Borneo Journal of Resource Science and Technology (2023), 13(1): 120-131
DOI: https:doi.org/10.33736/bjrst.4943.2023

Body Indices and Population Dynamics of *Setipinna breviceps* (Cantor, 1849) from Batang Lassa Estuary, Sarawak, Malaysia

M. GOLAM MUSTAFA[1,4], AMY HALIMAH RAJAEE*[1,2], HADI HAMLI[1] & KHAIRUL ADHA A. RAHIM[3]

[1]Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak, Malaysia; [2]Institut Ekosains Borneo, Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak, Malaysia; [3]Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia; [4]Department of Oceanography, Noakhali Science and Technology University, Noakhali-3814, Bangladesh
*Corresponding author: amyhalimah@upm.edu.my
Received: 26 August 2022 Accepted: 22 May 2023 Published: 30 June 2023

ABSTRACT

The *Setipinna breviceps* is a commercially important and highly esteemed food fish. This species has scant of scientific formation particularly on population parameters like growth, mortality and recruitment. The present study aimed to estimate the body indices and population parameters of *Setipinna breviceps* of Batang Lassa Estuary (BLE). Samples were collected between April 2019 and September 2020. A local made bag net known as *Gnian* (mesh size 1.25 to 4.00 cm) was used for sampling the fish. A total of 287 qualified specimens were used for this study. The length and weight of individual fish was measured to the nearest 0.1 cm and 0.01 g, respectively. The length ranged from 5.50 to 24.00 cm and growth coefficient (b) was 2.563 ($R^2 = 0.87$) which clearly indicated a negative allometric growth. About 50% of individuals showed flat or slender body (Kn<1) and 47% of the specimens were rounded shaped (Kn>1) while 2.44% of fishes measured an ideal shape (Kn = 1). The parameters of growth L_∞, K and ϕ' were estimated at 24.15 cm, 0.23 yr^{-2} and 2.13, respectively. The estimated natural mortality and fishing mortality were 0.74 and 0.29 yr^{-2}, respectively and exploitation rate was 0.28. The recruitment pattern during the study was observed at two possible unequal peaks. The present study concluded that the anchovy was under exploited (E<0.5) as demonstrated by the under-sized fishes caught with small mesh size net. However, considering the minimum lengths and length at first catch, the BLE could be a productive nursery ground for *S. breviceps*. Therefore, management actions are required to avoid juvenile catches.

Keywords: Borneo Island, fish population dynamics, Short head hairfin anchovy

INTRODUCTION

Fisheries resource sustainability is a major challenge for coastal resource management (Mustafa *et al*., 2021a). Malaysia is home to approximately 1,951 fish species, including marine, estuarine and freshwater, making it one of the world's major diversity hotspots (Chong *et al*., 2010), and East Malaysia contributes a significant share of fishery resources. Sarawak coastal resources are endowed with huge estuarine and coastal fisheries. A total of 564 fish species has been recorded from Sarawak water mentioned by Abu Hena *et al*. (2022). Batang Lassa is one of the important estuaries having deltaic influence of lower Rajang river that supports many commercial fishes. Marine capture fisheries account for around 79.21% reported by SEAFDEC (2017). This resource contributes significantly to the country's income, foreign exchange, and jobs, where, the contribution of fisheries sector in Malaysian GDP is 0.8% alone and about 12.5% in agricultural GDP of Malaysia (DoSM, 2020). Worldwide, eight species and variety of *Setipinna* were listed in FishBase (Froese & Pauly, 2020) out of which about six species occurred in Malaysian water bodies. *Setipinna breviceps* is a highly esteemed food fish in Malaysia with commercial value.

Setipinna breviceps (Cantor, 1849), popularly known as short head hairfin anchovy, is a commercial and highly esteemed food fish under the class Clupeiformes and family Engraulidae. The body of this species is compressed and the head is very short (Munroe & Nizinski, 1999). This species can be grounded in marine or estuarine habitat, but perhaps also ascending into freshwater. The species is distributed in Western Central Pacific Ocean especially Sumatra, Kalimantan & Sarawak; and reported from India, Bangladesh and Myanmar, too (Kapoor *et al*., 2002).

The length weight relationships (LWRs) and the condition factors (Kn) are important parameters which provide valuable expression of fish body condition and robustness, hence are useful in the management and conservation of species (Yu-Abit, 2011; Arshad *et al*., 2012). Population dynamic parameters of fish are prerequisites for management and conservation of any fish stock. The fundamental goal of stock evaluation is to establish guidelines for the most efficient use of any aquatic living resources (Sparre & Venema, 1998).

The information about body indices and population dynamics of *Setipinna breviceps* in the scientific repositories are very limited or scant. There are very few studies on body indices and population dynamic parameters of several species under Engraulidae including Whitehead *et al*. (1988), Islam *et al*. (1998), Rahman (1989), Baird *et al*. (1999), Munroe & Nizinski, (1999), Vidthayanonet *et al*. (2005), Hossain *et al*. (2015), Sarma (2015), Abu Hena *et al*. (2017), Xiong *et al*. (2017), Zhai and Pauly (2017 & 2019), Liang *et al*. (2020), Qing *et al*. (2020), Zarni (2020), and Brijesh *et al*. (2021). The past studies focused to documenting the species occurrence and morphological measurements (Tables 1 and 2), while parameters of population of the species were merely discussed. Therefore, the present study aimed to quantify the body indices and the population parameters of *S. breviceps* from the Batang Lassa Estuary (BLE), Sarawak, Malaysia.

