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Growth and mortality rates of ornate threadfin bream, *Nemipterus hexodon*, in Banate Bay, Philippines

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Abstract
Growth and mortality rates of ornate threadfin bream *Nemipterus hexodon* in Banate Bay were analyzed using total samples of 2,417 from multiple hooks and line, handlines, and gillnets. The von Bertallaffy growth parameters L_∞ K, and ϕ' were 25.80 cm, 0.63 year^{-1}, and 2.61, respectively. The mortality parameters Z, M, and F were 1.87 year^{-1}, 1.38 year^{-1}, and 0.49 year^{-1}. The *N. hexodon* in Banate Bay is underfished (0.26 < $E_{0.5}$ (0.49), this suggests that fishing efforts utilizing environmentally favorable gears can be increased by 47% to increase catch yield. This study gives estimates of growth and mortality rates, which may be utilized as biological input variables in future stock assessments in the bay. The Local Government Units (LGUs) surrounding Banate Bay should maintain their relevant effective fisheries management practices in order to have a sustainable supply of this species, as it is essential for both the supply of dietary protein and the livelihood of fishermen.

Keywords: Banate Bay, growth parameters, mortality rate, exploitation rate, nemipterid

1. Introduction
The demersal fish ornate threadfin bream *Nemipterus hexodon* is found from the Indian Ocean to the Pacific Ocean but is absent from the eastern Pacific and Atlantic Oceans. It is one of the most abundant catches in Southeast Asian trawl fisheries (Russell *et al.*, 2016; Stobutzki *et al.*, 2006) [22, 26]. *Nemipterus hexodon* flesh is white and gels better than red-fleshed fish (Hastuti *et al.*, 2017) [11]. From 2019 to 2021 data, it has been estimated that the Philippines produced 32,872 metric tons of various threadfin bream species worth Php4, 283, 577, 000 annually. Also, from 2019 to 2021, Region VI – Western Visayas, where Banate Bay is located, was the leading producer of nemipterid fish (Nemipteridae) in the country, with an annual production of 7,900 metric tons valued at approximately Php1,186,598,000 pesos (PSA, 2022) [19].
Ornate threadfin breams, locally known as "lagaw", are economically important in Banate Bay which is part of the bigger Visayan Sea fishing ground located in the central part of the country and home to numerous high-value species, including tuna, herring, mackerel, blue swimming crabs, sardines, and other fish. *Nemipterus spp.* had previously been identified as a demersal finfish resource exploited in Philippine waters, notably in Honda Bay (Schroeder, 1977) [23], the Guimaras waters (Balisco & Babaran, 2012) [3], and the Visayan Sea (Guanco *et al.*, 2009) [8]. However, no scientific studies on the species of *Nemipterus hexodon* have been undertaken in Banate Bay to examine its exploitation level and population dynamics.
This study was conducted to analyze these parameters for *Nemipterus hexodon* due to the importance of basic biological attributes, such as growth parameters and mortality estimates, for efficient decision-making. Additionally, to help manage the fishery for the sustainability of this species in the Banate Bay fishing ground.

2. Materials and Methods
2.1 Study Site and Data Gathering
Data were gathered twice weekly in Banate Bay (10°58'26" N, 122°48'11" E) from August 2020 to July 2021 (Figure 1). The *N. hexodon* was weighed using a 5,000 g Cascade digital weighing scale to the nearest 0.01 g. Using a 30-cm measuring board, the total length (TL) was measured to the nearest 0.1 cm. Identification keys from Carpenter and Niem (2001) [4] were used to identify the *N. hexodon* species (ornate threadfin bream).

