH *Plotosus canius* FROM PORT DICKSON, MALAYSIA

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ABSTRACT

Given the scarcity of information suitable for stock assessments of the Plotosidae, the study on growth and population dynamics of the Gray Eel Catfish *Plotosus canius* from the coastal waters of Port Dickson, Peninsular Malaysia was carried between January and December, 2021 and estimated using the ELEFAN I routine in FiSAT software. Estimated von Bertalanffy growth parameters were asymptotic length (L_∞) = 67.20 cm, growth coefficient (K) = 0.95 yr-1, Predicted extreme length (Lmax) = 63.54, and growth performance index (φ') = 3.63. The estimated total mortality (Z) value was 2.73 yr-1 during the study period. Natural mortality (M) and fishing mortality (F) were estimated at 1.31 yr-1 and 1.42 yr-1 respectively. The value of exploitation rate (E) obtained for *P. canius* was 0.48. Two major recruitment events were observed per year and the recruitment pattern was continuous. The findings from the analyses suggested that the *P. canius* fishery in the study area is slightly below the optimum level of exploitation. However, more research is suggested in such direction to corroborate the present findings as management for this fish is indispensable for maximum sustainable yield. The length-structured virtual population analysis revealed that *P. canius* fishery of Port Dickson experiences growth overfishing as opposed to recruitment overfishing, with fishing mortality being higher than natural mortality (F>M). Based on these findings, small-sized mesh fishing net and reduced fishing efforts (legal and illicit) must be enforced in order to maintain the potential of this commercially significant species in Port Dickson, Malaysia.

Keywords: Growth; Mortality; Recruitment; Catfish; *Plotosus canius*; Malaysia

INTRODUCTION

The gray-eel catfish, scientifically known as *Plotosus canius* (Hamilton, 1822) belongs to the family Plotosidae and predominantly found in marine and brackish waters. The fish is a native species throughout the Indo-West Pacific, coasts of India, Sri Lanka, Bangladesh and Myanmar, Indo-Australian Archipelago, Philippines, and Papua New Guinea (Kundu *et al*., 2019). It is a commercially important fish, marketed mostly fresh on the coastal areas of Peninsular Malaysia where it is locally familiar as "Sembilang" or "Semilang" (Usman *et al*., 2016). Morphologically, *P. canius* is easily identified by having elongated, eel-like and sub-cylindrical body which turns out to be tapered and flattened on the verge of the tail region. There is also the presence of four long barbels; with the nasal barbel stretching well behind the eye almost reaching the nape. As stated by Kundu *et al*. (2019), nine different species of the genus *Plotosus* (Family Plotosidae) have been identified. *P. canius* is easily distinguished from other members of the family by the lack of body stripes.

The amphidromous gray eel catfish, *P. canius* has been an important fishery resource in the Peninsular Malaysia. The annual landings of the fish in the region based on Malaysian fisheries statistics from 1990 to 2013 fluctuated between 637 and 2204 metric tonnes during the period. Despite the economic importance of *P. canius* in Peninsular Malaysia, the percentage contribution of the fish ranged between 0.12 to 0.30% (average 0.21%) which was less than 1% of the total annual fish landings of Peninsular Malaysia. In 2013, the total production of *P. canius* was estimated at about 2018 metric tonnes; which was about 0.28% of the total annual fish landings (DOF, 2013). However, in recent times, their fisheries landings have been reported to drastically decrease and is one of the near threaten catfish of Asia (IUCN, 2015).

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Besides the original description, *P. canius* has been exclusively discussed on their morphology (Kumar, 2012; Usman *et al*., 2013), morphometric (Usman *et al*., 2016), feeding biology (Leh *et al*., 2012), biological properties (Prithiviraj 2014), and bioactive properties (Prithiviraj and Annadurai, 2012). However, the population dynamics of *P. canius* has never been discussed from the Malaysian waters. Meanwhile, basic knowledge on the population dynamics is essential for policy makers and managers to form regulation measures to sustain the population. Hence, the combined study of growth, mortality, recruitment pattern, and exploitation studies are necessary to know the population dynamics.

