

RESEARCH ARTICLE

Population Parameters of Shortfin scad *Decapterus macrosoma* (Bleeker, 1851) in Antique, Philippines

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ABSTRACT

Growth, mortality, exploitation rate, and recruitment of *Decapterus macrosoma* in the waters off Antique province, Philippines, were investigated based on the length-frequency data collected from April 2019 until March 2020. Using the FISAT-II software, *D. macrosoma* growth parameters were computed as follows: $L_{\infty} = 26.18$ cm TL, $K = 1.00$ yr⁻¹, $\phi' = 2.836$ yr⁻¹, and an estimated life span of 3 years. Mortality values were estimated as: total mortality (Z) = 4.66 yr⁻¹; natural mortality (M) = 1.88 yr⁻¹; and fishing mortality (F) = 2.78 yr⁻¹. The exploitation rate (E) was computed as 0.60 while $E_{\max}$ was 0.42 yr⁻¹. The length at first capture L_c/L_{50} was estimated at 11.96 cm TL. There were two recruitment events in one year: July and December. *D. macrosoma* in Antique was growing isometrically and in good condition with the relative condition factor (K_n) values ranging from 0.99 to 3.39. The computed exploitation rate suggested that *D. macrosoma* faces a high level of exploitation in Antique waters. These results offer valuable information on the utilization, conservation, and management of *D. macrosoma* in the East Sulu Sea area.

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1. INTRODUCTION

The shortfin scad *Decapterus macrosoma* (Bleeker, 1851) is a schooling species that typically occurs in open waters. It is commonly distributed in tropical waters such as the Indo-Pacific, East Africa, Red Sea, Eastern Pacific, Galapagos Islands, and Peru (Smith-Vaniz and Williams 2016). In the Philippines, *D. macrosoma* is one of the popular commercial species caught in many parts of the country (Sangalang and Quinay 2015). The traditional fishing grounds for this species includes the Sulu Sea, Visayan Sea, Moro Gulf, Lamon Bay, Cuyo Pass, Ragay Gulf, Batangas coast, Tayabas Bay, Samar Sea, Camotes Sea, Sibuyan Sea, Bohol Sea, Davao Gulf, Babuyan Channel, and Mindoro Strait (Pastoral et al. 2000; Sangalang and Quinay 2015; Gonzales et al. 2021). In the early 1990s, this species was a cheap source of protein for Filipinos and was considered a poor man's fish because of its low price (Jimenez et al.

2020). Unfortunately, overexploitation is threatening the natural stock due to increased fishing pressure brought about by increasing demand. While several studies have investigated the biological characteristics (e.g., age, reproduction, and growth) of *D. macrosoma* in the Philippines and other parts of the world, local information is best for quantifiable assessment in an area; hence there is a need to provide more literature on this species (Gonzales et al. 2000).

The East Sulu Sea is one of the principal fishing grounds in the Philippines; wherein *D. macrosoma* is abundantly caught. This fishery serves as a source of income for the coastal community of San Jose de Buenavista and Hamtic, Antique of Panay Island. Based on the reports of the Philippine Statistics Authority (2022), the annual round scad landings in Antique for the past 12 years (i.e., 2010 -2021) have been declining for both municipal and commercial fisheries sub-sectors (Figure 1). Unfortunately, except for one study (i.e., San Diego and Fisher 2014) that

