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Population Characteristics of the Japanese Threadfin Bream *Nemipterus japonicus* (Bloch, 1791) (Actinopterygii: Nemipteridae) at Bintulu Coast, Sarawak, South China Sea

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Abstract: *Nemipterus japonicus* (Japanese threadfin bream) is one of the most significant fish species throughout the Indo-Pacific regions. No previous studies on the population dynamics of *N. japonicus* have been carried out in the Eastern Malaysia (Malaysian Borneo). The present study focused on the population dynamics of *N. japonicus* from April 2013 to March 2014 in the coastal area of Bintulu, South China Sea. Local fishermen provided samples, which were then analysed. The FiSAT II software was used to evaluate the collected length frequency data. The asymptotic length (L_∞) and growth coefficient (K) were 26.78 cm and 0.85 yr-1, respectively. The growth performance index (ϕ'), total mortality co-efficient (Z), natural mortality (M) and fishing mortality (F) were 2.785, 2.97, 1.63 and 1.34 per year, respectively. According to the estimates, the exploitation rate (E) for *N. japonicus* was 0.45, while the $E_{0.1}$, $E_{0.5}$ and E_{max} were determined as 0.72, 0.4 and 0.806, respectively. The obtained value of exploitation was less than $E_{max,}$ although slightly higher than $E_{0.5}$. The recruitment characteristics of *N. japonicus* have been stable throughout the year, with one peak pulse. The results contribute to the knowledge of the dynamics of *N. japonicus* populations and are important for the sustainable management of the Sarawak fishing resources.

Key words: fishery, growth, mortality, exploitation, Malaysia

Introduction

The Japanese threadfin bream *Nemipterus japonicus* (Bloch, 1791) (Nemipteridae) is characterised by pinkish body colour, silvery underside, and 11–12 faint golden-yellow stripes running down the body from below the head to the base (Elhaweet 2013). Almost entirely of the Indo West Pacific waters is home to *N. japonicus*, from east Africa to the Indo-Malay Archipelago (Elhaweet 2013, Ning et al. 2015, Imtiaz et al. 2016, Farivar et al. 2017, Ogwang et al. 2021). It lives in shallow mud or sandy bottoms, at depths from 5 to 80 m. It is a commercially significant species in the South China Sea, where commercial trawling takes place in large numbers (Russell 1986, 1990, 1993, Russell & Gouws 2013, Ning et al. 2015).

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Its importance has lead this species to be extensively studied, although most of the stock and population assessment were carried out in the waters of Indian subcontinent (Masoomi et al. 2023; Raza et al. 2022; Rao et al. 2018; Sen et al. 2014; Joshi 2010). Findings from research on population dynamics might help in planning and managing marine resources by providing information on numerous population characteristics such as asymptotic length, growth coefficients, mortality rates from natural and fishery sources and the exploitation level (Nurul Amin et al. 1999, 2009, Al-Mamun et al. 2021). More than 30 studies have been accompanied on population dynamic of *N. japonicus* in different part of the globe, including the Northern Arabian Sea (Iqbal 1991), off Karnakata (Zacharia 1998), off Visakhapatnam (Rajkumar et al. 2003), off Cochin (Joshi 2010), Madras (Vivekanandan & James 1986), Brunei (Silvestre & Garces 2004); however, no studies from East Malaysia (Malaysian Borneo) have been carried out. The first report of this species in east Malaysian waters can be tracked back in 1977 (Weber & Jothy 1977). Later on, a little number of published documents dealt with different aspects of *N. japonicus* in Sarawak or Sabah waters, including the status, breeding biology and genetic characteristics (Khatib 2015, Imtiaz et al. 2016, Lim et al. 2016). The breeding biology and feed preferences of *N. japonicus* were studied in Sarawak water (Nettely et al. 2016, Tonnie et al. 2018), while the genetic differentiation among the populations was investigated from Peninsular Malaysia (Lim et al. 2016). Population genetics research discovered similarities between *N. japonicus* found in the western Pacific and the Indian Oceans (Imtiaz et al. 2016). However, the population structures of *N. japonicus* in east Malaysian waters, especially in Sarawak waters, are still unknown.

The present study was performed in order to cover the gaps about the population dynamics of *N. japonicus*. One of the primary goals of this investigation was to estimate the population characteristics and exploitation rate of *N. japonicus* with the purpose of evaluating the stock condition of *N. japonicus* in the coastal region of Bintulu, Sarawak, South China Sea.

