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Original Article

Stock assessment of *Nemipterus japonicus* (Bloch, 1791) in Tha-Bawt-Seik coastal area, Dawei, Myanmar

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Abstract
The stock assessment of the threadfin beam, *Nemipterus japonicus*, collected from the Tha-Bawt-Seik of the Andaman Sea in Myanmar were analysed from January to December 2018. The purpose of this study is to evaluate the condition of the *N. japonicus* population. For all 1866 specimens, the asymptotic length (L_∞), growth rate (K) and growth performance index ($\acute{\emptyset}$) were 22.05 cm, 1.4 year^{-1} and 2.833 respectively. There were 4.89 year^{-1}, 2.47 year^{-1} and 2.41 year^{-1} for the total mortality rate (Z), natural mortality rate (M) and fishing mortality rate (Z) respectively. The maximum exploitation rate (E_{max}) was 0.703, while the exploitation rate ($E_{current}$) was 0.49. There were two main recruitment pulses in the pattern of continual recruitment. When the dry season began, threadfin beams became one of the principal species in Tha-Bawt-Seik. The outcomes of the study showed that while the *N. japonicus* stock is currently safe; there are signs of growth overfishing and any rise in the existing pace of exploitation is likely to exacerbate this issue.

Keywords: Andaman Sea; exploitation rate; growth rate; stock; threadfin

1 | INTRODUCTION

Nemipterus japonicus (Bloch, 1791), a member of the Nemipteridae family, is known for its pinkish body colour, silvery underbelly, and 11–12 thin golden-yellow stripes that extend from the base to the base of the fish's head (Elhaweet 2013). Fisheries across the Indo-West Pacific region are heavily interested in nemipterid fishes, which include threadfin breams, whiptail breams, monocle breams, dwarf monocle breams and coral breams. It covers a large area of the Indo-Pacific region, extending from India in the east to the Arabian Sea in the west, the Sea of Japan in the north, Australia in the south and so on (Russell 1990; Elhaweet 2013; Ning *et al*. 2015; Imtiaz *et al.* 2016; Farivar *et al*. 2017; Ogwang *et al*. 2021).

Nephipterid fishes are one of the most abundant species along the coastal areas in Myanmar (Druzhinin and Phone Hlaing 1972; Pauly and San Aung 1984). From a business perspective, all species are grouped together under the common name "threadfin," which is referred to locally as "Shwe Ngar" or "Ngar Ni". Among the 15 economically significant fish species in Myanmar, threadfin beams (*Nemipterus* spp.) are important ones. It was noted that Yangon, one of Myanmar's main fish landing places, received 3040.45 tonnes of threadfin beams in 2005, accounting for 5.89% of all marine fishes (FAO 2024).

Nemipterus species are found on mud and sand bottoms in coastal inshore and offshore areas, with depth ranging up to around 300 m, while the majority of species are found in considerably shallower water (Russel 1990). *Nemipterus japonicus* is also one of the most common inshore fish species in the area. This species is found from extremely shallow depths up to a maximum of roughly 50 m (Eggleston 1972). It is an inshore species (Isa 1988). Local knowledge indicates that *N. japonicus* can be captured at a depth of 10 m. A vast majority of threadfin beams were primarily caught by bottom trawl nets in offshore fishing boats in Myanmar. However, they can be captured with gill net, drift net, and bottom long lines near the coastal areas (DoF and SAFDC 2009).

Planning and managing marine resources may benefit from the knowledge gained from population dynamics research, which offers data on a variety of population characteristics, including asymptotic length, growth coefficients, mortality rates from fisheries and natural sources and the degree of exploitation (Nurul Amin *et al*. 1999, Al-Mamun *et al*. 2021). Thabawseik landing area is a seaside village located in Long Lone township, Dawei District, Myanmar. It is also close to the well-known and prominent Maung Makan beach. The people of that village are mainly engaged in fishing and it is also the main distribution point of marine fish for all the four townships in Dawei district. The number of the inshore fishery boats in Dawei, Rephyu, Tharet Chaou, Longlong also transported their fishes into Tha-Bawt-Seik. So this village has a beach market where they sell marine fish. Over thirty studies have been conducted worldwide to examine the population dynamics of *N. japonicus* (Tonie *et al*. 2023). Although some information on *N. japonicus* was originally recorded in 1984 in the waters around Myanmar by Pauly & Sann Aung, the species has not been researched in the Tha-Bawt-Seik coastal area (Pauly and Sann Aung 1984). The goal of the current investigation was to fill in the gaps about *N. japonicus* population dynamics. Estimating the population features and exploitation rate of *N. japonicus* was one of the main objectives of this study, which was to assess the state of the species' stock in the coastal regions of Tha-Bawt-Seik, Dawei, Myanmar and the Andaman Sea.