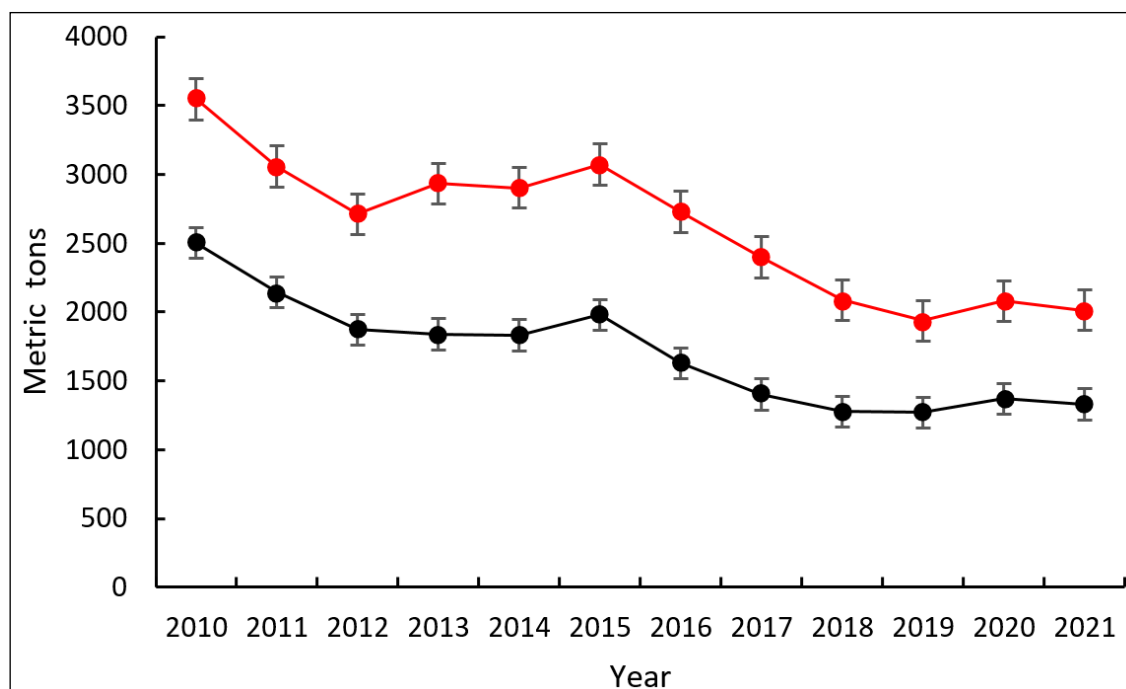


Figure 1. Landings of round scad in Antique, Philippines from 2010 to 2021. Red line indicates Total Round scad Catch. Black line indicates Commercial Fisheries Sector Catch (Source: PSA 2022).

reported fisheries trends in Cuyo East Pass, near the Antique fishing ground, no other scientific reports can provide information on its population parameters. Therefore, this paper investigated the *D. macrosoma* fishery off Antique Province by determining population parameters such as growth, mortalities, exploitation rate, recruitment, probability of catch, and length-weight relationship of *D. macrosoma* to add literature relevant to fisheries management in the area. However, we have not studied the maximum sustainable yield (MSY), another predictive model, for the *D. macrosoma* stock because the data covered only one year, and the number of samples was insufficient for MSY estimation.

2. MATERIALS AND METHODS

A total of 1,042 randomly collected samples of *D. macrosoma* from April 2019 to March 2020 at the eastern Sulu Sea area off the coast of Antique (10°36'39.6" N, 121°53'29.76" E) (Figure 2) were analyzed. Samples were obtained onboard a ring net (locally called *likos*) at 35–700 fathoms. The fishing ground off Antique was 4.3–10.3 nautical miles from the coastline and can be reached in about 2 hours at an average travel speed of 3.5–5.7 knots (source: GPS Magellan eXplorist during actual fishing operations). For one year, sampling was carried out twice a month

(i.e., every second week and last week of the month). Twenty-one (21) typhoons were recorded during the study period, of which 18 occurred in the study area and severely affected ring net operations. However, despite the frequent typhoons, ring net fishers were still able to operate immediately following the exit of the typhoons, thus allowing us to collect data for each month. Fish samples were measured to the nearest 0.1 cm for their total length (TL) using a fish measuring board, while body weight (BW) was measured to the nearest 0.1 g using a top-loading balance. The estimation of growth parameters [asymptotic length (L_{∞})] and growth coefficient (K) was performed using the ELEFAN I (response surface; class interval = 0.5 cm), which is incorporated in the FISAT-II software package (Gaynilo et al. 2005). The growth performance index (ϕ') was obtained using the following formula (Pauly and Munro 1984):

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

Natural mortality was estimated using Pauly's M empirical equation (Pauly 1980):

$$\log M = -0.006 - 0.279 \log L_{\infty} + 0.6453 \log K + 0.4634 \log T$$

where:

M = natural mortality

L_{∞} = asymptotic length

K = growth coefficient of the VBGF (von Bertalanffy growth function)