FiSAT (FAO-ICLARM Stock Assessment Tools) is among the tools commonly employed in assessing the status and exploitation level of any fishery stock (Haihua *et al*., 2018; Privitera-Johnson and Punt, 2020; Bashar *et al*., 2021). By means of FiSAT, important parameters like asymptotic length (L_{∞}), growth coefficient (K), natural mortality (M), fishing mortality (F) and exploitation level (E) can be estimated. Thus, realizing the commercial importance of the fish, the present study aimed to examine the population structure and status of the *P. canius* fishery stock in the coastal waters of Port Dickson, Peninsular Malaysia.

MATERIALS AND METHODS

Study sites

The research was conducted between January and December, 2021 in the Kampung Telok (Kg. Telok) (02^{0}24.98'N; 101^{0}56.53'E) coastal waters. Kg. Telok is a fishing village located in Port Dickson, Negeri sembilan (Fig. 1). It is located in the western cost of Peninsular Malaysia, along the Straits of Malacca. The Straits of Malacca has been reported as one of the busiest sea-lanes in the world, which connects the Indian Ocean to the South China Sea and the Pacific Ocean (Praveena *et al*., 2011). The area is exposed to numerous types of environmental stresses due to its purposeful position as a major international shipping corridor. Furthermore, the area has a tropical climate with an annual rainfall of 2381 mm, temperature between 21–32^{o}C; whereas humidity is usually between 80–90%. It is made up of shallow waters (about 20m) and the water is well mixed and there are considerable resources of marine finfish as well as shell fish in the area (Praveena *et al*., 2011).

Collection of samples

Samples of *P. canius* were collected on monthly basis for a period of twelve months. The samples were collected during full moon directly from the local