Table 1. Estimated length-weight relationships (LWRs) and condition factor (Kn) of *Setipinna* spp. by studies

Fish species	Max. Length (cm)	LWR *(b)*	Condition factor (Kn)	References
Setipinna breviceps (Cantor, 1849)	24.0 cm SL	-	-	Whitehead *et al.,* 1988
Setipinna brevifilis (Valenciennes, 1848)	26.0 cm SL	-	-	Whitehead *et al.,* 1988
Setipinna tenuifilis (Valenciennes, 1848)	22.0 cm SL	-	-	Munroe & Nizinski, 1999
	30.0 cm TL	1.13	1.09	Zarni, 2020
	17.7 cm TL	3.38	-	Xiong *et al*., 2017
	18.5 cm TL	3.09	-	Qing-qiang *et al*., 2020
Setipinna phasa (Hamilton, 1822)	40.0 cm TL	-	-	Whitehead *et al.*, 1988
	28.0 cm SL	2.76-3.21	0.85-1.10	Sarma, 2015
	-	-	0.42-0.81	Brijesh *et al.*, 2021
Setipinna melanochir (Bleeker, 1849)	33.0 cm SL	-	-	Baird *et al*., 1999
	18.3 cm TL	2.46	-	Abu Hena *et al*., 2017
	19.0 cm SL	-	-	Munroe & Nizinski, 1999
Setipinna taty (Valenciennes, 1848)	22.1 cm SL	-	-	Rahman, 1989
	19.5 cm TL	2.51	-	Hossain *et al*., 2015
Setipinna wheeleri (Wongratana, 1983)	30.0 cm	-	-	Vidthayanon *et al.,* 2005

Table 2. Estimated population parameters by different studies of *Settipinna* spp.

Species	L∞ (cm)	K (yr^{-1})	Phi (ϕ')	M (yr^{-1})	F (yr^{-1})	Z (yr^{-1})	E	References
Setipinna tenuifilis	18.60	0.31		0.70	0.60			Zhai & Pauly, 2019
	21.2	0.31	2.14	0.70	0.60	1.30	0.46	Zhai & Pauly, 2017
Setipinna taty	20.0	0.60						Liang *et al.*, 2020
	21.3	0.53		1.28	0.80	2.08	0.28	Islam *et al.*, 1998

Note: L∞ = maximum theoretical length; K = growth coefficient; ϕ' = growth performance index; M = natural mortality; F = fishing mortality; Z = total mortality and E = exploitation ratio.

MATERIALS AND METHODS

Study Location and Sampling Procedure

The study was undertaken in the Batang Lassa Estuary (BLE). It is a part of lower Rajang River, located in Daro, Sarawak, Malaysia. The study areas of BLE is presented in Figure 1. The BLE is comparatively less explored fishing estuary as there is limited number of registered fishermen. On the other hand, BLE is deltaic outfall of longest Rajang River which facilitate more ecological dynamic feature of the environment. An Estuarine Set Bag Net (ESBN), locally known as *Gnian*, was used to gather samples monthly from April 2019 to September 2020. The sampling period is excluded from March to June 2020 due to the Covid-19 outbreak and movement control order. It is also noted that, the species reported in this study was not available during certain months of the sampling period in the monthly catch. The *Gnian* is a stationary set bag net (SBN) operates against tidal current having conical shape with code end which facilitate maximum number of species catch. Some conventional taxonomic identification keys were used to identify the samples (Ambak *et al*., 2010; Froese & Pauly, 2020). Total length (TL) was measured to the nearest 0.1 cm with a vernier caliper, and total body weight (W) was recorded with a digital electronic balance with 0.01 g accuracy. A total of 287 qualified specimens were used for this study.

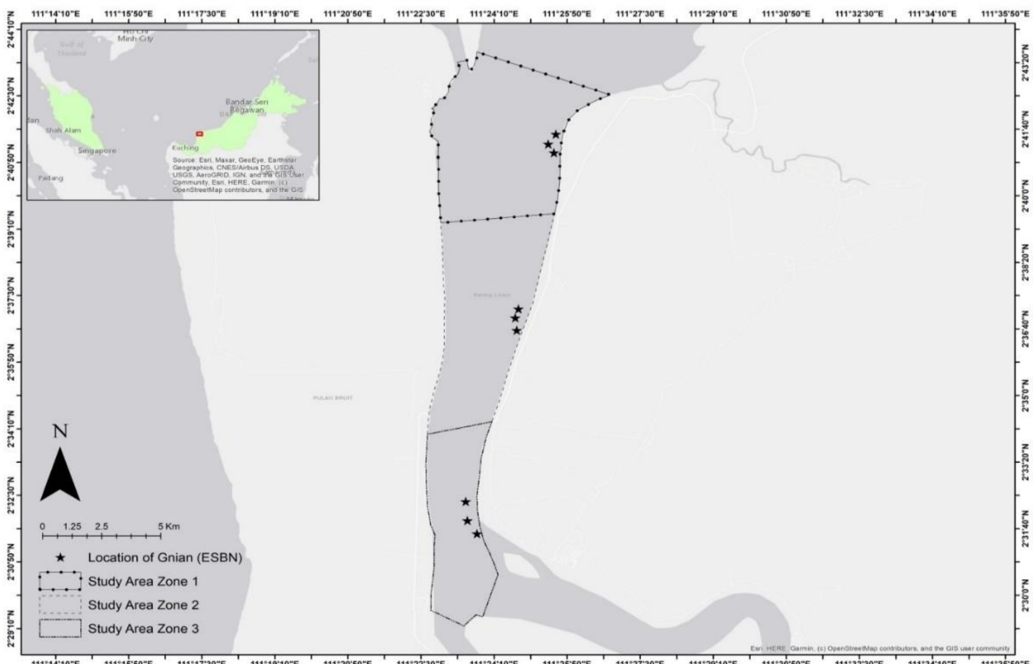

Figure 1. Study area of Batang Lassa Estuary, Sarawak, Malaysia

Length-weight relationships (LWRs) and growth patterns

The LWRs of *S. breviceps* were calculated using regression analysis of length-weight (LW) data following Le Cren (1951) in Eq. (1):

$$W = a \times L^b \qquad \text{Eq. (1)}$$

where, W denotes the fish body weight and L is the TL, a is the intercept, and b the slope of the curve.