2 | METHODOLOGY

2.1 Study area

Samples of threadfin breams *N. japonicus* were collected from commercial fish landing station at Tha-Bawt-Seik (14°06′8″N, 98°06′15″E) during the period of January to December 2018 (Figure 1).

2.2 Growth parameters

The length frequency data were divided into groups using three-centimetre intervals. According to Gayanilo *et al*. (1996), the computer software program's FISAT II was used to examine the data. We used the ELEFAN-I software package, which is part of the FiSAT II software package, to find the growth co-efficient (K) and asymptotic length (L_∞) of the von Bertalanffy equation for increase in length. To find out if the K value was accurately assessed, the K scan procedure was used. The evaluated L_∞ and K were used to calculate the growth performance index, or ϕ', using the following formula: $\phi' = 2 \log 10\ L_\infty + \log 10\ K$. The potential longevity (t_{max}) of the studied species was ascertained in accordance with Pauly (1984) and Taylor (1958), who obtained at their conclusions by utilizing the equation $t_{max} = 3 / K + t_0$.

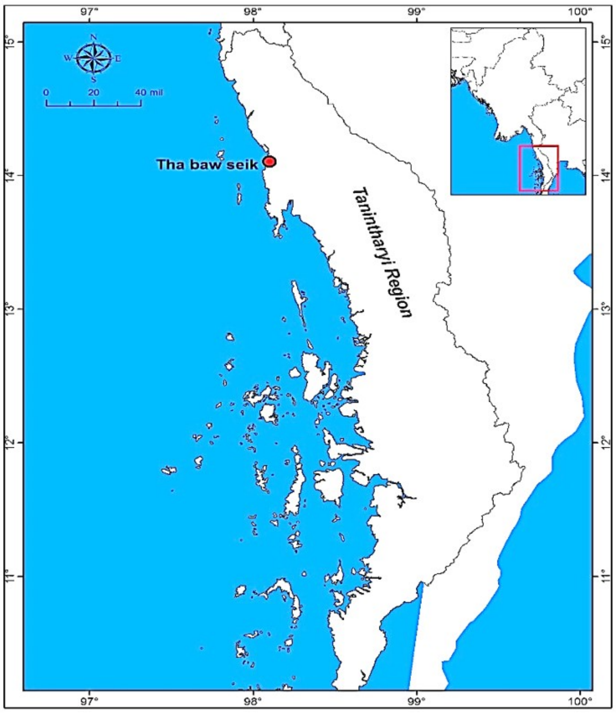

FIGURE 1 Map showing the sampling site in Tanintharyi region of Myanmar.

2.3 Mortality parameters

The total mortality coefficient (Z) was calculated by converting the catch curve by the length (Pauly 1984). Pauly's empirical relationship (Pauly and Martosubroto 1980) states that the empirical formula derived from the empirical relationship was used to estimate the M (natural mortality rate). Log10 M is equal to $-0.0066 \log 10\ L_\infty + 0.6543 \log 10\ K + 0.4634 \log 10\ T$. The yearly mean temperature (29°C) of the habitat water is denoted by T in this equation. As soon as Z and M values are known, it is possible to determine fishing mortality (F). The F was calculated as $F = Z - M$. The exploitation level (E) was estimated by $E = F / Z = F / (F + M)$ (Gulland 1971). The formula for estimating the greatest fishing effort (F_{max}) is $F_{max} = 0.67\ K / 0.67 - L_c$ (Hoggarth *et al.* 2006), where L_c is equal to L_c 50 / L_∞. According to Patterson (1992), the computation of the cautious limit reference point (F_{limit}) was $F_{limit} = (2 / 3) \times M$. According to Pauly (1984), the cautious target reference point (F_{opt}) was computed as follows: $F_{opt} = 0.4 \times M$.

2.4 Length at first maturity

Using the method developed by Hoggarth *et al*. (2006), the length at first maturity (L_{m50}) for the evaluated species was calculated as follows: Length at first maturity (L_{m50}) = $2 / 3 \times (L_\infty)$. The model's input parameters consisted solely of asymptotic length (L_∞). The age at length equation, developed by Goonetileke and Sivasubramania (1987), was used to determine the age at first maturity

(t_{m50}): $t_{m50} = -(1 / K) \text{Ln} (1 - L_{m50} / L_{\infty}) + to$, where L_{m50} is the length at first maturity.