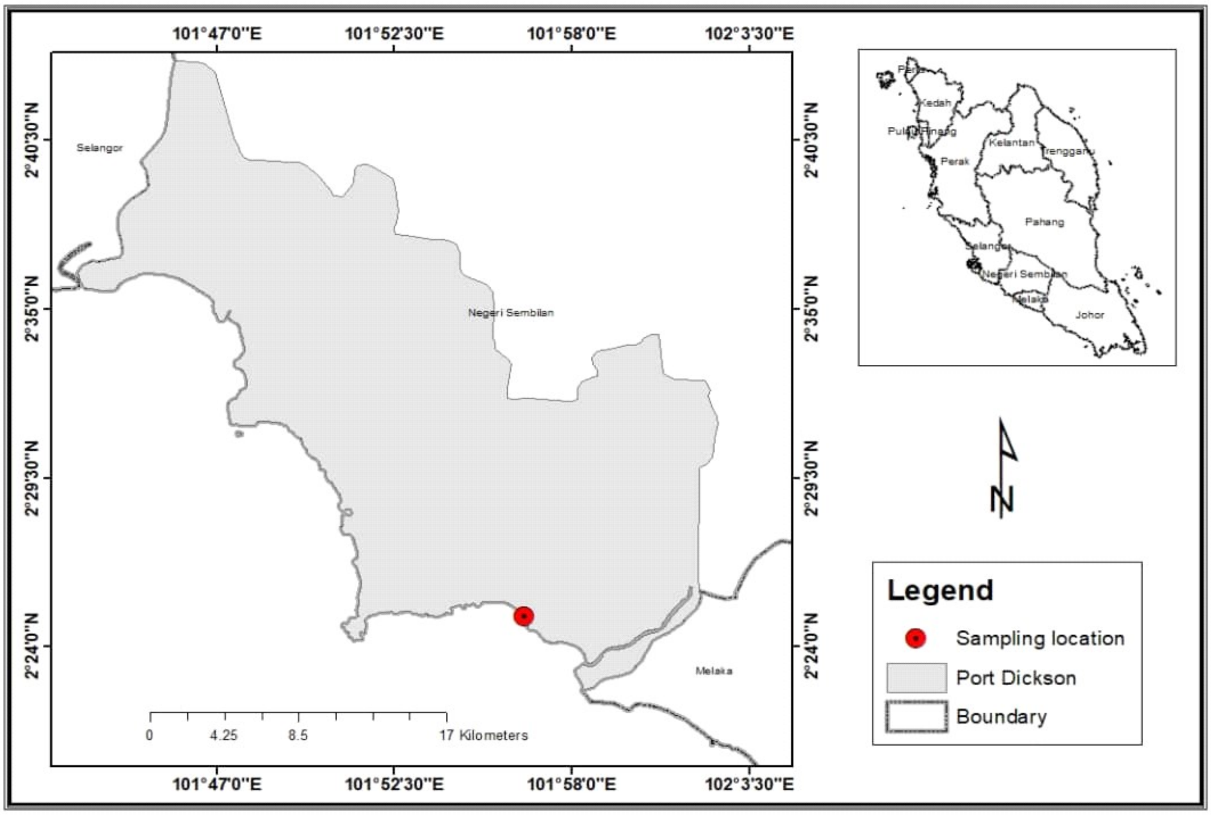

Figure 1. Map of geographical location of the sampling station in Peninsular Malaysia

fishermen of the coastal areas of Kg. Telok, Port Dickson, Negeri Sembilan. The fishermen mostly use local fish traps known as 'Lukah Ikan' and set net of about 5.1 (±0.89) cm to 7.6 (±0.63) cm mesh size to catch the fish which is usually available during the full moon. The samples were immediately stored in ice-boxes to keep them fresh and were immediately taken to the Marine Science laboratory of the Institute of Biological Sciences, Universiti Putra Malaysia for further analysis.

Stock assessment

In the laboratory, each fish was measured and recorded for its total length to the nearest 1.0 cm using a measuring board. For the population dynamics, the length-frequency data of *P. canius* was analyzed using FiSAT (FAO ICLARM Stock Assessment Tools) software (Gayanilo *et al*., 2005). Due to scarcity of the fish, the monthly length-frequency data was not enough for running FiSAT programme. Therefore, the length-frequency data was pooled bimonthly and grouped into 2 cm length for getting better results of population parameters.

The parameters of the von Bertalanffy growth function (VBGF), asymptotic length (L_∞) and growth coefficient (K) were analyzed using ELEFAN-1 (Pauly and David, 1981) incorporated into FiSAT software. To assess a reliable estimate of the K value, the K-scan routine was performed. The estimated L_∞ and K were used to assess the growth performance index (φ') (Pauly and Munro, 1984) of the *P. canius* using the equation:

$$\varphi' = 2 \log_{10} L_\infty + \log_{10} K$$

Total mortality (Z) was calculated using the length converted catch curve (Pauly, 1984). Natural mortality rate (M) was estimated using empirical relationship of Pauly (1980):

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

Where M = natural mortality, L_∞ = asymptotic length, K = growth coefficient of the VBGF and T = the mean annual habitat water temperature (°C). Once Z and M were obtained, then fishing mortality (F) was estimated using the relationship:

$$F = Z - M$$

Where Z = total mortality, F = fishing mortality and M = natural mortality. The exploitation level (E) was obtained by the relationship of Gulland (2013):

$$E = F/Z = F/(F + M)$$

The recruitment pattern of the stock was ascertained by backward projection on the length axis of the set of available length–frequency data as illustrated in FiSAT. The routine reconstructs the recruitment pulse from a time series of length–frequency data to assess the number of pulses per year and the relative strength of each pulse. Input parameters were the L_∞, K and t_0 (t_0 = 0). Normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT.

The relative yield per recruit (Y/R) and relative biomass-per recruit (B/R) were estimated by using the modified model of Pauly and Soriano (1986) and incorporated in FiSAT software package. From the analysis, the maximum allowable limit of exploitation (Emax) giving maximum relative yield-per-recruit was estimated. Also $E_{0.1,}$ the exploitation rate at which the marginal increase in relative yield-per-recruit is 10% of its value at E = 0, and $E_{0.5,}$ the exploitation rate corresponding to 50% of the unexploited relative biomass-per-recruit (B/R), were estimated.

The estimated length structured virtual population analysis and cohort analyses were carried out from the FiSAT routine. The values of L_∞, K, M, F, a (constant) and b (exponent) were used as inputs to a VPA analysis (Pauly, 1984).