The power equation was expressed by logarithmic transformation as Eq. (2):

$$ln\, W = ln\, a + b\, ln\, L \qquad \text{Eq. (2)}$$

Before regression analysis, outliers were removed from the LW dataset by fitting Log-log plots of W and L data (Froese, 2006). To fit the regression model, the coefficient of determination (r^2) was calculated (Pervaiz *et al*., 2012).

Condition factors and expression of body-shape

Following Le Cren (1951), the relative condition factor (Kn) was estimated using Eq. (3):

$$Kn = W/a \times L^b \qquad \text{Eq. (3)}$$

where, *W* is the body-weight and *L* is total length, and *a* = intercept, and *b* = slope of the curve of LWR regression. Categorizations of body shape were done according to Firdaus *et al.* (2018).

Growth Parameters

The growth and age were calculated by employing von Bertalanffy Growth Function (VBGF) (von Bertalanffy, 1938; Beverton & Holt, 1957) in Eq. (4):

$$L_t = L_\infty(1 - exp^{(-k(t-to))}) \qquad \text{Eq. (4)}$$

where L_t is the length at time t; L_∞ is the maximum theoretical length (cm); *K* is the growth coefficient (year^{-1}); t is the age of the fish, and t_0 is the age of the fish at zero length.

Growth performance index (ϕ')

The growth performance index (ϕ') was determined by using Pauly and Munro (1984) in Eq. (5):

$$\varphi' = logK + 2logL_\infty \qquad \text{Eq. (5)}$$

Estimation of total, natural and fishing mortality

The total mortality, *Z* (yr^{-1}), was estimated from the length-converted catch curve (Beverton & Holt, 1957; 1966) by means of the final estimates L_∞ and *K* and the length frequency distribution data. The natural mortality, *M* (yr^{-1}), was determined by using empirical equation (Pauly, 1980) in Eq. (6):

$$\boldsymbol{log_{10}M = -0.0066 - 0.279log_{10}L_\infty + 0.06543log_{10}K + 0.04634log_{10}T} \qquad \text{Eq. (6)}$$

where, T is the mean annual water temperature (29 °C for current study based on year round average water temperature in the study area).

This approach makes the assumption that size and natural mortality are related. Since an animal living in warmer water will die more frequently than an analogous animal living in cooler water, the relationship, which is already rather weak, is strengthened when the mean environmental temperature is taken into account (Pauly, 1980). The relationships were created using data on 287 fish of the species *S. breviceps* natural mortality and ambient temperature. Pauly (1980) used this empirical equation for most tropical fishes where it derived from 175 independent sets of estimates when *L* or *W* is available.

The fishing mortality, F (year^{-1}), was obtained by Silvestre and Garces (2004) as in Eq. (7):

$$F = Z - M \qquad \text{Eq. (7)}$$

where, Z is the total mortality and M is the natural mortality.

Exploitation ratio (E)

The exploitation ratio, *E* was estimated by dividing of fishing mortality with the sum of natural and fishing mortality as in Eq. (8) (Beverton & Holt, 1966; Gulland, 1971):

$$E = F/(F + M) \qquad \text{Eq. (8)}$$

Probability of capture

Probability of capture at different length was estimated from the length-converted catch curve. The estimates of the values of L_{25}, L_{50} and L_{75} represents different lengths at which 25%, 50% and 75% of the fish will be vulnerable to the fishing gear (Pauly & Munro, 1984).

Patterns of recruitment

Backward projection of frequencies onto the time axis of a time-series of samples following a trajectory described by the VBGF by von Bertalanffy (1938), yielded the recruitment pattern. This procedure calculates the number of recruiting pulses per year and the relative strength of each pulse using a time series of length-frequency data (Gayanilo *et al.*, 2005). Estimation of all the population dynamics parameters was performed by employing the FiSAT-II software (Version 1.2.2) developed by FAO-ICLARM (Gayanilo *et al.*, 2005).

RESULTS

Length-frequency Distribution

Setipinna breviceps shows year-round contribution to the catch composition from BLE. Out of 66 species recorded during the study, *S. breviceps* contributed roughly 0.80% of the total catch, and roughly 15% of total anchovy. The TL ranged from 5.50 to 24.00 cm using total 287 fish specimens of *S. breviceps* throughout the sampling period. The length-based frequency distribution and predicted extreme length (95% confidence interval range) of *S. breviceps* is presented in Figure 2.

Length Weight Relationships (LWRs) and Growth Pattern

The slope (growth coefficient, *b*) and intercept (*a*) of regression of *S. breviceps* are 2.5630 and 0.0153, respectively with the r^2 value of 0.87. The growth co-efficient indicates the studied species had a negative allometric growth pattern. The parameters of regression (*a* and *b*) with curves of LWR are shown in Figure 3.