2.5 Probability of capture

The process described in the FISAT II tool (Gayanilo *et al.* 2005) was used to determine the chance of capture. The length at first capture (L_{c50}) was determined to correspond to the cumulative probability at 50% by graphing the cumulative probability of capture against mid-length. Furthermore, the lengths at which 25% and 75% of the stock is caught were determined by comparing them to the corresponding cumulative probabilities at those percentages. According to Beverton and Holt (1957), the age at first capture (t_{c50}) was calculated as follows: $t_{c50} = -(1 / K) \text{Ln} (1 - L_{c50} / L_{\infty}) + t_0$.

2.6 Recruitment pattern

The process outlined in the FiSAT routine (Gayanilo *et al.* 2005) was used to obtain the recruitment pattern. According to Gheshlaghi *et al.* (2012), the mid length of the smallest length interval was used to estimate the length at initial recruitment (L_{r50}). According to Beverton and Holt (1957), the age at first recruitment (t_{r50}) was calculated as follows: $t_{r50} = -(1 / K) \text{Ln} (1 - L_{r50} / L_{\infty}) + t_0$.

2.7 Relative yield per recruit and relative biomass per recruit

The predicted growth parameters and the probability of capture by length were used to calculate the relative yield per recruit (Y/R) and relative biomass per recruit (B/R) values as a function of *E* (Pauly and Soriano 1986). Using the Knife-edge option in the FiSAT II, the maximum exploitation rate (E_{max}), which denotes the exploitation rate producing maximum yield, the exploitation rate at which the stock is 10% of its virgin stock ($E_{0.1}$), and the exploitation rate under which the stock is reduced to half of its virgin biomass ($E_{0.5}$) were calculated.

2.8 Virtual population analysis (VPA)

The estimated length structured VPA was carried out using the FiSAT method (Gayanilo *et al.* 2005). The inputs for the species were the values of the L_{∞}, K, M, F, a (constant) and b (exponent). It was estimated that the t_0 value was zero. Using the formula $W = aL^b$, where W is the body weight and Length is the matching standard length, the constants a and b for the species were calculated from the length-weight connection (Pauly 1984). The approach by Jones (1984) was followed in order to calculate the biomass (tons), yield (tons), total and fishing mortality and exploitation ratios using the length-based VPA**.**

2.9 Yield isopleth

Using the FiSAT II Tool (Gayanilo *et al.* 2005), yield contours that characterise yield isopleth were plotted to determine the impact on yield based on changes in exploitation rate (E_{max}) and critical, which is length at initial capture (Lc_{50}) to asymptotic length (L_{∞}) ratio.

2.10 Catch rate for seasonal abundance

The catch rate was determined by using the following equation. CPUE = Catch / fishing boats or fishing day trips.

3 | RESULTS

3.1 Growth parameters of *N. japonicus*

The results showed that the expected and observed extreme lengths (L_{max}) were 21 cm and 22.79 cm respectively. The corrected growth curve was overlaid with the reconstructed length-frequency histograms (Figure 2). With a 95% confidence level, the extreme length range was found to be between 21.43 and 24.16 cm (Figure 3). The growth coefficient (K) was best estimated to be 0.85 year^{-1}. The asymptotic length was found to be L_{∞} = 26.78 cm and the response surface (R_n) value was found to be 0.261. The growth performance index (ϕ') of *N. japonicus* during the current experiment was calculated to be 2.833 (Figure 4). The length frequency values employed in this investigation as well as the population parameter results were also considered (Table 1 and 2).

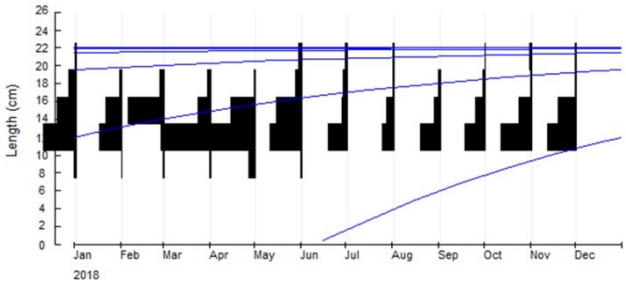

FIGURE 2 Restructured length-frequency data of *Nemipterus japonicus* superimposed with the estimated growth curve.

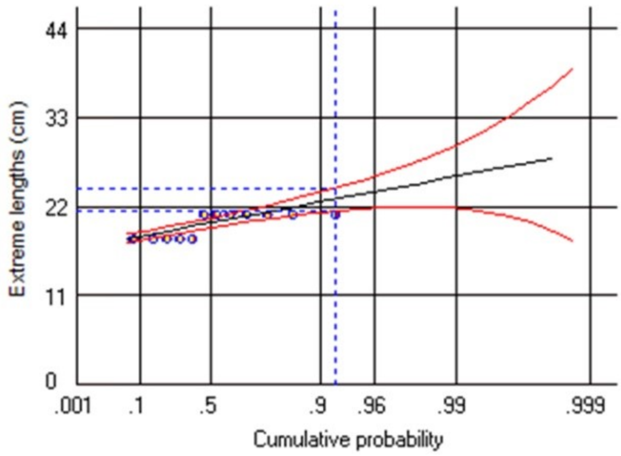

FIGURE 3 The anticipated L_{max} value and the 95% confidence level, determined by intersecting the inclusive L_{max} value.