RESULTS AND DISCUSSION

Results

Growth parameters

Figure 2 shows the predicted maximum length value where the 95% confidence interval is obtained from the intersection of overall maximum length with the line y and x, z. The observed and predicted extreme lengths (L_{max}) of *P. canius* were estimated to be 64.00 cm and 63.54 cm respectively. The range at 95% confidence interval for extreme lengths was calculated as 60.51 – 66.57 cm. The response surface (Rn) was estimated as 0.20 and the best combination of growth factor were L_∞ = 67.20 cm and K = 0.95 yr^{-1}. The optimized growth curve was superimposed on the restructured length-frequency histograms (Figure 3). The calculated value for the growth performance index, φ' of *P. canius* during the present investigation was 3.16. The best value of VBGF growth constant (K) was calculated as 0.95 yr^{-1} by ELEFAN-1 (Figure 4).

Age and Growth

Based on the growth parameters of the twelve

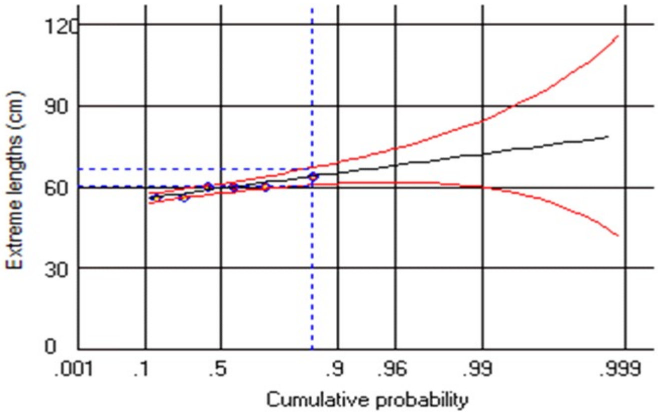

Figure 2. Predicted maximum lengths of *P. canius* during January to December, 2021 based on extreme value theory

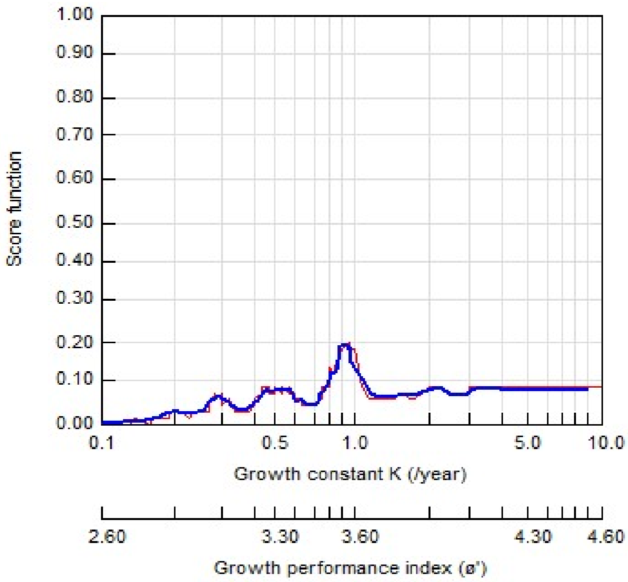

Figure 3. K-scan routine for determination of best growth curvature giving best value of asymptotic length (L_∞) with growth performance index of *P. canius* between January to December, 2021

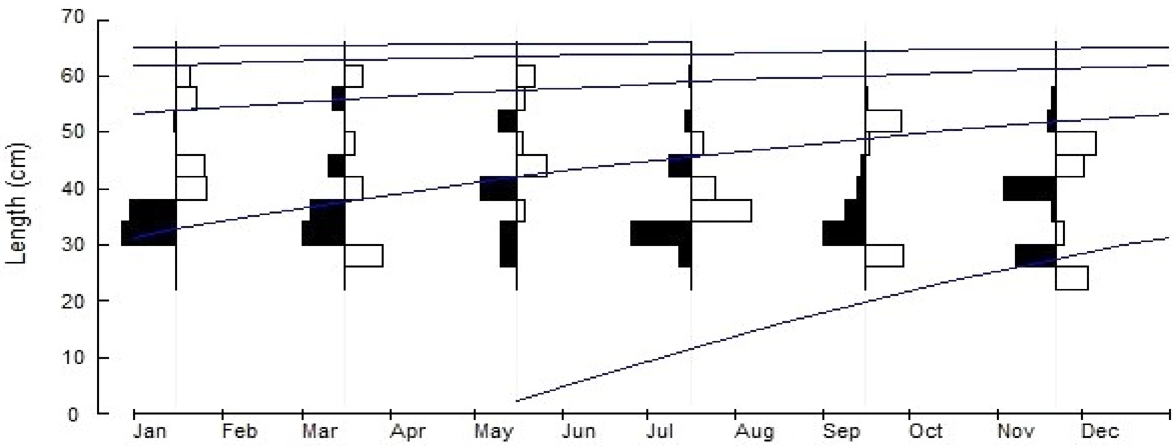

Figure 4. von Bertalanffy growth curve of *P. canius* between January to December, 2021 superimposed on the restructured length-frequency histograms. The black and white bars are positive and negative deviation from the “weighed” moving average of three length classes and they represent psedo-cohorts