Materials and Methods

Samples of threadfin breams *N. japonicus* were collected from commercial fish landing station at Bintulu (3°10' 13.9" N, 113°02'22.9" E) and Kuala Nyalau village (3°38' 26.9" N, 113°23'0.46" E) during the period of April 2013 to March 2014 (Fig. 1). The fishermen used a v-shaped purse seine net with a mesh size of 4 inch. All samples were measured to the closest 0.1 cm for total length. Following that, one-centimetre intervals were utilised to partition the length frequency data into groups.

As described by Gayanilo et al. (1996), the data were evaluated by means of the FISAT II in the computer software programme. In order to determine the asymptotic length (L_∞) and growth co-efficient (K) of the von Bertalanffy equation for increase in length, we used the ELEFAN-I software package included in the FiSAT II software package. The K scan process was carried out in order to determine whether an accurate assessment of the K value was obtained. The assessed L_∞ and K were accustomed to produce the ϕ' (growth performance index) with the formula,

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

The possible longetivity (t_{max}) of the investigated species was determined according to Pauly (1984) and Taylor (1958), who used the equation $t_{max}=3/K+t0$ to arrive at his results. Finding the lengths at different ages was accomplished by the use of the inverse von Bertalanfy growth equation. The non-linear squares estimation approaches were accustomed to fit the VBGF in order to estimate the length-at-age curve. The following is the definition of the VBGF formula,

$$L_t=L_\infty[1-e^{-k(t-t_0)}]$$

Where L_t is the mean length at age t, while t is age of the species and t_0 is the hypothetical age at when the length is zero.

The catch curve converted by the length was used to determine the total mortality coefficient (Z) (Pauly 1984). According to Pauly's empirical relationship (Pauly & Martosubroto 1980), the M (natural mortality rate) was estimated with the empirical formula obtained from the empirical connection as follows,

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

In this equation, T is the annual mean temperature (in °C) of the habitat water.

As soon as Z and M values are known, it is possible to determine fishing mortality (F). F was calculated based on:

$$F=Z-M$$

The exploitation level (E) was estimated by the Gulland (1971) relationship:

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

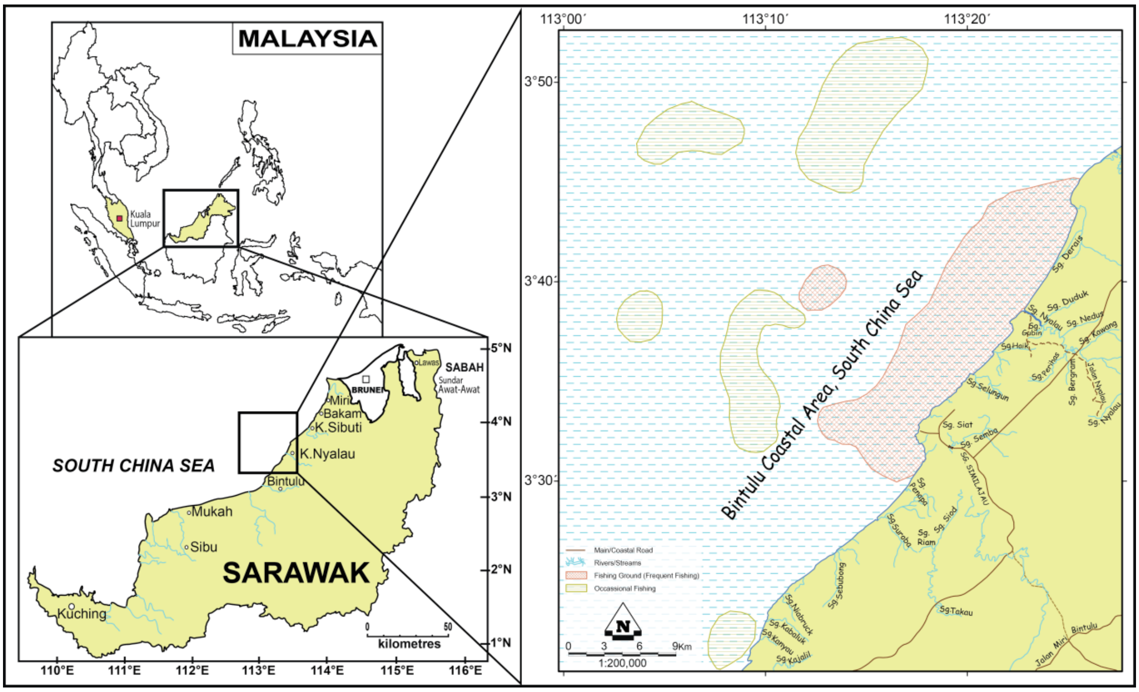

Fig. 1. Sampling sites covered the coastal area of Bintulu in South China Sea.