3.2 Mortality and exploitation rate

The total mortality (Z) was determined to be 4.87 year^{-1}, while the natural mortality (M) was calculated to be 2.47 year^{-1}. The Z value led to the determination that the fishing mortality (F) was 2.41 year^{-1}. Exploitation rate ($E_{current}$) of 0.49 was computed using these data, which was quite close to the ideal level (E = 0.50) (Figure 5). The optimum fishing rate (F_{opt}), maximum fishing limit (F_{max}) and the precautionary fishing limit (F_{limit}) were 0.98 year^{-1}, 4.65 year^{-1} and 1.63 year^{-1} respectively.

TABLE 1 The length frequency values of *Nemipterus japonicus* from the coastal area of Tha-Bawt-Seik, Dawei, Myanmar, Andaman Sea.

Length Interval (cm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9	4	2	4	4	22	4	0	0	0	0	0	0
12	104	74	12	158	166	104	60	38	64	66	100	94
15	62	52	117	40	82	84	18	24	18	32	41	60
18	22	10	14	10	4	22	14	4	4	6	4	6
21	2	0	0	0	0	10	6	2	0	2	8	6

TABLE 2 Various population characteristics of *Nemipterus japonicus* collected from the coastal area of Tha-Bawt-Seik, Dawei, Myanmar, Andaman Sea.

Parameters	Values
L_∞	22.05 cm
K	1.4 year^{-1}
ϕ'	2.833
Z	4.89 year^{-1}
M	2.47 year^{-1}
F	2.41 year^{-1}
$E_{current}$	0.49
E_{max}	0.703
F_{opt}	0.98 year^{-1}
F_{max}	4.65 year^{-1}
F_{limit}	1.63 year^{-1}
L_{m50}	14.7 cm
L_{c50}	10.45 cm
L_{r50}	8 cm
t_{max}	2.14 year
t_{m50}	0.63 year
t_{c50}	0.45 year
t_{r50}	0.31 year
N (sample size)	1866

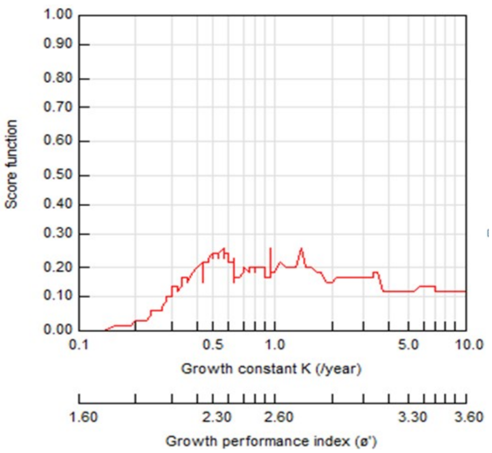

FIGURE 4 The ϕ' of *Nemipterus japonicus* collected from the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

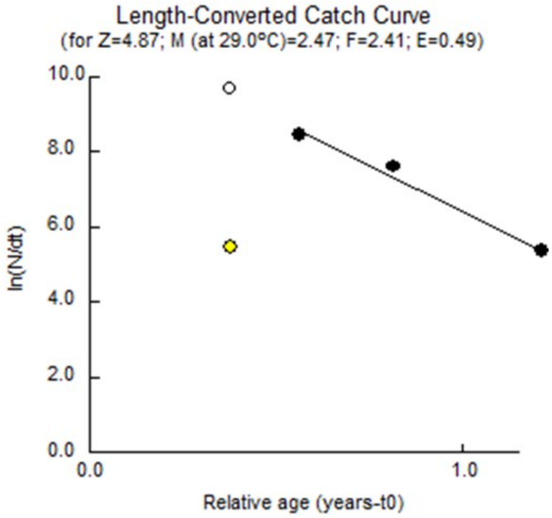

FIGURE 5 The length-converted catch curve of *Nemipterus japonicus* collected from the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

3.4 Probability of capture and Length at first maturity (L_{m50})

The lengths at which 25% (L_{c25}) and 75% (L_{c75}) of the stock were seized were 8.20 cm and 12.72 cm respectively, while the length at first capture (L_{c50}) was 10.45 cm (Figure 6). It was estimated that the length at first maturity (L_{m50}) was 14.7 cm. The age at first maturity (t_{m50}) and first capture (t_{c50}) were estimated 0.63 and 0.45 years.