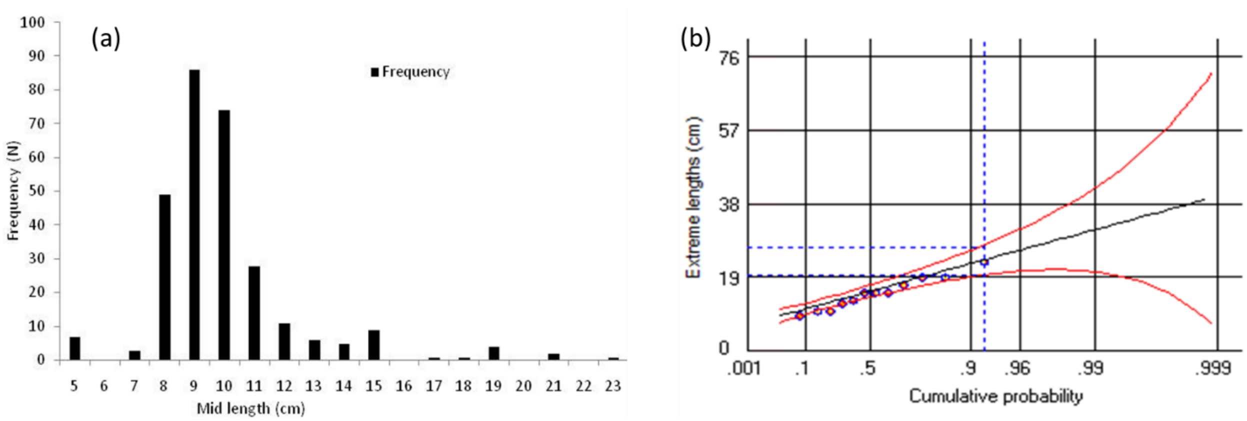

Figure 2. Length-frequency distribution (a) and predicted extreme length (b) of *Setipinna breviceps*

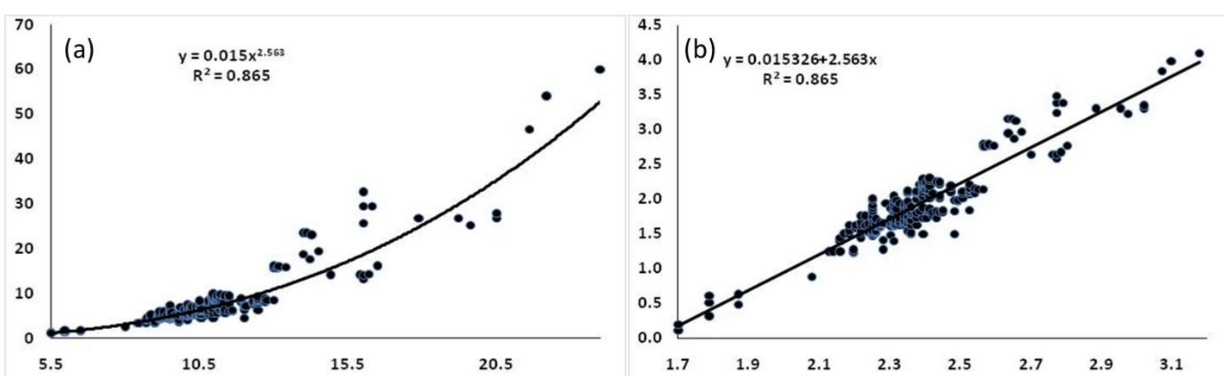

Figure 3. Length-weight relationships (LWRs) in parabolic (a) and logarithmic (b) form for the *Setipinna breviceps.* (X axis= total length (cm) and Y axis= Weight (g))

Body Condition Factors and Expression of Body Shape

The mean relative condition factors (Kn) was 1.02 ± 0.22. It is observed that about 50% of fishes found flat or thin shape (Kn<1), 44% were rounded or fat (Kn>1) where only 2.44% fishes exhibited proportional body shape (Kn = 1). The detailed body shape expression of *S. breviceps*is is presented in Table 3.

Population Parameters of Growth Indices

The estimated asymptotic length (L_∞), growth coefficients (K) and growth performance indices (ϕ′) of *S. breviceps* were 24.15 cm, 0.23 yr^{-1} and 2.13, respectively. Table 4 shows the estimated growth parameters and the growth curve. Growth coefficient on length-frequency distribution is exhibited in Figure 4.

Table 4. Population parameters of *Setipinna breviceps* from Batang Lassa Estuary

Population Dynamics Parameters	Values
Asymptotic Length (L_∞) in cm	24.15
Growth Coefficient (K) yr^{-1}	0.23
Growth Performance Index (ϕ′)	2.13
Natural Mortality (M) yr^{-1}	0.74
Fishing Mortality (F) yr^{-1}	0.29
Total Mortality (Z) yr^{-1}	1.03
Length at First Catch (Lc) in cm	7.50
Exploitation ratio (E)	0.28
E_{max}	0.34
Age in year	6.1

Table 3. Relative condition factor (Kn) and body shape inferences of *Setipinna breviceps*

Fish	Relative condition factor (Kn)	N	%	Body Shape Inference
Setipinna breviceps	<=0.49	0	0.00	Very flat or thin shape
	0.50-0.99	145	50.52	Flat or thin shape
	1	7	2.44	Proportional shape
	1.01-1.49	127	44.25	Rounded or fat shape
	>=1.50	8	2.79	Very rounded or fat shape
	Min=0.50			Flat or thin
	Max=1.76			Very rounded or fat
	Mean=1.02±0.22			Proportional or slightly rounded