According to the approach of Pauly & Soriano (1986), the rising leftward arm of the length-converted catch curve was utilized to examine the likelihood of capture of each length class. By charting the cumulative likelihood of capture against the mid-length at first capture (Lc), it was determined by corresponded to the cumulative probability at 50 %.

A backward projection of cluster of accessible length frequency data on the length axis, as termed in software package, was used to identify the stock recruitment characteristics. The L_∞, K, and t0 (t=0) were the parameters used in the simulation. NORMSEP was used to determine the typical distribution of the recruitment configuration.

The FiSAT protocol was used to perform the assessed length regulated virtual population analysis (VPA) and the cohort analysis for the assessed length regulated VPA. An analysis using the values of a (constant) and b (exponent) was performed on the values of L_∞, K, M, F, a (constant), and b (exponent). The value of t0 was assumed to be zero.

According to the model developed by Beverton and Holt and updated by Pauly & Soriano (1986), the relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) were calculated and implemented into the FiSAT. It was necessary to provide the values of LC/L_∞ and M/K as input requirements for the operation to work. It was determined that the maximum permitted limit of exploitation (E_{max}) was reached, resulting in the highest possible Y/R ratio. Additionally, the exploitation rates $E_{0.1}$, at which the marginal increase in relative Y/R is 10% of its value at E = 0 as well as $E_{0.5}$, at which the marginal increase in relative B/R is 50% of its value at E = 0, were calculated.

Results

Length frequency and population parameters

The overall 1532 individual of *N. japonicus* were collected in present investigation. The lowest and highest total length were 10.5 cm and 25.5 cm respectively (Table 1). The asymptotic length ($L\infty$) was 26.78, while the growth co-efficient (K) was 0.85 (Table 2).

Growth parameters of *Nemipterus japonicus*

According to the results, the observed and anticipated extreme lengths (L_{max}) were 25.50 cm and 26.36 cm respectively (Fig. 2). The extreme length range was determined to be between 25.26 cm and 27.45 cm with a 95% confidence. The best estimate of the growth co-efficient (K) was 0.85 yr^1. The response surface (Rn) was determined to be 0.240, and asymptotic length was found to be $L\infty$=26.78 cm. During the current experiment, the computed value for growth performance index (ϕ') of *N. japonicus* was 2.785 (Fig. 3). The reconstructed length-frequency histograms were superimposed on top of the improved growth curve (Fig. 4).

Mortality and exploitation rate

The Z was found to be 2.97 yr^{-1}, while the M was calculated to be 1.63 yr^1 (Fig. 5). The F was determined to be 1.34 yr^1 based on the Z value. Based on

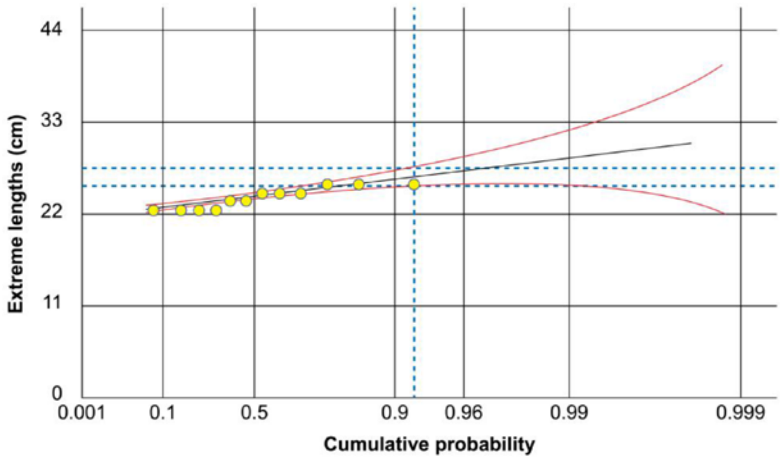

Fig. 2. The anticipated L_{max} value and the 95 % confidence level are determined by intersecting the inclusive L_{max} with the lines b and a, c, respectively.

Table 1. The length frequency values of *Nemipterus japonicus* from the coastal area of Bintulu, Sarawak, South China Sea.