3.4 Recruitment pattern

The recruitment pattern using the FISAT II tool (Figure 7) indicated two significant recruitment peaks, with the one peak occurring in April to June, and the other peak occurring in September and October, based on the size distribution of the catch. The length at first recruitment (L_r) measured by macro examination was 8 cm while the age at first recruitment (t_{r50}) was calculated as 0.31 years.

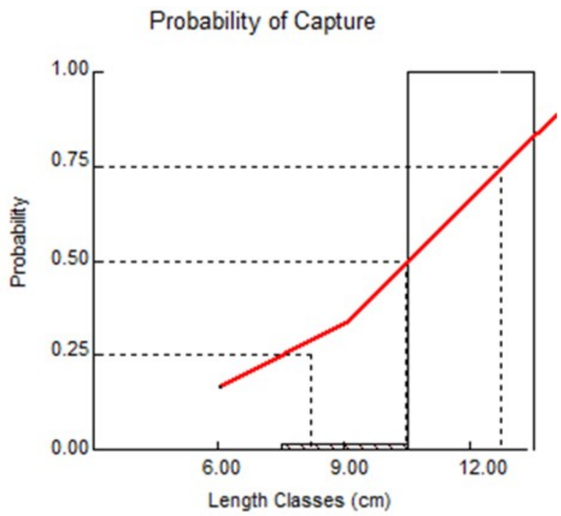

FIGURE 6 Probability of capture of each length class of the *Nemipterus japonicus* ($L_{25\%}$ = 8.20 cm, $L_{50\%}$ = 10.45 cm and $L_{75\%}$ = 12.72 cm) from the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

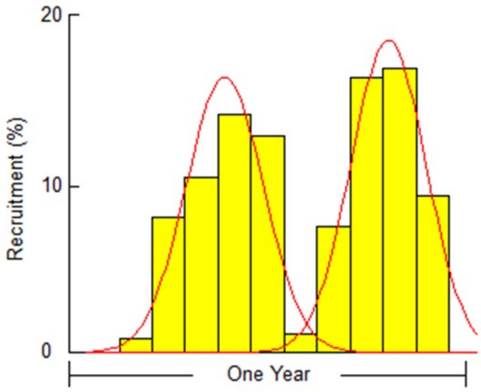

FIGURE 7 The characteristics of recruitment pattern of *Nemipterus japonicus* in the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

3.4 Virtual population analysis (VPA)

The bulk of *N. japonicus* were harvested between 10 and 12 cm, according to VPA data, with *F* values reaching 1.90 per year. In the length range of 13 to 15 cm, the *F* peaked at the highest rate ($F = 2.648$ year^{-1}; Figure 8).

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

The greatest relative Y/R is related to the E_{max}, which yields the maximum relative yield per recruit (0.703). At the exploitation rates, the maximum and economic increases of Y/R were 0.703 (E_{max}) and 0.601 ($E_{0.10}$) respectively. The biomass was reduced to half of its unexploited ($E_{0.5}$) amount at an exploitation rate of 0.354 (Figure 9).

3.6 Yield isopleths

The response of the fish recruit to variations in L_c = 0.47 and E = 0.49 (Figure 10). Based on the yield isopleths, *N. japonicus* is predicted by the yield contours for Tha-Bawt-Seik coastal waters, which fall within Quadrant B.

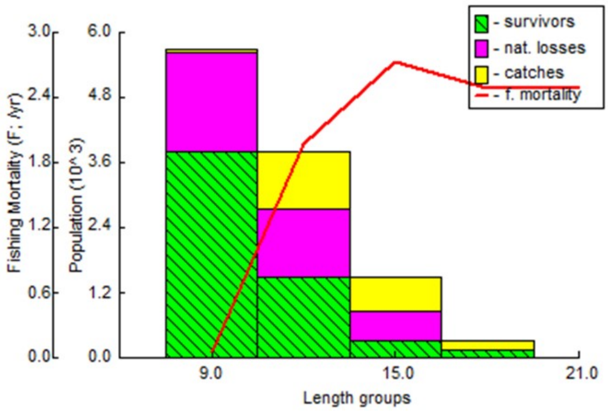

FIGURE 8 Virtual population study of *Nemipterus japonicus* based on length in the coastal area of Tha-Bawt-Seik, Dawei, Myanmar, Andaman Sea.