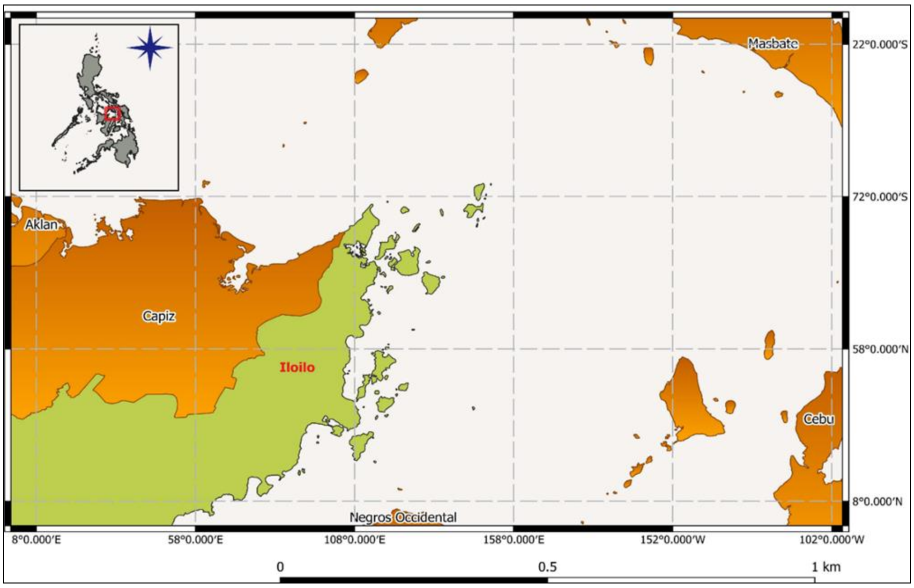

Fig 1: Map showing the study site in Banate Bay (red circle).

2.2 Length-weight relationship (LWR)

The length-weight relationship was computed from the equation (Le Cren, 1951) [13]:

$$W = aL^{b}$$

where W is the total fish weight (g), and L is the total fish length (cm). The parameters a and b describe the length-weight relationship, where a is a coefficient related to the body form, and b is an exponent indicating isometric growth when equal to 3 (Pauly, 1984) [18]. Its logarithmic form was computed using the formula:

$$\log W = \log a + b \log L$$

where log L is the logarithm of the total fish length (cm), log W is the logarithm of weight (g), log a is a logarithm coefficient, and log b is the logarithm of the exponent. Through linear regressions, this logarithmic form was utilized to calculate the significance level of r^2.

2.3 Growth parameters

The theoretical age at birth (t_0) was estimated using Pauly's empirical formula (1979):

$$\log_{10}(-t_0) = -0.3922 - 0.275 * \log_{10} L_\infty - 1.038 * \log_{10} K$$

where t_0 is the theoretical age at length zero year), L_∞ is the asymptotic length (cm), and K is the growth constant (yr^{-1}).

The growth performance index was determined from the equation of Munro and Pauly (1983) [14]:

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

Where ϕ' is the growth performance index, L_∞ represents the asymptotic length, and K is the VBGF curvature parameter (Growth constant).

The values for L∞ and K from the corrected length-frequency data were fitted to the classical von Bertalanffy Growth Function (VBGF). Accordingly, the growth constant (K) and asymptotic length (L_∞) were determined using the VBGF fitted in ELEFAN-I routine of FiSAT program (Gayanilo *et al*., 2005) [6] following the expression of Pauly (1984) [18] as:

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

Where L_t is the length at time *t*, L_∞ represents the asymptotic length, e is the exponential constant with an approximate value of 2.718, K is the VBGF curvature parameter (growth constant), and t_0 is the theoretical is the theoretical age of fish at length zero.

2.4 Mortality rates

The total mortality rate (Z) was estimated from the length-converted catch curve result. In contrast, the natural mortality rate (M) was calculated using Pauly's empirical formula (Pauly, 1980) [16]:

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

Where M = natural mortality (yr^{-1}), and T = mean annual surface temperature of the water in which the stocks live (taken at 28 °C). Fishing mortality (F) was computed using the following formula (Gulland, 1971) [9]:

$$F = Z - M$$

Where Z = total mortality (yr^{-1}), F = fishing mortality (yr^{-1}), and M = natural mortality (yr^{-1}). The exploitation level (E) was estimated by Gulland (1971) [9]:

$$E = \frac{F}{Z}$$

3. Results and Discussions

3.1 Length-Weight relationship

The length (TL) frequencies of 2,417 *Nemipterus hexodon* individuals collected using multiple hooks and line, handlines and gillnets fishing gears in Banate Bay had lengths ranging from 6.00 to 25.30 cm. The mean length was 19.57 cm (±9.88). This species' recorded body weights ranged from 11.20 to 215.00 g, with a mean weight of 66.43 g (±33.20) (Table 1).