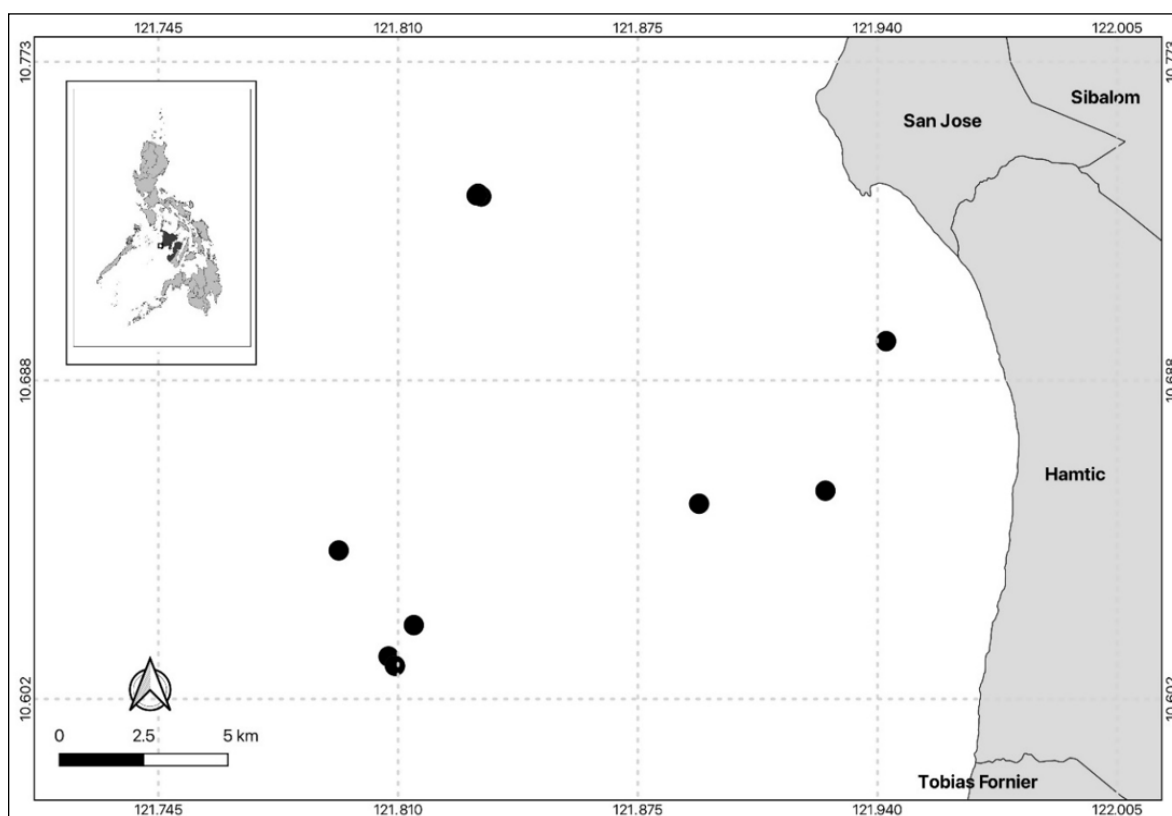


Figure 2. Map showing the location of sampling sites (scatter dots) in waters off Antique, Panay Island, Philippines

T = average annual habitat water temperature (i.e., 28.7°C during this study).

The fishing mortality coefficient (F) was estimated using the formula:

$$F = Z - M$$

where:

F = fishing mortality

Z = total mortality

M = natural mortality.

To estimate the total mortality, the length converted catch curved (LCC) method which is also incorporated in FISAT-II software package was used (Gaynilo et al. 2005). The exploitation (E) rate was calculated through the formula (Gulland 1971):

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

The $E_{\max}$ and E_{50} were estimated using relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) based on Beverton and Holt (1966) modified by Pauly and Soriano (1986), which were then incorporated into the FISAT software (Mohd Azim et al 2017).

The inverse von Bertalanffy growth equation was applied (Sparre and Venema 1998) to estimate the lengths at various ages. The non-linear least-squares method was used to fit a growth curve to a set of mean length and age data of fish with the following formula (King 2007):

$$L_t = L_{\infty} (1 - \exp[-K(t-t_0)])$$

where:

L_t = mean length at age

t = age

t_0 = hypothetical age at which the length of fish is zero (Pauly and David 1981).