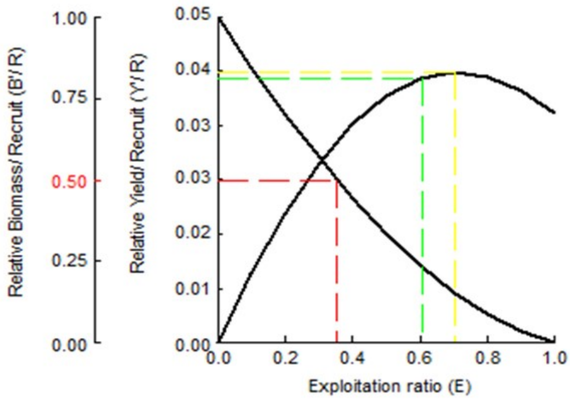

FIGURE 9 The Y/R and B/R of *Nemipterus japonicus* in the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

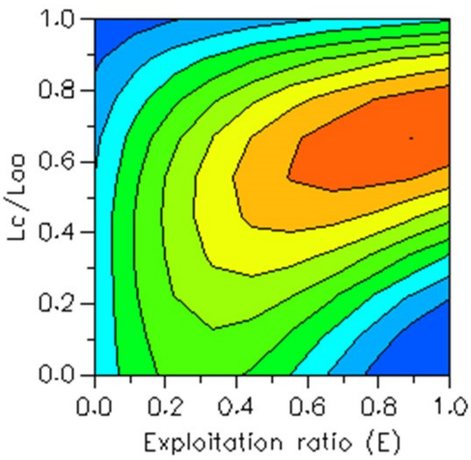

FIGURE 10 The Y/R and B/R of *Nemipterus japonicus* in the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

3.7 The seasonal abundance of *N. japonicas*

The average monthly catch of the *N. japonicus* was the highest in November and December and the lowest in May. From November to March, the catch weight and the number of *N. japonicus* fish increased, but from April to July, the catch weight and the number decreased, reaching their lowest point in May. The catch weight was highest in September, while the number declined between September and October (Figure 11A).

The number of boats and trip days for CPUE were used in the fishing efforts. These two fishing operations had an increase from October to February, then a sharp decrease from March to May. The least amount of fishing was done throughout the year from May to July. However, the efforts substantially rose in August before sharply declining in September and October (Figure 11B).

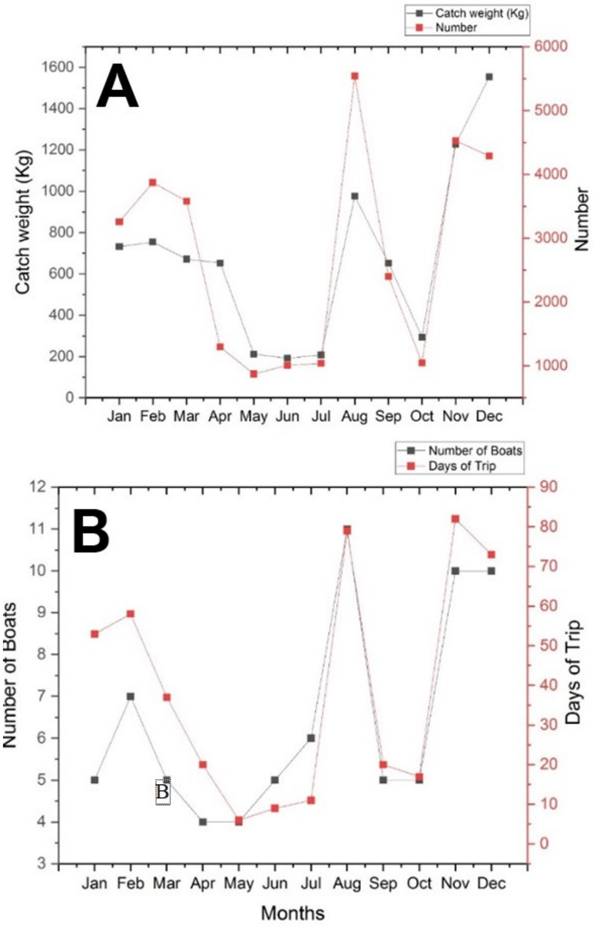

FIGURE 11 (A) Monthly catch weight (kg) and (B) number of boats of *Nemipterus japonicus* in the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

From November to January, both the rates of CPUE kg/boat and the CPUE kg/days increased. However, in February, the CPUE rates somewhat decreased before increasing again in March. In September, the CPUE rate was at its greatest. Between May, June, and July, there is a considerable difference in CPUE kg/boat and CPUE kg/days. CPUE kg/day rates peaked in June and were slightly higher during these months overall, but CPUE kg/boat rates fell precipitously during these months relative to earlier ones. CPUE kg/boat, which peaks in June, is not significantly lower in May to July than it is in other months, although it is lower than other months (Figure 12).