months' study period, the maximum life span (t_{max}) of *P. canius* was 3.16 years (Table 2). It was assumed in the ELEFAN-I analysis that the value of the third parameter of von Bertalanffy growth function t_0 be zero. Therefore, the size attained by *P. canius* was 41.21 cm at the end of 1 year and 57.15 cm at the end of 2 years. The growth pattern of *P. canius* is depicted in Figure 5.

Mortality and exploitation

Total mortality, Z value of *P. canius* was estimated by making use of the dark point of this curve (Figure 6) and fitting a least square regression line to them. Good fit to the descending right hand limits of the catch curve was considered with mentioned regression line values (Y = 9.688 + (-2.989) X (R^2 = 0.9997)). In Table 2, the estimated total mortality (Z) value was 2.73 yr^{-1} during the study period. Natural mortality (M) and fishing mortality (F) were estimated at 1.31 yr^{-1} and 1.42 yr^{-1} respectively. The value of exploitation rate (E) obtained for *P. canius* in the coastal waters of Kg. Telok, Port Dickson between January to December, 2021 was 0.48.

Length at first capture

The length at first capture, Lc (the length at which 50 % of the fish becomes vulnerable to the gear) of *P. canius* in the coastal waters of Kg. Telok, Port Dickson was calculated as a component of the converted catch curve analysis (Figure 7). The value obtained from the analysis of probability of capture was 28.39 cm for $L_{50\%}$. The length at which 25 % and 75 % of *P.*

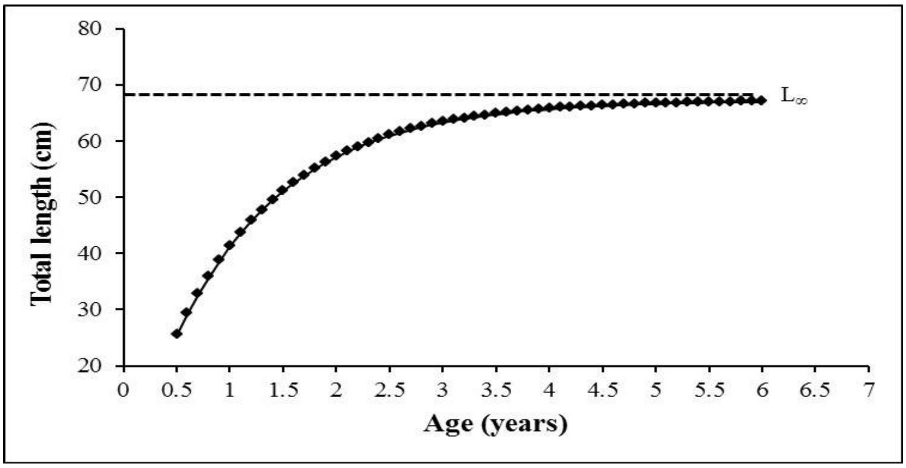

Figure 5. Plot of age and growth based on computed mean growth parameters of *P. canius* (L_∞ = 67.20 cm and K = 0.95)