Table 1: Total length (cm) and total weight (TW, g) relationship of ornate threadfin bream *Nemipterus hexodon* surveyed from the fishing ground of Banate Bay.

Length-Weight relationship					
Study Site	**$L_{min-max}$(cm)**	**Mean L (cm)**	**$W_{min-max}$ (g)**	**Mean W (g)**	**n**
Banate Bay	6.00-25.30	19.57 (±9.88)	11.20-215.0	66.43 (±33.20)	2,417

Figure 2 depicts relationships between total weight (TW, g) and total length (TL, cm) data that were logarithmically converted and obtained from Banate Bay for the ornate threadfin bream *Nemipterus hexodon*. Indicating a trend of negative allometric growth, the slope (b<3) of the linear regression substantially deviated from 3 (t-test, p<0.05). This negative allometric growth of the ornate threadfin bream *Nemipterus hexodon* deduced that this species has a relatively slow growth rate and tends to be thinner**.** In reality, a wide range of natural and human-related factors, including geographic patterns (e.g., longitude, latitude, and altitude), environmental factors (e.g., temperature, climate, and salinity), biological factors (e.g., sex, habitat, health, and diet), and human activity (e.g., habitat alteration or destruction, pollution, and fishing pressure), have an impact on fish growth and the LWR.) (Balasubramanian & Murugan, 2017; Kelly & Smokorowski, 2017; Ribeiro, 2014; Giacalone *et al*., 2010; & Gurkan & Taskayak, 2007) [2, 12, 21, 7, 10].

The equation describes the length-weight relationship, $W = 0.020L^{2.82}$, while its logarithmic equation is $\log W = \log 0.020 + 2.82 \log L$. The regression coefficient is, $r^2 = 0.89$. The regression coefficient value (r^2) indicates a strong positive linear relationship between the body's length and weight of *Nemipterus hexodon* (Figure 2).

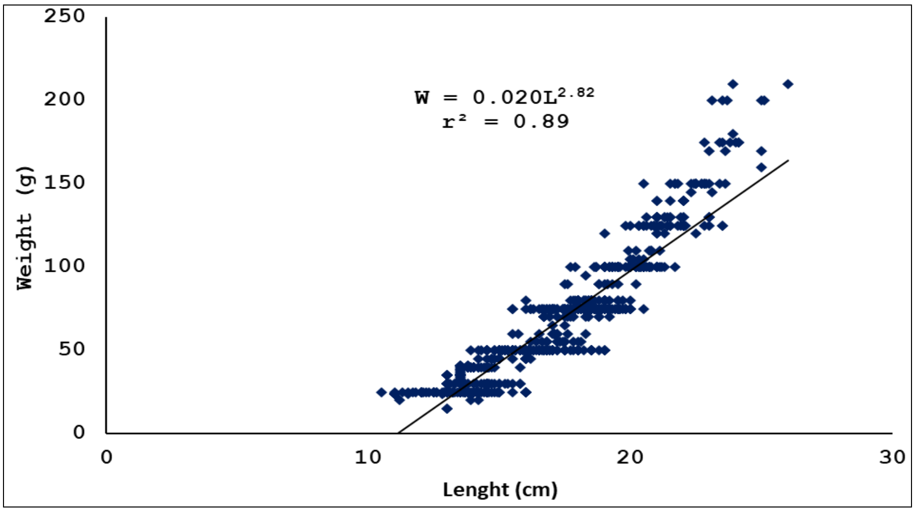

Fig 2: Length – weight relationship (LWR) of *Nemipterus hexodon* in Banate Bay.

3.2 Growth Parameters

Estimated asymptotic length (L∞) and growth coefficient (K) of the von Bertalanffy Growth Formula (VBGF) by ELEFAN-I were 25.80 cm and 0.63 yr^{-1} of ornate threadfin bream caught in Banate Bay (Table 2). Figure 3 shows length frequency distributions and the superimposed growth curves estimated by ELEFAN-I for *N. hexodon*. The growth performance index calculated with the parameter estimates from ELEFAN-I (Φ') was 2.61.