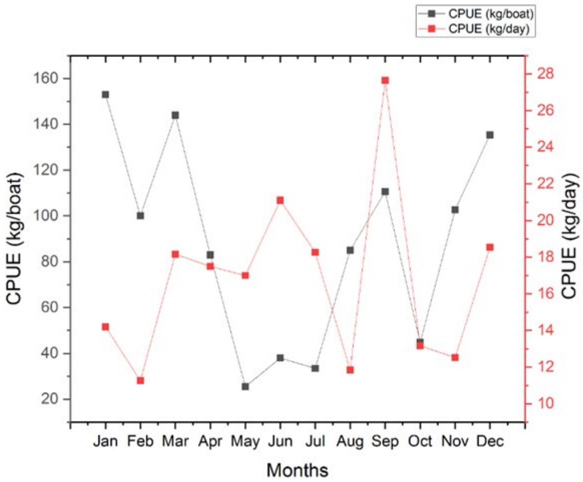

FIGURE 12 Monthly catch per unit effort of *Nemipterus japonicus* in the coastal area of Tha-Bawt-Seik, Dawei, Myanmar.

4 | DISCUSSION

The focus of this investigation was limited to the inshore stock below a depth of 10 meters. In Myanmar, this species is primarily harvested by offshore fishing vessels using bottom trawl nets, although it is also obtainable in significant quantities from inshore locations using drift gill nets.

According to earlier studies, the values of Lα from 20.9 cm to 35.6 cm and the values of *K* ranged from 0.27 to 1.06 year^{-1} respectively (Table 3). Therefore, the value of L_{α}, which was determined to be 22.05 cm and it was comparatively shorter and the computed value of *K* (1.4 year^{-1}) was higher than the range. There have been significant differences in the stock's depth between the current study and previous research, which explains why the *K* value is higher than in past studies. The reasons for the varying outcomes could include variations in the biggest fish that were captured, the duration of the sample period, the depth distribution of the stock, computational methods, and other environmental conditions (Rijavec 1973; Pajuelo and Lorenzo 1998; Amponsah 2016).

Fast growth is indicated by $K = 1.0$, medium growth by $K = 0.5$ and slow growth by $K = 0.2$. It was clear from this species' greater growth coefficient of 1.0 that they often grow quickly and have short lifespans (Sparre and Venema 1992). The length frequency approaches indicate that the species' longevity (t_{max}) was 2.14 years. Most previous studies suggested that the maximum life span of *N. japonicus* was 3 – 5 years and short lived species (El-Ganainy and Mehanna 2003; Amine 2012; El Haweet 2013; El-Ganainy *et al.* 2018; Ninawe *et al.* 2018).

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

Reference	Localities	L_∞ (cm)	K ($year^{-1}$)	Ǿ	*M* ($year^{-1}$)	*F* ($year^{-1}$)	*Z* ($year^{-1}$)	*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 and 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 and 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 and 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 and Vivekanandan (1991)	Veraval, India	33.70	0.73	2.91	-	-	-	-
Mathews and 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 and Mehanna (2003)	Gulf of Suez	28.35	0.63	2.79	-	-	-	-
Silvestre and 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
Khileri *et al.* (2017)	Veraval, Gujarat	26.8	0.75	4.73	1.50	1.64	3.14	0.52
Rao *et al.* (2018)	North east coast of India (northern region)	33.02	0.38	2.62	0.92	0.51	1.43	0.35
Rao *et al.* (2018)	(southern region)	29.8	0.42	2.57	1.01	0.57	1.58	0.36
Tonie (2023)	Bintulu coast, East Malaysia, South China Sea	26.78	0.85	2.79	1.63	1.34	2.97	0.45
Present study	Tha-Bawt-Seik, Dawei, Myanmar, Andaman Sea	22.05	1.4	2.833	4.89	2.47	2.41	0.49

The current study, however, did not support the hypothesis that *N. japonicus* can live up to eight years and that the fish cannot live for more than ten years (Lee 1975; Granada *et al.* 2004). Better growth comparisons between populations and ecosystems are possible through the use of the growth performance index, which is based on growth model parameters (VaKily 1988). As the most adaptable and accurate growth performance estimator, Ǿ value may be less subject to biases because fish frequently lose weight but infrequently lose length

(Mathews and Samuel 1990). The growth performance index (Ǿ = 2.8) in the present study was also within the range of values from stocks of *N. japonicus* previously recorded in other areas. Fish are able to develop larger and faster, as shown by the higher growth performance index number (Kalhoro *et al*. 2015).

Mortality and growth rates are closely linked. Growth influences a fish's susceptibility to fishing and predators, and it mostly establishes what food each fish needs to survive (Allen and Hightower 2010). Furthermore, the fishery and natural predators rely on the growth of individual fish to provide catch and prey. Because there are more natural losses (more predators) in small, quickly growing fish, natural mortality increases with temperature (Pauly 1984).