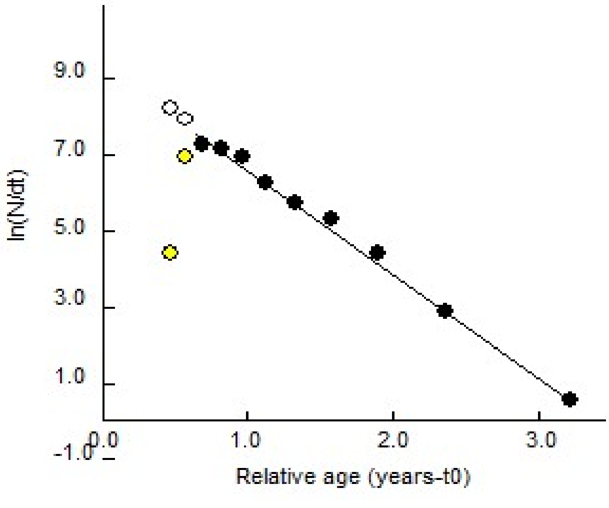

Figure 6. Length converted catch curve of *P. canius* between January and December, 2021, the darkened full dots represent the points used in calculating through least square linear regression and the open dots represent the points either not fully recruited or nearing to L_∞

Table 2. Estimated population parameters of *P. canius* in the coastal waters of Kg. Telok, Port Dickson between January and December 2021

Population parameters	**Values**
Predicted extreme length, Lmax (cm)	63.54
Confidence interval, 95% Lmax (cm)	60.51 – 66.57
Asymptotic length, L_∞ (TL, cm)	67.20
Growth coefficient, K (yr^{-1})	0.95
Response surface, R_n	0.20
Growth performance index, φ’	3.63
Maximum life span, t_{max}	3.16
Total mortality Z (yr^{-1})	2.73
Natural mortality, M (yr^{-1})	1.31
Fishing mortality, F (yr^{-1})	1.42
Length at first capture, Lc (cm)	28.39
L_{25} (cm)	25.38
L_{75} (cm)	31.46
Critical size ratio, L_c/ L_∞	0.42
M/K	1.00
Exploitation rate, E	0.48
Maximum allowable limit of exploitation, Emax	0.60
Exploitation level at 50% of relative biomass-per-recruit, E-50	0.35
Exploitation level at 50% of relative biomass-per-recruit, E-10	0.52
Total sample size, N	**341**

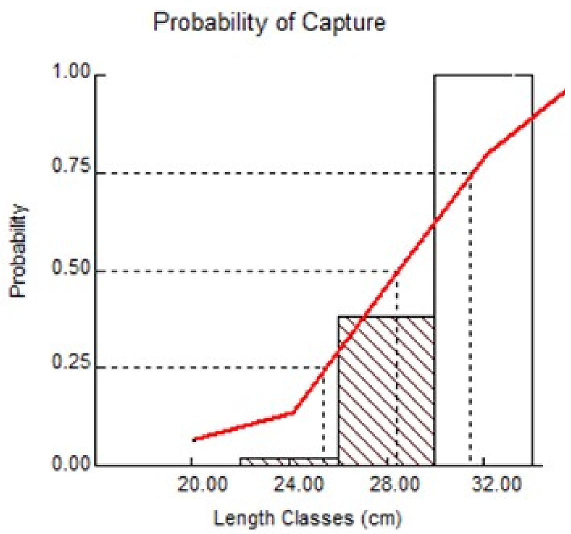

Figure 7. Logistic selection curve for probability of capture showing 25%, 50% and 75% selection length of *P. canius* between January and December, 2021

canius were retained in the gear were calculated as $L_{25\%}$ = 25.38 cm and $L_{75\%}$ = 31.46 cm.

Recruitment pattern

The annual recruitment pattern of *P. canius* showed continuous recruitment with two major peaks during the study period (Figure 8). The percentage of recruitment fluctuated from 0.00 % to 22.42 %. The first spell was from April to June with peak in May (11.56 %) and the second spell was from August to October with peak in September (22.42 %).

Relative yield-per-recruit and biomass-per-recruit

The relative yield-per-recruit (Y/R) and biomass-per-recruit (B/R) of *P. canius* were computed using knife-edge procedure assumption. The maximum allowable limit of exploitation (Emax) that gives the maximum relative-yield-per-recruit at maximum sustainable yield (MSY) level was estimated at 0.60 (Figure 9). The exploitation level (E-10) which corresponds to 10 % of the relative biomass-per-recruit of the unexploited stock was 0.52, whereas the exploitation level (E-50) which corresponds to the 50 % of the relative biomass-per-recruit of the unexploited stock was 0.35.

Virtual population analysis

Length-structured virtual population analysis (VPA) of *P. canius* is shown in Figure 10. The minimum and maximum fishing mortalities were 0.10 and 1.50 yr^{-1} recorded for mid lengths of 24 and 56 cm respectively.