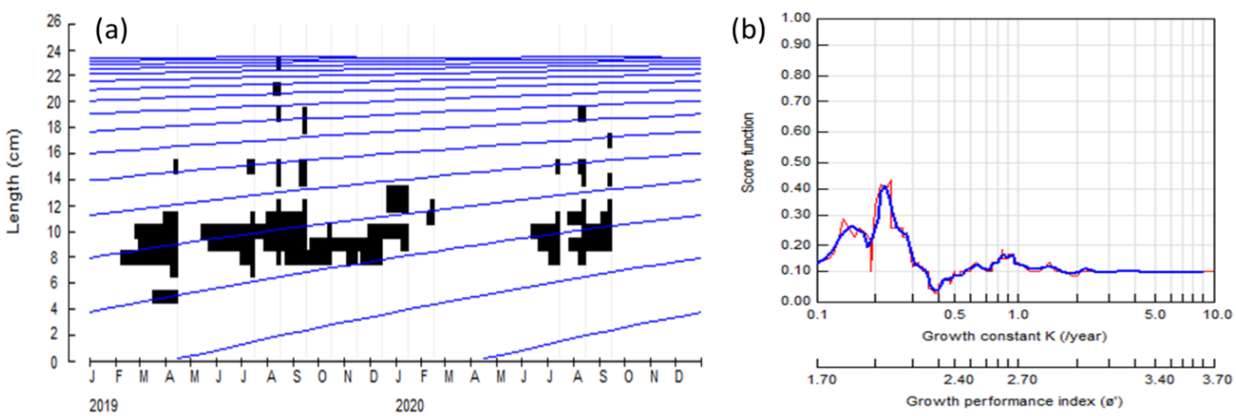

Figure 4. Growth curve (a), coefficient and performance index (b) of *Setipinna breviceps*

Mortality and Exploitation Parameters

The estimated natural mortality (M), fishing mortality (F) and total mortality (Z) of *S. breviceps* were 0.74, 0.29 and 1.03 yr^{-1}, respectively. The calculated exploitation ratio (E) was 0.28. Figure 5(a) shows the length converted catch curves that were used to estimate the mortality parameters M, F, and Z, as well as the E.

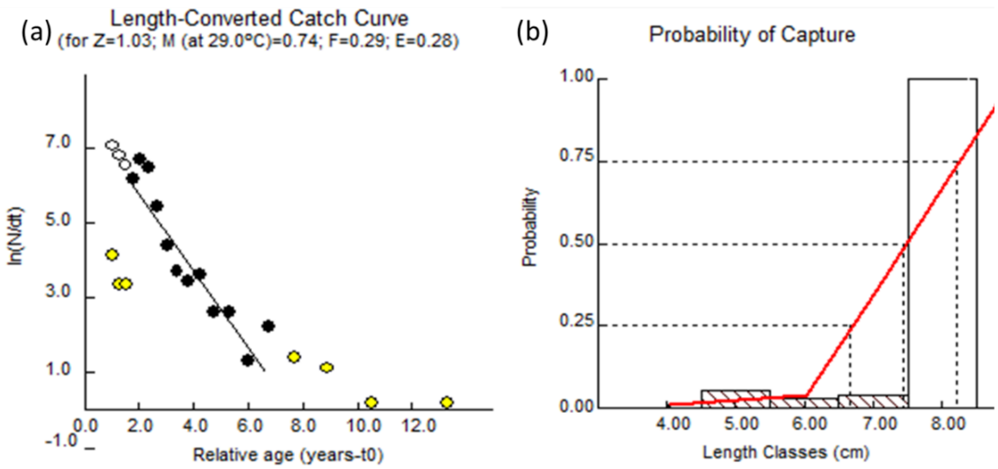

Figure 5. Length converted catch curve (a) and probability of capture (b) of *Setipinna breviceps*.

Capture Probability, Recruiting Pattern and Yield-per-recruit

Length of first capture (Lc) of *S. breviceps* was found to be 7.44 cm. The length sizes of captures were 6.66 cm, 7.44 cm and 8.22 cm against the 25% (L_{25}), 50% (L_{50}) and 75% (L_{75}) probability, respectively. Probability of capture of *S. breviceps* is presented in Figure 5(b).

The yield-per-recruit following knife edge procedure for *S. breviceps* was found to be 0.221 and 0.343 at E_{50} and E_{max}, respectively (Figure 6). The *S. breviceps* had shown round the year recruitment during the study. It is observed that the studied species might have roughly two possible unequal peaks yearly (Figure 7).

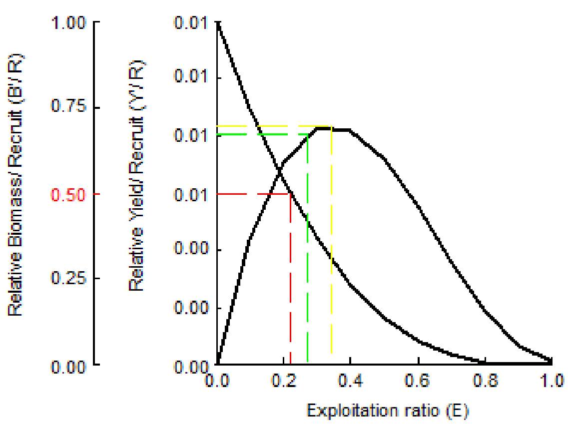

Figure 6. Relative Yield-per-recruit (Y/R) and Biomass-per-recruit (B/R) of *Setipinna breviceps*