Years	2013									2014		
Mid length (cm)	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
10.5										2		
11.5				11	3							
12.5				20	11							
13.5				3	17	1	3		3			7
14.5	3		4	2	9	4	19	3	12	1	3	14
15.5	6	5	6	22	2	18	24	10	15		7	15
16.5	10	13	12	36	13	25	31	24	11		9	26
17.5	13	18	18	29	19	24	21	29	21	2	25	30
18.5	21	23	19	16	25	20	11	25	38	8	31	31
19.5	25	24	19	4	18	18	8	12	19	6	25	34
20.5	10	5	20	5	20	11	8	4	11	16	15	17
21.5	6	3	10	2	8	5	3	2	2	24	3	8
22.5	4	5	4	1	2	1	3	2	1	25	1	4
23.5		3	2	1	1		2		1	12		2
24.5		1	1	1						7		
25.5			1		1		1					
	98	100	116	153	149	127	134	111	134	103	119	188

Table 2. Various population characteristics of *Nemipterus japonicus* collected from the coastal area of Bintulu, Sarawak, South China Sea.

Parameters	Values
$L\infty$	26.78
K	0.85
Lc	16.85
ϕ'	2.785
Z	2.97
M	1.63
F	1.34
E	0.45
E_{max}	0.806
N (Sample size)	1532

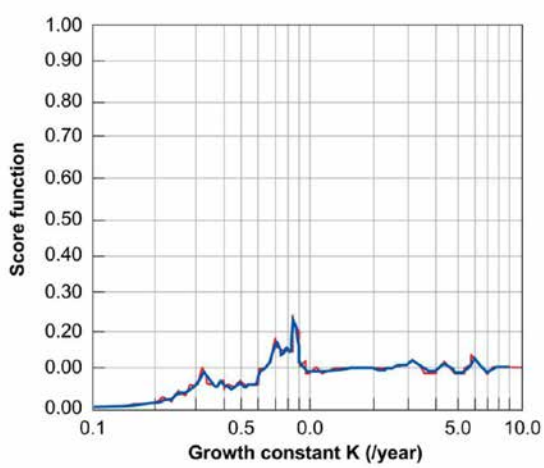

Fig. 3. The ϕ' of *Nemipterus japonicus* collected from Bintulu coast, Sarawak, South China Sea.

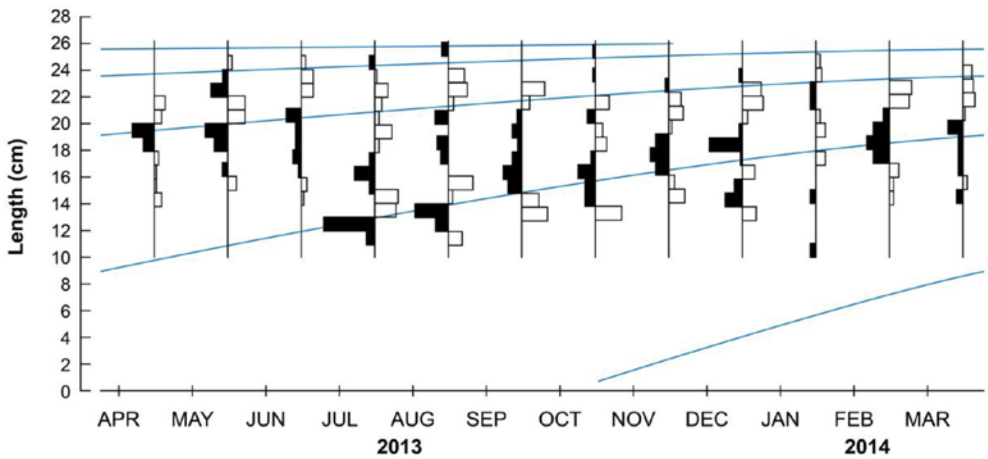

Fig. 4. The von Bertalanffy growth curves for *Nemipterus japonicus* (L∞ = 26.78 cm and K = 0.85 yr^{-1}) were overlaid on the reconstructed length frequency histograms.