The nearly identical natural mortality (M = 2.47 year^{-1}) and fishing mortality (F = 2.41 year^{-1}) show that the stock is being used to its full potential and is safe (Beverton and Holt 1957). The maximum fishing rate was higher than the computed F, despite the fact that the estimated limiting fishing mortality rate and optimal fishing mortality were lower than the F. This finding confirms that *N. japonicus* is not too utilised (Amponsah 2016).

The calculated F was equivalent to the values at West Malaysia and Off Visakhapatnam and the forecasted M was similar to the values at Madras (2.50 year^{-1}). The M was similar to that of the Bay of Bengal in Bangladesh (Vivekanandan and James 1986; Humayun *et al*. 1989; Ahmad *et al.* 2003; Rajkumar *et al.* 2003). Variation in M can be understood as a natural phenomenon that is impacted by a variety of density-dependent factors, including diseases and natural disasters, as well as density-dependent variables like food supply and predation. It was noted that different locations showed variable mortality rates within the same species (Sen *et al.* 2014).

In general, if the Z/K ratio is less than 1, the population is dominated by growth; if it is larger than 1, the population is dominated by mortality; and if it is equal to 1, the population is in an equilibrium condition where growth and mortality are balanced (Barry and Tegner 1989). A mortality-dominated stock is considered weakly utilized when Z/K is equal to 2, whereas a mortality-dominated stock that is intensively exploited is indicated by a Z/K ratio greater than 2. According to the study, the Z/K ratio was 3.47, suggesting that the *N. japonicus* stock in the studied area is intensively exploited and dominated by mortality (Etim *et al*. 2002).

There may have been growth overfishing in the *N. japonicus* population because the estimated length at first maturity was greater than the comparable length at first capture (Amponsah *et al*. 2016). It appears from the VPA result that fish smaller than 14.7 cm were harvested at a comparatively higher rate. This kind of circumstance is a sign of growth overfishing, in which smaller fish are taken before they can contribute to the biomass of the population.

As a result, any increase in the current exploitation rate will likely accelerate the already-occurring growth overfishing. The current exploitation rate of *N. japonicus* in the study area indicates that exploitation has reached its optimum exploitation level based on the optimization category of E = 0.5 for sustainable exploitation of fish species (Pauly 1984). Fish landing was comparatively less than the MSY, though, as indicated by the fact that the current exploitation rate was less than the maximum exploitation rate.

The present study's twofold recruitment peaks claim that double recruitment pulses annually are a common occurrence in tropical fish species (Pauly 1984) The fact that practically all recruitment happens year-round demonstrated that spawning takes place almost year-round and that recruitment is not dysfunctional. Previous research has discovered one recruitment pattern for *N. japonicus* along the Bintulu Coast of Sarawak in the South China Sea, as well as three recruitment pattern with two major peaks and one minor peak, and one recruitment pattern in Veraval, Gujarat (Sen *et al.* 2014; Khileri *et al*. 2017; Tonie *et al*. 2023).

Since juveniles are recruited into the stock before they are harvested, the computed length at first recruitment was less than the length at first catch, indicating that the *N. japonicus* fishery is currently active in terms of recruitment. The majority of individuals at the length of the first recruitment, according to the results of the virtual population analysis, apparently became survivors, supporting the claim that the recruitment process within the *N. japonicus* fishery in the coastal water is functional (Amponsah *et al*. 2016).

The estimated age at first maturity (t_{m50}) of 0.63 years suggested that *N. japonicus* first becomes matured during their transition into the one year. The computed age at first capture (t_{c50}) of 0.45 years indicated that majority of the stock moving into their 0.45 years become vulnerable to capture by any fishing gears after their birth. The age at first recruitment (t_{r50}) of 0.31 years in population implied that newly produced *N. japonicus* get recruitment into the stock before 0.31 years. The *N. japonicus* fishery is in its eumetric or developing stage, as shown by the quadrant B category from the yield isopleth (Pauly and Soriano 1986). *Nemipterus japonicus* fishing is described as "catching small size fishes at low fishing effort level, hence requiring no management intervention" using the same quadrant rule that is used to assess fisheries. However, if fishing attempts continue to climb, mesh sizes should be increased as a preventive measure to avoid the potential collapse of this significant fishery.

5| CONCLUSIONS

Tha-Bawt-Seik coastal region is currently experiencing ideal exploitation of the *N. japonicus* fishery, but there are indicators of overfishing growth, which could have a negative impact on the size of the population and food security within vulnerable fishing households in the future. Thus, to avert the consequences of growth overfishing, sustainable fisheries measures including monitoring of fishing efforts and increase in mesh size should be implemented and enforced.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request to the corresponding author.

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