The length class of the probability of capture (length of *D. macrosoma* that is vulnerable to the gear) (L_{25} , L_{50} , and L_{75}) was obtained using the ascending left arm of the length converted catch curve based on the method of Pauly (1980) (Mohd Azim et al. 2017).

The length-weight relationship (LWR) for males and females was determined using the following formula (Le Cren 1951):

$$W = aL^b$$

where:

W = weight (g)

L = total length (cm)

a = intercept

b = slope.

It was estimated through the following logarithmic transformation:

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

where a and b were estimated by least square regression.

The relative condition factor (K_n) was used to evaluate the condition index of *D. macrosoma* with the following formula (Le Cren 1951):

$$K_n = W/aL^b$$

where:

W = observed mean weight

aL^b = predicted weight of fish from a length-weight relationship model

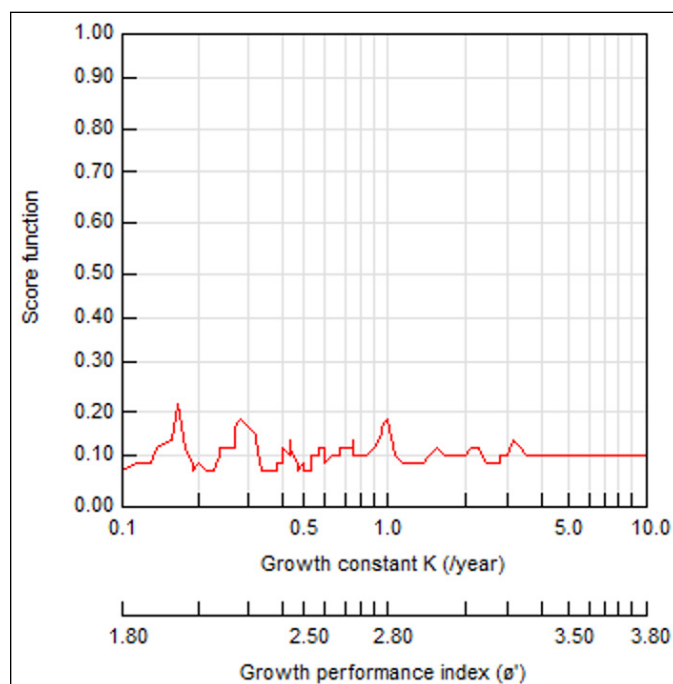


Figure 3. K-scan routine for determining the growth curvature, which gives the value of asymptotic length with the growth performance index of *D. macrosoma* in Antique

3. RESULTS

The goodness of fit (R_n) revealed that L_∞ was 26.18 cm TL. The K value was 1.00 yr^{-1} while ϕ' was 2.836 yr^{-1} (Figure 3). The extreme length ($L_{\max}$) observed throughout this study was 22.42 cm TL. The extreme mid-length was 21.50 cm TL, with a 20.78–24.07 cm TL range. The restructured length-frequency (LF) data for *D. macrosoma* in Antique with superimposed growth curves showed two distinct broods, one started in May and the other in October (Figure 4).

The LCCC model revealed that M was 1.88 yr^{-1} , F was 2.78 yr^{-1} , and Z was 4.66 yr^{-1} . Based on these values, E was computed as 0.60 (Figure 5). The estimation was based on the result of regression analysis (coefficient for the regression (R) = -0.92, coefficient of determination (R^2) = 0.84 (84%), intercept (a) = 10.321, and slope (b) = -4.64).

The relative yield-per-recruit (Y/R) showed that the maximum allowable limit of exploitation ($E_{\max}$) was 0.421, while the optimum exploitation rate (E_{50}) was 0.278, and the 10% of the marginal increase (E_{10}) was 0.355 (Figure 6). The von Bertalanffy growth function (VBGF) model estimated that *D. macrosoma* age ranged from 0.0 to 3.0 (Figure 7).

Recruitment revealed a bimodal recruitment pattern, suggesting two peak periods that varied from 11.87% in August to 18.07% in December 2019 (Figure 8). The probability of capture at L_{25} was 11.41 cm, L_{50} was 11.96 cm, and L_{75} was 12.51 cm (Figure 9). The corresponding regression generated values were intercept (a) = -23.94, slope (b) = 2.66, and $R = 0.89$.