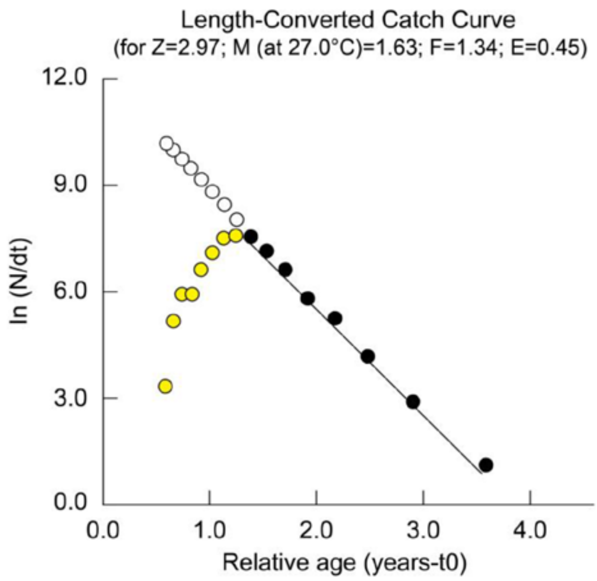

Fig. 5. Least square linear regression was used to calculate the length converted catch curve; darker complete dots reflect those spots, whereas open dots show those not fully recruited or approaching L∞. Using our formulas, we came up with mortality rates M of 1.63 and Z of 2.97.

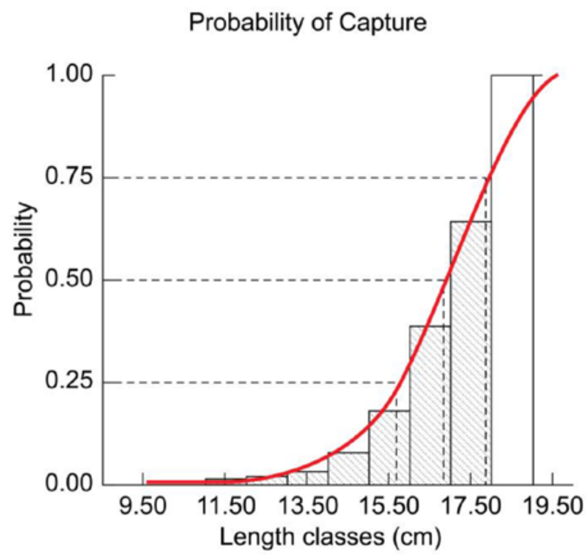

Fig. 6. Probability of capture of each length class of the *Nemipterus japonicus* ($L_{25\%}$=15.68 cm, $L_{50\%}$=16.85 cm and $L_{75\%}$=17.86 cm) from Bintulu coast, Sarawak, South China Sea.

these data, E of 0.45 was calculated, which was near to the optimal level (E=0.50).

Length at first capture

The $L_{50\%}$ =16.85 cm was derived from the examination of the likelihood of capture, and this is the result that was acquired. In this study, the length at which 75 % of *N. japonicus* remained in the gear was calculated to be $L_{75\%}$ =17.86 cm (Fig. 6).

Recruitment pattern

The pattern of recruitment of *N. japonicus* was consistent throughout the year, with a single peak in August? (Fig. 7). During the research period, the proportion of participants recruited ranged from 2.87 % to 21.32% of the total. The highest (21.32 %) was observed in November 2013 and the lowest (2.87 %) percent recruitment was in February 2014.

Virtual population analysis (VPA)

For the mid-lengths of 10.5 cm and 19.5 cm, the VPA of *N. japonicus* revealed that the lowest, F_{min} (minimum fishing mortality) and the F_{max} (maximum fishing mortality) were reported at 0.004 and 1.42 yr^{-1}, respectively (Fig. 8).

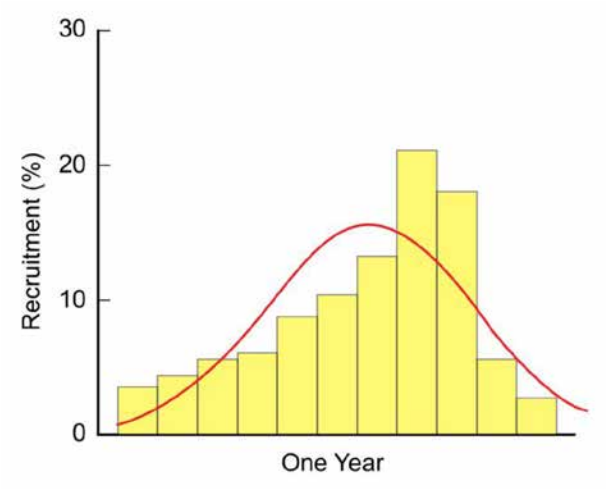

Fig. 7. One peak pulse in the study year was seen in the characteristics of recruitment of *Nemipterus japonicus* in the Bintulu coast, Sarawak, South China Sea.