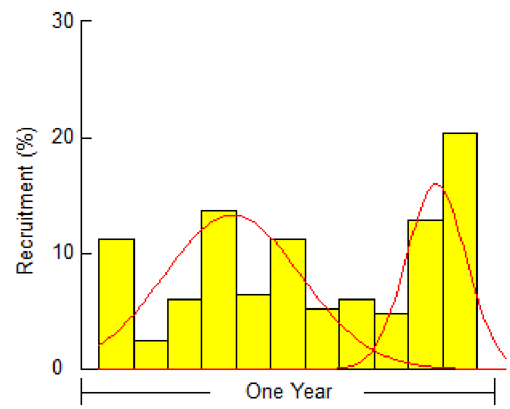

Figure 7. Recruitment pattern of *Setipinna breviceps* from BLE

DISCUSSION

Distribution of Length-frequency

The measured TL of *S. breviceps* ranged between 5.50 cm to 24.00 cm throughout the study period. Among the studied specimens (n = 287), maximum frequencies (31%) comprised about 9 cm length class followed by 26% of 10 cm class, 17% of 8 cm class, 9% of 1 cm class and 12 and 15 cm classes comprise 3.5% each and rest of 10% distributed sporadically up to 24 cm in length. Whitehead *et al.* (1988) reported maximum TL of *S. breviceps as* 24.00 cm. Maximum TL for other related species were 26.00 cm for *S. brevifilis* (Whitehead *et al*., 1988), 30.00 cm for *S. tenufilis* (Zarni, 2020), 40.00 cm for *S. phasa* (Whitehead *et al*., 1988), 33.00 cm for *S. melanochir* (Baird *et* *al*. 1999), 22.10 cm for *Setipinna taty* (Rahman, 1989) and 30.00 cm for *S. wheeleri* (Vidthayanon *et al.* 2005). It revealed that the maximum TL of the present finding is similar to the other researchers. Furthermore, the studied *S. breviceps* exhibits year-round contribution in the catch. The present study found wide range (5.5 to 24 cm) of specimen during sampling; it implies that the fish can reach maximum size if can control small meshed net. Overall, the current finding implies a comparatively good situation to reach maximum length with respect to available records so far.

Length Weight Relationship (LWRs) and Pattern of Growth

The estimated growth coefficient (*b*) of *S. breviceps* was 2.56 which express a negative allometric growth. The *b* value of the regression model generally falls between 2.5 to 3.5 (Frose, 2006). The coefficient of determination (r^2) of *a* and *b* in the regression model of LWRs was 0.87 in the current study which indicates the good prediction and small data dispersion (Correia *et al*., 2018). There is no information about LWR for *S. breviceps*. Sarma (2015) found *b* values 2.76 to 3.21 for *S. phassa* species where Abu Hena *et al.* (2017) reported *b* values as 2.46 for the species *S. melanochir* that indicated negative allometric growth as well. Nonetheless, maximum number of specimens caught in small meshed net could be the reasons of lower growth coefficient of present studied species.

Relative Condition Factors and Expression of Body Shape

The condition factors (Kn) of *S. breviceps* were varied from 0.50 to 1.76 with mean 1.02 ± 0.22. There is no study on Kn of *S. breviceps*. Sarma (2015) reported that the *Kn* values of *S. phassa* varied from 0.85 to 1.10 which is roughly similar to present finding of *S. breviceps*. Brijesh *et al.* (2021) reported Kn values varied from 0.42 to 0.81 for *S. phassa* which is slightly lower than *S. breviceps*. Generally, Kn values vary with life stage of fish, species, and natural condition with food availability. *Setipinna breviceps* in the present study found with maximum numbers of flat/thin shapes followed by rounded/fat shaped with a considerable number of very fat shaped. This finding is nearly similar to Firdaus *et al*. (2018) and Mustafa *et al*. (2021b) where they identified 50.52% of fishes in the 'flat or thin' (Kn<1), 44.25% in the 'rounded or fat' (Kn>1), and only 2.44 percent in the 'proportional' (Kn = 1) categories. There is a limitation of information on such body-shape expressions study of fishes. It is presumed that body shape indices of *S. breviceps* were proportional on both sides.

Growth Parameters

Present estimation of asymptotic length (L_∞) of *S. breviceps* was 24.15 cm. Zhai and Pauly (2019) estimated L_∞ 18.60 cm for *S. tenuifilis* where 20.0 cm reported by Liang *et al*. (2020) for *S. taty*, and Islam *et al.* (1998) found 21.3 cm for *S. taty*. There is no information on asymptotic length of *S. breviceps*. However, these variations may be due to species differences and location-wise stock differences. The current growth coefficient (k) of *S. breviceps* was 0.23 yr^{-1}. Zhai and Pauly (2019) reported *K* 0.31 yr^{-1} for *S. tenuifilis*, Liang *et al*. (2020) estimate *K* 0.60 yr^{-1} for *S. taty*, and Islam *et al.* (1998) reported *K* 0.53 yr^{-1} for *S. taty*. Though there are no reports on *K* for *S. breviceps*, it implies that the *S. breviceps* growth is closer to *S. tenuifilis* than *S. taty*. The estimated growth performance index (ɸ’) of *S. breviceps* was 2.13. Zhai and Pauly (2017) reported growth performance index 2.14 for *S. tenuifilis* which is similar to the present finding of *S. breviceps*.

Mortality and Exploitation Parameters

Mortality and exploitation status denotes the indication of over-fishing conditions of any stock (Mustafa *et. al*., 2014). The present estimates of natural mortality (M) fishing mortality (F) and total mortality (Z) of *S. breviceps* were 0.74, 0.29 and 1.03 yr^{-1}, respectively. There is scanty of reports or information on mortality parameters for *S. breviceps*. However, the estimated M and F were reported as 0.70 and 0.60 yr^{-1} (Zhai & Pauly, 2019) for *S. tenuifilis.* Though the natural mortality is very similar with present findings, the fishing mortality is almost half in Batang Lassa compared with Zhai and Pauly (2019) findings. Islam *et al*. (1998) reported M and F values as 1.28 and 0.80 yr^{-1} which is unlikely to present finding that might be linked with extreme fishing pressure in the coast of Bangladesh. Present estimated exploitation ratio was 0.28. It is a clear sign of under-exploitation (E<0.5) of *S. breviceps* stock in Batang Lassa Estuary. Reported E as 0.46 for *S. tenuifilis* (Zhai & Pauly, 2017) which is higher than present finding but still under fishing where E value as 0.28 for *S. taty* (Islam *et al*., 1998) which is similar exploitation nature with present estimates for *S. breviceps*.