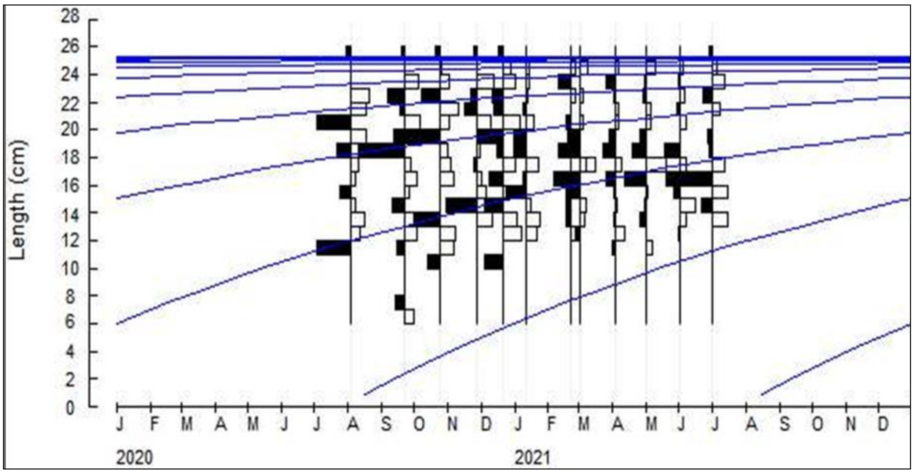

Fig 3 Restructured length-frequency distribution of samples in Banate Bay superimposed with growth curves

Ornate threadfin bream captured in Banate Bay had estimated asymptotic length (L∞) and growth coefficient (K) of the von Bertalanffy Growth Formula (VBGF) of 25.80 cm and 0.63 yr^{-1}, respectively (Table 2). Figure 3 displays the length frequency distributions and the ELEFAN-I-estimated growth curves for *N. hexodon*. The parameter estimations from

ELEFAN-I (ϕ') were used to generate the growth performance index, which obtained a value of 2.61.

Table 2: Population parameters of *Nemipterus hexodon* in Banate Bay.

Population parameters	Values
Asymptotic length (L∞) in cm	25.80
Growth coefficient (K) yr^{-1}	0.63
Growth performance index (ϕ')	2.61
Natural mortality (M) yr^{-1}	1.38
Fishing mortality (F) yr^{-1}	0.49
Total mortality (Z) yr^{-1}	1.87
Exploitation rate (E)	0.26

According to Ramos *et al.* (2018) [20], food availability and suitable environmental factors affect the growth condition of *Nemipterus* spp. The growth rate of the threadfin bream species is rapid when the fish are young, decreasing with age until they reach an asymptotic length, after which they stop growing in length. As a result of their rapid growth, young threadfin breams need a lot of food (Asriyana and Syafei, 2012) [1]. According to Sparre and Venema (1992) [25], a K value of 1.0 suggests that fish have rapid growth, whereas a value of 0.5 indicates medium growth, and a value of 0.2 indicates moderate growth. The K estimates of 0.63 yr^{-1} for *N. hexodon* caught in Banate Bay is regarded as being in the medium growth rate category.

The growth performance index (ϕ') value obtained in this study was ϕ'= 2.61 is nearly comparable to other published local studies, particularly in the studies of Dalzell and Ganaden (1987) in Maqueda Bay, Guimaras Strait, and Manila Bay, as well as some studies abroad conducted in Malaysia and Brunei (Table 3). However, this study suggests that the ornate threadfin bream grows identically in the Philippines and other Southeast Asian regions where it has been studied.

Table 3: Comparison of Growth performance index (ϕ') of *Nemipterus hexodon* from the Philippines and other Asian countries.