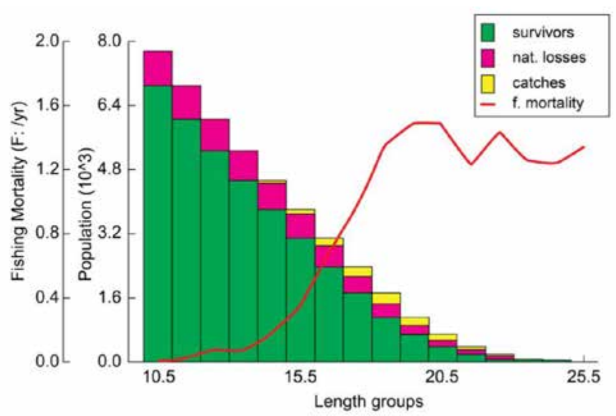

Fig. 8. Virtual population study of *Nemipterus japonicus* based on length in the Bintulu coast, Sarawak, South China Sea.

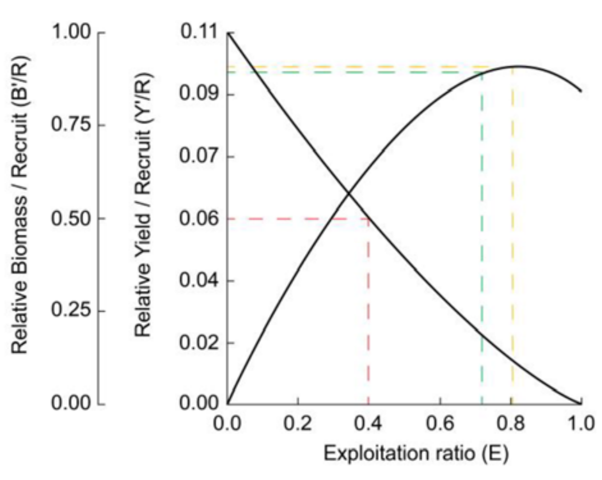

Fig. 9. The Y/R and B/R of *Nemipterus japonicus* by knife-edge procedure in the Bintulu coast, Sarawak, South China Sea.

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

The E_{max} that provides the maximum relative yield per recruit was calculated to be 0.806, which relates to the maximum relative Y/R (Fig. 9). The maximum and economic increases of Y/R at the exploitation rates were 0.806 (E_{max}) and 0.72 ($E_{0.10}$), respectively. The exploitation rate that reduces the biomass to 50% of its unexploited ($E_{0.5}$) one was 0.4.

Discussion

During the study, 1532 specimens of *N. japonicus* were studied, with lengths ranging from 10.5–25.5 cm. In accordance with the findings, the species of *N. japonicus* had L_∞ of 26.78 cm and K of 0.85 yr^1. Previous research revealed that the values of L_∞ varied from 24.5 cm to 34.5 cm and the values of K ranged from 0.27 year-1 to 1.0 year-1, respectively (Table 3). The lower value of L_∞ was recorded in Bay of Bengal by Mustafa (1994), while the higher was from Veraval water (Sen et al. 2014). For the K value the lower was from Pakistan water (Kalhoro et al. 2014) and the highest was from Madras (Vivekanandan & James 1986). The value of L_∞ obtained from the calculation was 26.78 cm, and the value of K acquired from the computation was 0.85 year^{-1}, which was considered the optimal value within the range for this species.

The K termed 'curvature parameter', which regulates how rapidly the fish approaches its L_∞ (Rahman & Cowx 2008) According to Adams (1980), species-specific ecological features, population size, and gene frequency all had a role in the disparities between documented L_∞ and K values. These factors which influenced by habitat and natural selection may cause to the different adaptation pattern during their life (Ulaski et al. 2020; Conover & Schultz 1997). Recent studies suggested that, the L_∞ and K of different fish species and biogeographic regions also might influenced by the climate change and global warming (Van Denderen et al. 2020, Wang et al. 2020, Borsetti et al. 2021).

The recorded growth performance index of *N. japonicus* in the current study was high compared to that recorded in previous works (Table 3). Performance index is important to determine the fish to be considered for aquaculture suitability. Fish often lose weight but rarely lose length so, that the ϕ may be less liable to biases (Mathews & Samuel 1990). Because of the differences in size composition across species and the technique of study, the differences in growth parameter and ϕ within various locales may be linked to these differences (Caramantin-Sori-

Table 3. The population parameters estimate of *Nemipterus japonicus* in various regions.