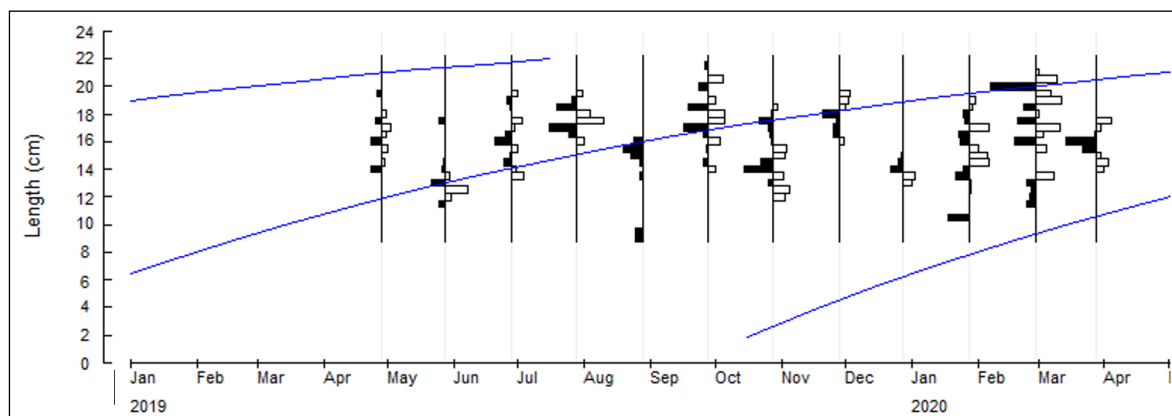


Figure 4. The von Bertalanffy growth curve for *D. macrosoma* in Antique

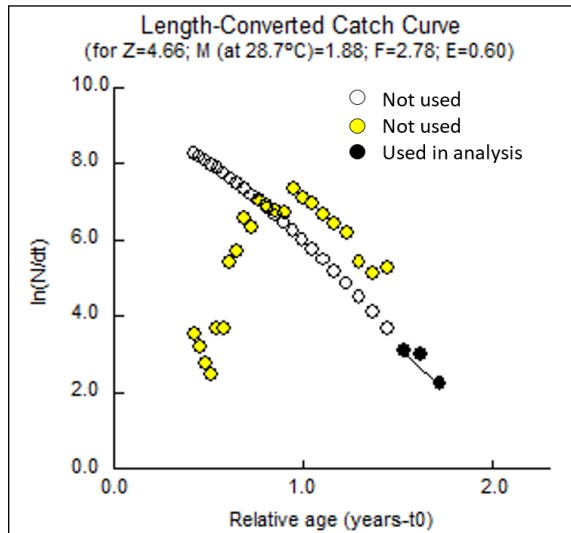


Figure 5. Length converted catch curve for *D. macrosoma* in Antique

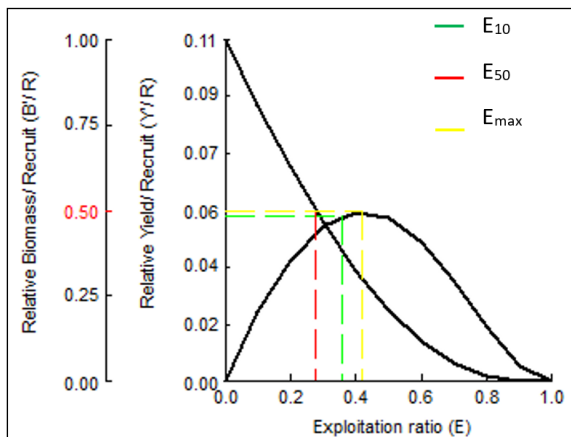


Figure 6. Relative Y/R and B/R of *D. macrosoma* in Antique, using a knife-edge procedure

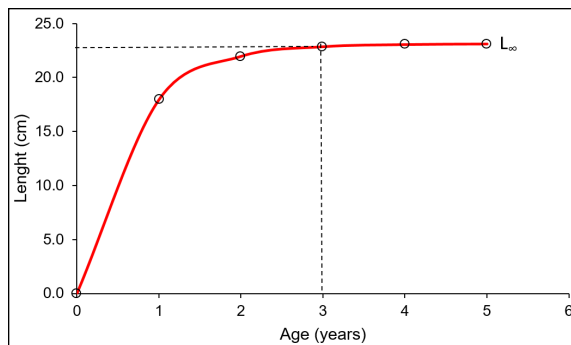


Figure 7. Growth curve to length at age of *D. macrosoma* based on the computed parameters of the VBGF model