Discussion

Information on growth and population dynamics is very vital to ensure sustainable management of any fishery stock. This is because fishing usually causes truncation of fish size structures due to the selectivity of fishing gears leading to fishery-induced evolution towards smaller size (or stunting) and early maturity (Borrell, 2013; Tesfaye *et al*., 2022). The finding from the present investigation on the age, growth and population dynamics of *P. canius* is the first of its kind from the coastal waters of Port Dickson, Malaysia. Thus, it can only be compared to similar records regarding this species in other part of the world.

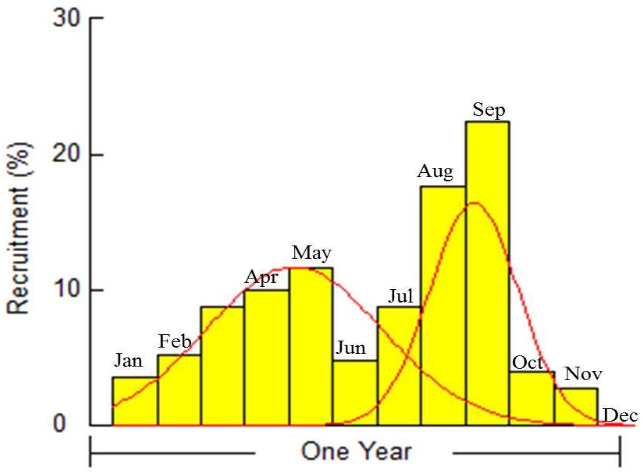

Figure 8. Recruitment pattern of *P. canius* in the coastal waters of Kg. Telok, Port Dickson between January and December, 2021

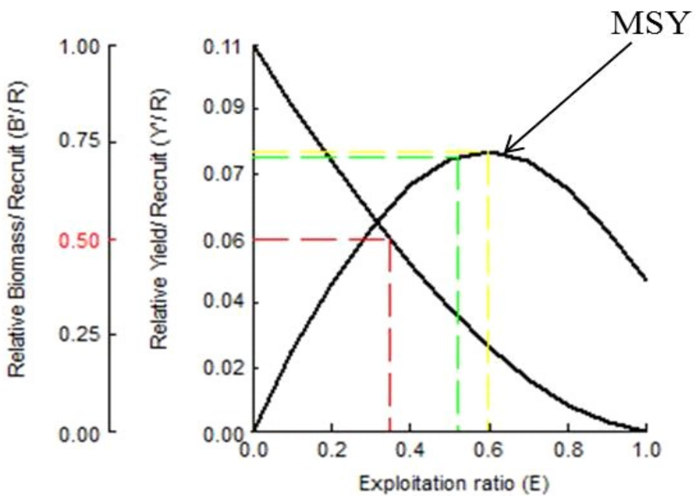

Figure 9. Yield-per-recruit and biomass-per-recruit model, showing level of yield index in *P. canius* from the coastal waters of Kg. Telok, Port Dickson between January and December, 2021

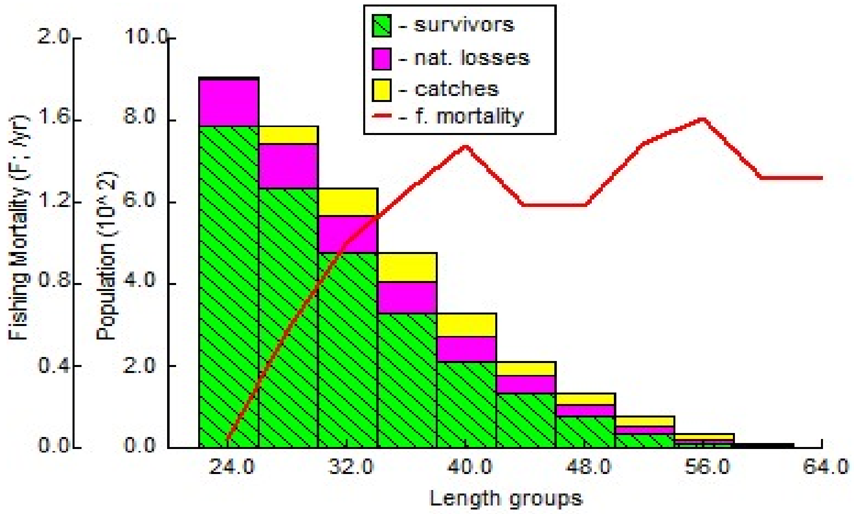

Figure 10. Length-structured virtual population analysis of *P. canius* in the coastal waters of Kg. Telok, Port Dickson between January and December, 2021