Reference	Localities	L_∞(cm)	K(yr⁻¹)	ϕ'	M(yr⁻¹)	F(yr⁻¹)	Z(yr⁻¹)	E
Krishnamoorthi (1971)	Andhra-Orissa coast, India	20.90	0.65	2.45	-	-	-	-
Krishnamoorthi (1971)	Andhra-Orissa coast, India	30.30	0.25	2.43	-	-	-	-
Krishnamoorthi (1973)	India (Andra, Orissa)	30.50	0.31	2.74	-	-	-	-
Lee (1975)	Hong Kong (females)	34.10	0.19	2.34	-	-	-	-
Lee (1975)	Hong Kong (males)	38.20	0.13	2.28	-	-	-	-
Murty (1984)	Kakinada	31.40	0.75	-	-	-	-	-
Pauly & Sann Aung (1984)	Northern Myanmar (Burma)	37.00	0.24	2.51	-	-	-	-
Pauly & Sann Aung (1984)	Southern Myanmar (Burma)	37.00	0.24	2.52	-	-	-	-
Ingles & pauly (1984)	Manila Bay, Philippines	30.00	0.70	2.80	-	-	-	-
Corpuz et al. (1985)	Carigara Bay, Philippines	23.50	0.730	2.61	-	-	-	-
Corpuz et al. (1985)	Samar Sea, Philippines	26.50	0.60	2.62	-	-	-	-
Edwards et al. (1985)	Gulf of Aden	29.10	0.31	2.42	0.85	0.45	0.67	-
Vivekanandan & james (1986)	Madras, India	30.50	1.00	2.97	2.50	0.45	2.98	-
Murty (1987)	Kakinada	33.90	0.52	2.78	1.11	1.53	2.64	-
Devaraj & gulati (1988)	India	29.80	0.82	2.86	-	-	-	-
Isa (1988)	Kedah, West Malaysia	31.50	0.53	2.72	1.18	2.84	4.02	0.71
Isa (1988)	Kedah, West Malaysia	31.40	0.55	2.73	1.21	2.51	3.72	0.68
Humayun et al. (1989)	Bay of Bengal, Bangladesh	26.50	0.60	2.62	1.32	3.39	4.71	-
Khan & Mustafa (1989)	Bangladesh	24.16	1.06	2.79	1.97	1.08	3.75	-
Iqbal (1991)	Northern Arabian Sea, Pakistan	28.80	0.46	2.58	-	-	-	-
Gopal & Vivekanandan (1991)	Veraval, India	33.70	0.73	2.91	-	-	-	-
Mathews & samuel (1991)	Kuwait	33.60	0.51	-	-	-	1.76	-
Murty et al. (1992)	Visakhapatnam, India	33.90	0.40	-	-	-	-	-
Breikaa (1992)	Gulf of Suez	28.64	0.50	2.61	-	-	-	-
Mustafa (1994)	Bay of Bengal	24.50	0.94	2.75	0.78	0.55	1.33	0.41
Chakraborty (1995)	Bombay, India	35.60	0.76	2.98	1.55	2.03	3.58	-
Breikaa (1996)	Gulf of Suez	29.27	0.46	2.60	-	-	-	-
Lavapie-Gonzales et al. (1997)	Philippine	28.30	-	-	-	-	-	-
Zacharia (1998)	Arabian Sea, off Karnataka, India	33.00	1.00	-	1.87	-	5.65	0.68
Mustafa (1999)	Bay of Bengal, Bangladesh	25.60	0.94	2.79	-	-	-	-
Ahmad et al. (2003)	West Malaysia	34.80	0.85	-	1.11	2.41	3.52	-
Rajkumar et al. (2003)	Off Visakhapatnam	34.00	0.52	-	1.11	2.41	3.52	0.69
El-ganainy & Mehanna (2003)	Gulf of Suez	28.35	0.63	2.79	-	-	-	-
Silvestre & Garces (2004)	Brunei	28.50	0.65	2.72	1.37	0.31	1.68	0.18
Joshi (2010)	Cochin, India (Male)	31.80	0.69	-	1.30	1.02	2.32	-
Joshi (2010)	Cochin, India (Female)	26.50	0.77	-	1.30	0.76	2.06	-
Joshi (2010)	Cochin, India (Pooled)	-	-	-	1.30	1.87	3.35	-
Amine (2012)	Gulf of Suez, Egypt	33.65	0.45	2.71	0.53	1.22	1.75	0.69
Kalhoro et al. (2014)	Pakistan waters	30.45	0.27	2.40	0.74	0.22	0.96	-
Sen et al. (2014)	Veraval, India	34.56	0.60	-	1.20	2.82	4.02	0.70
Present study	Bintulu coast, East Malaysia, SCS	26.78	0.85	2.79	1.63	1.34	2.97	0.45

Note: '-' (Not available)

ano et al. 2008, Mehanna et al. 2013, Kalhoro et al. 2017, Zain & Abdullah 2019).