Capture Probability, Recruiting Pattern and Yield-per-recruit

The calculated length at first capture (Lc) was 4.0 cm for *S. breviceps.* It clearly indicated that juvenile catch occurred in Batang Lassa Estuary frequently. It also reflected with habitat specialty of nursery ground for the studied species. The estimated length sizes at different probabilities (25%, 50% and 75%) of capture indicated a severe juvenile catch with the ESBN. This much scale juvenile catch probably due to small meshed selective net. Finally, the year-round recruitment pattern was observed clearly with two unequal peaks for *S. breviceps*. Therefore, following the recruitment peaks, operations of small meshed nets need to be controlled.

CONCLUSION

Setipinna breviceps is an important commercial food fish. This population dynamics study is open to the elements that the *S. breviceps* exhibited relatively lower growth, under exploited stock and higher juvenile catch. There might be some extent of recruitment overfishing in Batang Lassa Estuary and the result of this study could be due to gear selectivity (*Gnian*). The biometric information and population dynamic parameters found in this study indicate relatively new information. It could be useful in the direction of future aquatic resource management and conservation research.

ACKNOWLEDGEMENTS

The study is part of PhD work by the first author supported by the research grant provided by the Ministry of Higher Education Malaysia under the Fundamental Research Grant Scheme (FRGS/1/2019/WAB09/UPM/02/2; Project no. 07-01-19-2209FR).

REFERENCES

Abu Hena, M.K.A., Sinden, A., Idris, M.H., Asif, A.L., Hamli, H., Musa, N., Piah, R.M., Wahid, M.E., Rashdi, N. & Shahabuddin, A.M. (2022). Diversity of fisheries in Sarawak, Northwest Borneo: Present status and conservation issues. *Borneo Journal of Resource Science and Technology*, 12(1): 32-51. DOI: https:doi.org/10.33736/bjrst.4651.2022

Abu Hena, M.K.A., Idris, M.H. & Rajaee, A.H. (2017). Length–weight relationships of three fish species from a tropical mangrove estuary of Sarawak, Malaysia. *Journal of Applied Ichthyology*, 2017: 1-3. DOI:10.1111/jai.13385

Ambak, M.A., Isa, M., Zakaria, Z. & Ghaffar, M.A. (2010). *Fishes of Malaysia, 1st ed.* Malaysia: Penerbit Universiti Malaysia Terengganu. pp. 334.

Arshad, A., Amin, S.M.N. & Nuradiella, Y.L.Z. (2012). Population characteristics of *A. japonicus* from Kedah coastal waters of Peninsular Malaysia. *Journal of Fisheries and Aquatic Sciences,* 7(2): 162-172.

Baird, I.G., Inthaphaisy, V., Kisouvannalath, P., Phylavanh, B. & Mounsouphom, B. (1999). *The fishes of southern Lao.* Lao Community Fisheries and Dolphin Protection Project. Ministry of Agriculture and Forestry, Lao PDR. pp. 161.

Beverton, R.J.H. & Holt, S.J. (1966). *Manual of Methods for Fish Stock Assessment, Part 2; Tables of Yield Functions, Fisheries Technical Paper No. 38*. Food and Agricultural Organization of the United Nations. Rome, Italy.

Beverton, R.J.H. & Holt, S.J. (1957). On the dynamics of exploited fish populations. *Fisheries Investigations*, 19: 1-533.

Brijesh, K.C., Farah, B. & Serajuddin, M. (2021). Comparative study of reproductive traits in Gangetic Hairfin Anchovy, *Setipinnaphasa* (Hamilton, 1822) from estuarine and freshwater ecosystems. *Turkish Journal of Fisheries and Aquatic Sciences*, 21(4): 179-189. http://doi.org /10.4194/1303-2712-v21_04_03

Chong, V.C., Lee, P.K.Y. & Lau, C.M. (2010). Diversity, extinction risk and conservation of Malaysian fishes. *Journal of Biology*, 76: 2009-2066.

Correia, E., Granadeiro, J.P. & Regalla, A. (2018). Length-weight relationship of fish species from the Bijagos Archipelago Guinea-Bissau. *Journal of Applied Ichthyology*, 34(1): 177-179. DOI: 10.1111/jai.13522

Department of Statistics Malaysia (DoSM). 2020. Selected agricultural indicators. Retrieved March 21, 2022 from https://www.dosm.gov.my/portal-main/lan dingv2.

Firdaus, M., Lelono, R.D. & Saleh, R. (2018). The expression of the body shape in fish species *Hapadon nehereus* (Hamilton, 1822) in the waters of Juata Laut, Tarakan city, North Kalimantan. *ACCL Bioflux*, 11(3): 613-623.

Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22: 241-253.

Froese, R. & Pauly, D. (2020). *FishBase. World Wide Web electronic publication*. Retrieved March 24, 2021 from http://www.fishbase.org.

Gayanilo F.C., Sparre P. & Pauly D. (2005). *FAO-ICLARM Stock Assessment Tools II (FiSAT II), User's Guide, Computerized Information Series (Fisheries) No. 8, (Revised Version)*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Gulland, J.A. (1971). *The Fish Resources of the Ocean*, London. UK: Fishing News (Books) Ltd.

Hossain, M.Y., Sayed, S.R.M. & Rahman, M.M. (2015). Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. *Journal of Applied Ichthyolog*y, 1-3. Doi: 10.1111/jai.12823

Islam M.S., Khan M.G. & Quayum S.A. (1998). Estuarine set bag net fishery of Bangladesh. In Chowdhury, Z.A., Huq, Q.M., Islam, M.S., Khan, M.G., Mustafa, M.G., Paul, S.C., Quayum, S.A. and Sada, M.N. (eds.) *Studies of Interactive Marine fisheries of Bangladesh, BOBP (Bay of Bengal Program) Working Paper No 89*. Madras, India.