Location	Philippines	Growth performance index(ϕ')	Source
Banate Bay	Philippines	2.61	This study
Maqueda Bay	Philippines	2.49	Dalzell and Ganaden, 1987 [5]
Guimaras Strait	Philippines	2.49	Dalzell and Ganaden, 1987 [5]
Manila Bay	Philippines	2.49	Dalzell and Ganaden, 1987 [5]
Sarawak and Sabah	Malaysia	2.60	Pauly, 1980 [16]
Brunei Darussalam	Brunei	2.77	Silvestre and Garces, 2004 [24]

3.3 Mortality and Exploitation Rate

Total mortality (Z) for *N. hexodon* was estimated to be 1.87 yr^{-1} using length-converted catch curve analysis (Figure 4). The points utilized in the linear regression analysis to get Z was represented by the darkened circles. According to Pauly's empirical formula, Banate Bay had an estimated value of natural mortality (M = 1.38 yr^{-1}). The fishing mortality (F) was calculated to be 0.49 yr^{-1}. Fish can die naturally from predation, illness, aging, and environmental reasons. According to Pauly (1984) [18], natural mortality and water temperatures are related. The natural mortality of fish will rise as the temperature of the water rises. Further research should be done in order to identify the factors that led to the natural mortality of *N. hexodon* in Banate Bay.

The rate of exploitation (E), as depicted in Figure 4, was calculated to be 0.26. A stock is ideally exploited, according to Gulland (1971) [9], if fishing mortality equals natural mortality, F = M, or the exploitation rate (E) is equal to 0.5. This E value, 0.26 (which is below the 0.50 threshold level), shows that the *N. hexodon* stock in Banate Bay is underfished or underexploited. The selective fishing tools (gillnet, handline, and multiple hooks and line) used by the majority of fishermen in the bay, as well as management measures implemented by the municipalities surrounding the bay, have substantially impacted the present sustainable population of *N. Hexodon.*

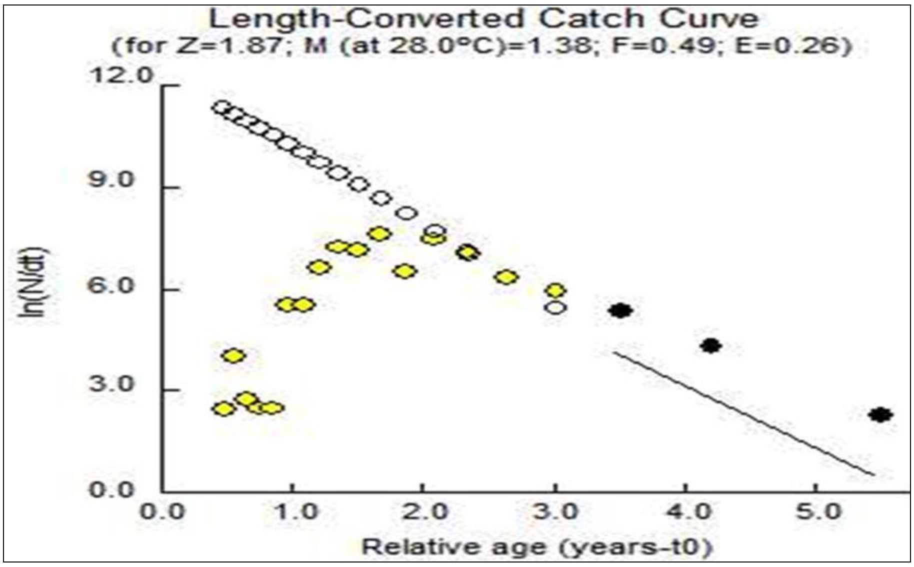

Fig 4: Length-converted catch curve plot of *Nemipterus hexodon* in Banate Bay

4. Conclusion
Nemipterus hexodon, which is found in the fishing grounds of Banate Bay, is a medium-fast growing species and essentially the same asymptotic length as other fishing grounds in the Philippines and abroad. The status in Banate Bay is underfished (0.26 < E0.5 (0.49), which suggests that fishing efforts using environment-friendly fishing gears can still be increased by 47% to increase catch yield.

Given the significant contribution of *N. hexodon* to the food protein supply and income of fisherfolks, relevant and effective fisheries management strategies of the Local Government Units (LGUs) surrounding Banate Bay should be continued to maintain this fish species' sustainable fish stock status.

Conflict of interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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