The minimum and maximum sizes of *D. macrosoma* were 9.0 cm and 21.5 cm TL, respectively, with a mean length of 16.09 ± 0.12 cm TL (mean $\pm$ SEM). The minimum and maximum BWs were 6.55 g and 94.57 g, respectively, with a mean weight of 40.07 ± 0.90 g BW (mean $\pm$ SEM). Figure 10 shows the LWR correlation pattern. A significant correlation ($p < 0.05$) was observed for all tested samples, with correlation coefficient (R) values that ranged from 0.86 to 1.00 and determination coefficient (R^2) ranging from 74.81 to 99.19% (Table 1). Isometric growth ($b = 3$, t-test, $\alpha > 0.05$) was observed in most of the months except in September, January, and February, when an allometric growth ($b > 3$, t-test, $\alpha < 0.05$) was

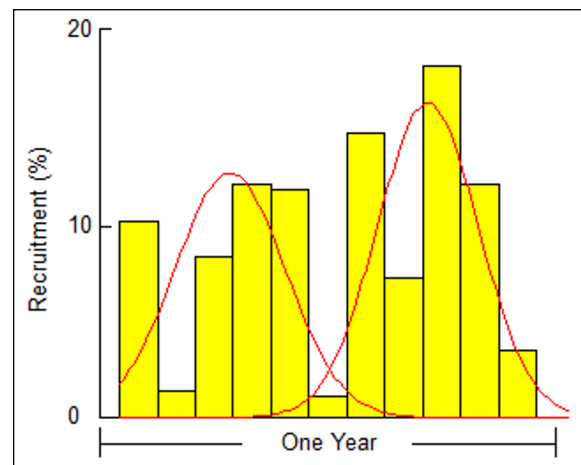


Figure 8. Recruitment pattern of *D. macrosoma* in Antique

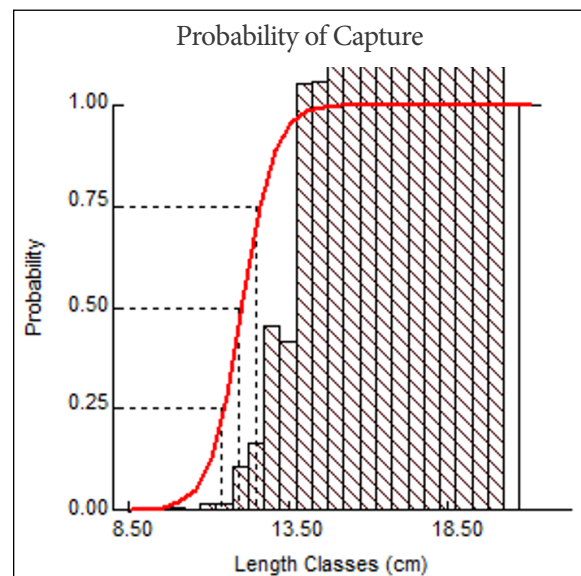


Figure 9. Logistic selection curve for the probability of capture, showing 25%, 50%, and 75% selection length of *D. macrosoma* in Antique

observed. The relative condition factor (Kn) values for *D. macrosoma* ranged from 0.99 to 3.39, with the highest value observed in May (3.39) and the lowest in August (0.99) (Table 1).

4. DISCUSSION

The L_{∞} is the theoretical maximum (asymptotic) length that the fish would reach if it lived indefinitely, while K indicates the rate at which maximum size is reached (King 2007). If the K value is more than 0.3 per year, the fish is considered to have a high growth rate (Faiza et al. 2018). The computed K value (1.00 yr^{-1}) suggests that *D. macrosoma* in Antique had a fast growth rate with the potential to reach its full size and contribute to a new cohort generation despite the uncertain environment (King 2007) and high level of exploitation rate. Based on the available literature, the L_{∞} of *D. macrosoma* in different

geographical locations ranged from 21.4 cm to 33.0 cm, while the growth coefficient varied between 0.5 to 2.05 (Table 2). This study's L_{∞} and K are both lower than those reported by Lavapie-Gonzales et al. (1997) in the southern part of the Sulu Sea. However, they are closely related to the reported L_{∞} and K values in South Sulu Sea, Samar Sea, Leyte Gulf, and Camotes Sea (Lavapie-Gonzales et al. 1997; Belga et al. 2018) (Table 2).