Kapoor, D., Dayal, R. & Ponniah, A.G. (2002). *Fish biodiversity of India*. India: National Bureau of Fish Genetic Resources Lucknow. pp. 775.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20(2): 201-219. https://doi.org/10.2307/1540

Liang, C., Xian, W. & Liu, S. (2020). Assessments of 14 exploited fish and invertebrate stocks in chinese waters using the LBB method. *Frontiers in Marine Science*, 7: 314. doi: 10.3389/fmars.2020.00314

Munroe, T.A. & Nizinski, M. (1999). Engraulidae. anchovies. p. 1698-1706. In Carpenter, K.E. and V.H. Niem (eds.) *FAO species identification guide for fishery purposes. The living marine resources of the WCP. Vol. 3. Batoid fishes, chimaeras and bony fishes part 1 (Elopidae to Linophrynidae)*. Rome: FAO.

Mustafa, M.G., Rajaee, A.H., Hamli, H. & Rahim, K.A.A. (2021a). Status and trends in coastal fishery resources of Sarawak, Malaysia -a focus on a tropical deltaic estuary. *AACL Bioflux*, 14(5): 2728-2740.

Mustafa, M.G., Rajaee, A.H., Hamli, H. & Rahim, K.A.A. (2021b). Biometric indices and population parameters of three polynemid fishes from Batang Lassa Estuary of East Malaysia. *PeerJ*, 9(2): e12183. DOI: 10.7717/peerj.12183

Mustafa, M.G., Sinha, S. & Islam, R. (2014). Population dynamics *Notopterusnotopterus* (Pallas, 1769) from the Kaptai Reservoir of Bangladesh. *SAARC Journal of Agriculture*, 12(2): 112-122.

Pauly D. (1980). On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks, *Journal of the International Council for the Exploration of the Sea*, 39(2): 175-192.

Pauly, D. & Munro, J.L. (1984). Once more on the comparison of growth in fish and invertebrates. *ICLARM: International Center for Living Aquatic Resources Management, Fishbyte*, 2(1): 21.

Pervaiz, K, Iqbal, Z. & Mirza, M.R. (2012). Length–weight, length–length relationships and feeding habits of wild Indus Mahseer, *Tor macrolepis*, from Attock, Pakistan. *Journal of Applied Ichthyology*, 28(4): 673-676. https://doi.org/10.1111/j.1439-0426.2012.01953.x

Qing-qiang, R., Qing, X. & Lan-lan, Z. (2020). Length-weight relationships of 11 fish species from the Min River Estuary and its adjacent waters, Fujian

Province, China. *Journal of Applied Ichthyolog*y, 00: 1-3. DOI: 10.1111/jai.14086

Rahman, A.K.A. (1989). *Freshwater fishes of Bangladesh. Zoological Society of Bangladesh*. Dhaka: University of Dhaka. pp. 364.

Sarma P.K. (2015). Length - weight relationship and relative condition factor of gigantic hairfin anchovy *Setipinna phasa* (Hamilton, 1822) in Dhubri district of Assam, India. *Advanced Applied Science Research*, 6(1): 5-10.

SEAFDEC (2017). SEAFDEC Annual Report. Southeast Asian Fisheries Development Center. Retrieved June 28, 2023 from http://hdl.handle .net/20.500.12066/1344

Silvestre, G.T. & Garces L.R. (2004). Population parameters and exploitation rate of demersal fishes in Brunei Darussalam (1989–1990). *Fisheries Research* 69: 73-90.

Sparre, P.J. & Venema, S.C. (1998). *Introduction to Tropical Fish Stock Assessment part I: Manual FAO Tech Pap No. 306/Rev 2*. Rome: FAO. pp. 407.

Vidthayanon, C., Termvidchakorn, A. & Pe, M. (2005). *Inland fishes of Myanmar*. Thailand: Southeast Asian Fisheries Development Center. pp. 160.

von Bertalanffy L. (1938). A quantitative theory of organic growth. *Human Biology*, 10: 181-213.

Whitehead, P.J.P., Nelson, G.J. & Wongratana, T. (1988). *FAO Species Catalogue. Vol. 7. Clupeoid fishes of the world (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings*. Rome: FOA. pp. 305-579.

Xiong, X., Zhu, X. & Xie, D. (2017). Length-weight relationships of eight fish species from mangroves of Guangdong, China. *Journal of Applied Ichthyology*, 34: 729-730. DOI: 10.1111/jai.13588.

Yu-Abit, I.L. (2011). Length-weight relationship and condition factor of three dominant species from the lake Tasik Kenyir, Terengganu, Malaysia. *Journal of Fisheries and Aquatic Sciences*, 6(7): 852-856.

Zarni, K.K. (2020). Length-weight relationship and condition factor of some commercial fish species from kyaikkhami fish landing center, Mon coastal area. *Journal of the Myanmar Academy of Arts and Science*, 18(4B): 327-334.

Zhai, L. & Pauly, D. (2017). Growth and mortality of exploited fishes in China's coastal seas and their uses for yield- per- recruit analyses. *Journal of Applied Ichthyolog*y, 33: 746-756. DOI:10.1111 /jai.13379

Zhai, L. & Pauly, D. (2019). Yield-per-recruit, utility-per-recruit, and relative biomass of 21 exploited fish species in China's coastal seas. *Frontiers in Marine Science*, 6: 724. doi:10.3389/fmars.2019.00724