For other species of *Nemipterus* such as *N. delagoa*, the estimated growth parameter for length frequency data at Tutocorin are L_∞ =36.2 cm and K=1.06^{XY}. The growth parameters of *N. mesoprion* from Mumbai waters (Chakraborty 2002) based on data from 1989-1994 reported as L_∞=27.4 mm, K=0.7628. The following parameter values of threadfin bream recorded from a Western Kalimantan, South China Sea (Pauly & Martosubroto 1980) was L_∞ =24.5 cm and K = 0.42. When compared to the other related demersal species, the stock of *N. marginatus* evaluated can only be fished more tightly and the optimal fishing method, including the amount of effort expended, the mesh size and the types of gear employed (O'Neill et al. 2018, Humphries et al. 2019, Lima et al. 2020, Robert et al. 2020, Salazar-Pérez et al. 2020). *Nemipterus randalli* was studied along the Arabian Sea coast of Oman by al-Kiyumi et al. (2014) estimating that L_∞=22.12 cm and K=0.64 year^{-1}. The Z, as well as M and F, were assessed to be 3.0, 1.4, and 1.6 respectively. The exploitation ratio and rate were computed and were found to be 0.53 and 0.51, respectively, in this study. The L_∞ of *N. delagoa* was the longest measured among the various species, while the shortest measured length (L_∞) was *N. randalli*.

The current research found that the F ranged from 0.22 to 2.82. The estimated M, which was comparable with those reported in previous studies with the ranged between 0.74 and 2.52. The Z measured by length converted catch curve for *N. japonicus* in Bintulu coastal water was 2.97 yr^{-1} and comparable to the value at Madras (2.985 yr^{-1}) reported by Vivekanandan & james (1986). The exploitation level of 0.45 shows that the *N. japonicus* fishery in Bintulu coastal waters was being under exploitation during the study periods. This was based on the premise that the stock was maximally exploited when the F was equal to M, or when E= (F/Z) = 0.5, or when F was equal to M.

Variation in M may be interpreted as a natural phenomenon influenced by both density-dependent variables such as predation and food availability as well as density-independent causes such as diseases and natural catastrophes, among others. It was observed that the mortalities varied within same species in different location (Sen et al. 2014).

A single recruitment event each year has been seen for *N. japonicus* (Fig. 6), which is in keeping with previous research by SEN et al. (2014) from Veraval water which found that the recruitment pattern for this species occurs constantly year round, with a top peak in May to July. It was found that between 2.71 and 16.25 % of those surveyed were successful in getting jobs. The month of June had the greatest rate of recruiting (16.25 %), while the months of January and November had the lowest rates.

Among other things, length at first capture is a significant input in the evaluation of relative Y/R and comparable B/R when using the knife edge selection procedure because it is assumed that fishes of smaller size than length at first capture were not caught by fishing gears (Beddington & Kirkwood 2005, Carruthers et al. 2014, Udoh & Ukpatu 2017).

It was determined in the present study that the greatest permitted limit of E_{max} that would result in the highest possible relative Y/R was assessed to be 0.8006. This is in contrast to the E that was found to be 0.45. Using the ideal value of 0.50 as a benchmark, it can be determined that the fisheries was being exploited optimally. This conclusion was reached after conducting a mortality-based exploitation rate study and calculating the relative Y/R. The results of these analyses suggested that the this species are exploiting below its ideal level. As a result, it is recommended that the fishing pressure on the stock be maintained at the present level or reduced. Furthermore, fish were captured before they reached maturity size, which may have an impact on the future population and stock size (Hutchings & Reynolds 2004, Pinsky et al. 2011, Ben-Hasan et al. 2021). Because of the decline in the mesh size of trawl nets at the cod-end, it is possible to see a fall in the lengths at first catch (LC_{50}), which may lead to recruitment overfishing over an extended period of time (O'neill & Kynoch 1996, Herrmann 2005, Sala et al. 2016, Robert et al. 2020).

Conclusions

Findings from the present study indicate that *N. japonicus* particularly peak during the post-monsoon period. The exploitation rate for the species was 0.45, indicating that the resource is being under exploitation. It is feasible to get further information on the other *Nemipterus* spp. of Sarawak using SCS in order to ensure their sustainable harvest and to estimate the probable stock.

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