The growth performance index (ϕ') showed that *D. macrosoma* in Antique (2.836) was growing relatively faster than in Tawi-Tawi ($\phi' = 2.68$) (Aripin and Showers 2000) and Palawan ($\phi' = 2.82$) (Ingles and Pauly 1984) (Table 2). The ϕ' of this study was close to previous studies, which indicates the reliability of the new estimated values of L_{∞} and K (Sparre and Venema 1998) because ϕ' expresses a commonality between the growth patterns of different fishes (Pauly 1991). Although the values from previous studies have a

Table 1. Length-weight relationship and growth pattern of *D. macrosoma* from April 2019 to March 2020 in waters off Antique, Panay Island, Philippines

Period	$W=aL^b$	R	R ²	Range of b at P=0.05	Growth pattern	$K_n(W/aL^b)$
Apr 2019	$W = 0.031 L^{2.55}$	0.90	0.80	2.18 - 2.92	I	1.00
May	$W = 0.009 L^{2.55}$	0.97	0.94	2.75 - 3.25	I	3.39
Jun	$W = 0.019 L^{2.75}$	0.94	0.89	2.59 - 2.91	I	1.02
Jul	$W = 0.028 L^{2.62}$	0.95	0.91	2.43 - 2.82	I	1.01
Aug	$W = 0.011 L^{2.95}$	0.99	0.98	2.79 - 3.11	I	0.99
Sept	$W = 0.005 L^{3.19}$	0.98	0.95	3.03 - 3.35	A+	1.13
Oct	$W = 0.058 L^{2.31}$	0.93	0.87	2.17 - 2.45	I	1.01
Nov	$W = 0.026 L^{2.63}$	0.86	0.75	2.30 - 2.96	I	1.02
Dec	$W = 0.024 L^{2.65}$	0.94	0.88	2.34 - 2.96	I	1.00
Jan 2020	$W = 0.005 L^{3.24}$	0.93	0.87	3.04 - 3.45	A+	1.04
Feb	$W = 0.005 L^{3.21}$	1.00	0.99	3.15 - 3.27	A+	1.16
Mar	$W = 0.019 L^{2.73}$	0.90	0.81	2.50 - 2.95	I	1.01
Mean	$W = 0.020 L^{2.78}$	0.94	0.89	2.61 - 3.03	I	1.23

Note: R = correlation coefficient; R² = determination coefficient; a = intercept/coefficient for body weight; b = slope/coefficient for shape parameter for the body; A+ = positive allometric growth; I = isometric growth; Kn = relative condition factor

Table 2. Comparison of estimated growth and mortality parameters of *Decapterus macrosoma* from various studies in the Philippines and other countries in Asia

Area	L_{∞} (cm)	L_{max} (cm)	K (yr ⁻¹)	ϕ'	M (yr ⁻¹)	F (yr ⁻¹)	Z (yr ⁻¹)	E (yr ⁻¹)	Source
Antique	26.18	22.42	1.00	2.836	1.88	2.78	4.66	0.60	Present study
Philippines	23.0 - 33.0	----	0.50 -1.26	----	----	----	----	----	Ingles and Pauly (1984)
Manila Bay	31.5	----	2.05	----	1.33	2.41	3.74	----	Ingles and Pauly (1984)
Palawan	30	----	0.74	2.82	1.47	4.32	5.79	0.75	Ingles and Pauly (1984)
Manila Bay	26.9 - 33.0	----	0.45 - 0.80	----	----	----	----	---	Corpuz et al. (1985)
Leyte Gulf	27.3	27.62	1.4	----	2.28	2.39	4.67	---	Lavapie- Gonzales et al. (1997)
Visayan Sea	31.3	29.57	----	----	----	----	----	----	Lavapie- Gonzales et al. (1997)
Guimaras Strait	31.7	30.02	----	----	----	----	----	----	Lavapie- Gonzales et al. (1997)
Samar Sea	27	27.11	----	----	----	----	----	----	Lavapie- Gonzales et al. (1997)
Camotes Sea	28	30.02	1.6	----	2.47	2.66	5.13	0.51	Lavapie- Gonzales et al. (1997)
Camotes Sea	27.56					----		0.71	Belga et al (2018)
Davao Gulf	29.9	31.21	----	----	----	----	----	----	Lavapie- Gonzales et al. (1997)
South Sulu Sea	27.8	26.8	1.2	----	2.45	4.8	7.25	0.72	Lavapie- Gonzales et al. (1997)
Moro Gulf/ Illana Bay	21.4	24.48	2.3	----	3.28	0.97	4.25	0.2	Lavapie- Gonzales et al. (1997)
Tawi-Tawi	24.9		0.77	2.68	1.59	1.9	3.49	0.54	Aripin and Showers (2000)