The estimated asymptotic length value (L_∞) for *P. canius* was 67.20 cm, implying that if the populations of the fish in the coastal waters of Port Dickson were to grow indefinitely, the average length they will attain is 67.20 cm. However, it was predicted that *P. canius* can attain larger sizes and can reach up to 150 cm in length (Asriyana *et al*., 2020; Hortle and Phommanivong, 2021).

The parameter of growth coefficient (K) is clearly associated to the metabolic rate of any fish species. A high value of 'K' suggests a high metabolic rate; as a consequence, such fishes mature at a size which is large in comparison their asymptotic length (L_∞) (Pauly, 1998). The estimated parameter of K obtained in this study was relatively high and comparable to the 0.95 yr^{-1} recorded for *Chrysichthys nigrodigitatus* (Ajagbe *et al*., 2021). Growth coefficient, K e" 1 is relatively described as high growth, whereas K d" 0.5 is low growth (Hyndes & Potter, 1997).

Age and growth are very vital in stock management of any fish. The current findings suggest that *P. canius* attains 41.21, 57.15 and 63.31 cm in the first, second and third years respectively. The result also implied that the longevity of *P. canius* in the coastal waters of Port Dickson was up to three years old and growth rate was higher up to 1.5 years of age. This is lower than the longevity of *Heterotis. Niloticus* estimated as 9 years, 4 months (Otogo & Enin, 2020).

In the present study, total mortality (Z) for *P. canius* in the coastal waters of Port Dickson was 2.73 yr^{-1}. The value of natural mortality and fishing mortality suggest unbalance position in the stock of *P. canius* from this coastal water. According to Kuparinen & Hutchings (2014), fishes with low natural mortality exhibit slow growth. The exploitation level (E) in the current study was 0.48 suggesting that the fishery of *P. canius* in the coastal waters of Port Dickson was slightly below the optimum level of exploitation (E = 0.50). This is based on the hypothesis that a stock is optimally exploited when fishing mortality (F) equals natural mortality (M), or E = F/Z = 0.5 (Gulland, 2013). This result is comparable to that of Santo *et al*. (2022) who reported total mortality rate, natural mortality and fishing mortality rate of 0.22, 0.15 and 0.07 $year^{-1}$, respectively, for *Trachurus picturatus*. Current study revealed that natural mortality rate was less than fishing mortality in Port Dickson, Peninsular. Natural mortality rate mostly depends on some factors, i.e. predation, old age, environmental stress, and parasitic affects or disease (Rabby *et al*., 2022).

There were two major recruitment events per year for the fish. The first spell was from April to June, with peak in May; whereas the second was from August to October with peak in September. The highest recruitment peak in April to June coincides with the major spawning season. This is similar to the report on flying fish of Indonesia, where highest recruitment (14.82%) coincides with peak season in June (Rehatta *et al*., 2021). The findings of probability of capture in the current study suggested that more than 75% of the exploited stock were above 32.00 cm, more than 50% were above 28.00 cm and more than 25% were below 25.00 cm.

The relative yield per recruit is a function of different values of exploitation rate (E) and length-at –first-capture. The critical size ratio in the present study indicates that *P. canius* are caught at high effort level and this is similar to that reported by Udoh *et al*. (2015) on *Chrysichthys nigrodigitatus* (Lacépède, 1803) in the lower Cross River of Nigeria.

The virtual population analysis (VPA) is a necessary precursor for standing stock and fishing mortalities assessments. The VPA revealed that *P. canius* fishery of Port Dickson experiences growth overfishing as opposed to recruitment overfishing, with fishing mortality being higher than natural mortality. Based on these findings, we propose that small-sized mesh fishing net usage be restricted or controlled as part of the management of coastal fisheries. In order to maintain the potential of this commercially significant species in Port Dickson, fishing efforts (legal and illicit) must also be reduced.

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