L_{∞} = estimated asymptotic length; L_{max} = predicted maximum length; K = growth coefficient; ϕ' (phi prime) = growth performance index; M = estimated natural mortality; F = estimated fishing mortality; Z = estimated total mortality; E = estimated exploitation rate.

Continuation of Table 2. Comparison of estimated growth and mortality parameters of *Decapterus macrosoma* from various studies in the Philippines and other countries in Asia

Area	L_{∞} (cm)	L_{max} (cm)	K (yr ⁻¹)	ϕ'	M (yr ⁻¹)	F (yr ⁻¹)	Z (yr ⁻¹)	E (yr ⁻¹)	Source
Other countries									
Indonesia	25.6	----	1.05	----	----	----	----	----	Sadhotomo & Atmadja (1985)
Thailand	23.2 - 27.5	----	1.05	----	----	----	----	----	Anon (1985)
Java sea, Indonesia	22.4 - 26.5	----	0.86 - 1.31	----	----	----	----	----	Atmadja (1988)
Java Sea, Indonesia	23.1 - 25.6	----	0.7 - 1.1	----	----	----	----	----	Widodo (1988)
Vinzhiujam Coast, India	25.7	----	0.9	----	----	----	----	----	Balasubramanian (1997)
Suez, Egypt	26.97	----	0.56	----	----	----	1.11	----	Mehanna (1999)
Karnataka Coast, India	23.8	----	0.75	----	----	----	----	0.2	Rohit & Shanbhogue (2005)

L_{∞} = estimated asymptotic length; L_{max} = predicted maximum length; K = growth coefficient; ϕ' (phi prime) = growth performance index; M = estimated natural mortality; F = estimated fishing mortality; Z = estimated total mortality; E = estimated exploitation rate.

slight difference, these differences can be attributed to environmental factors such as environmental stresses, changes in temperature, and food availability (Pauly 1998; Barton 2002; Froese 2006). Given that the biotic and abiotic factors in the marine environment are so dynamic, physiological responses and different survival strategies of fish may be expected. For example, if species have perceived a poor survival in a particular environment, they are likely to grow rapidly with a small body size, exhibit early spawning, and possess a short lifespan (King 2007). Compared to the nearby Palawan waters, this study's L_{∞} result is lower but higher in terms of K. The differences are probably because Palawan has a natural resource advantage due to the presence of the Tubbataha Reef Natural Park and a long coast line that provides ample food for optimal growth of *D. macrosoma*.

The maximum length (L_{max} 22.42 cm TL) in the present study is lower than the previously recorded L_{max} in the Philippines (Table 2), International Union

for Conservation of Nature and Natural Resources (IUCN) (Smith-Vaniz 1986; Smith-Vaniz and Williams 2016), and FishBase (Froese and Pauly 2021) (25-35 cm TL). Not surprisingly, previous studies (Table 2) showed that different geographical locations had different growth rates, which might be due to the scope and limitation of the study. The size of fish can be attributed to other factors such as food. Food ingested by a fish provides much of its dietary energy for body maintenance, activity, and reproduction. Only a small part (often less than one-third) becomes available for growth in size (King 2007). In addition, tropical species which are not subjected to large temperature fluctuations over the year exhibit continuous or at least protracted spawning (King 2007). Thus, in a tropical country like the Philippines, *D. macrosoma* will perhaps allot a large percentage of its energy for reproduction rather than growth in size.

The estimated age of *D. macrosoma* ranged from 0.0 to 3.0 years, which was the estimated

lifespan of this species to reach the L_{∞} . The same values were reported for *D. tabl* in the Camotes Sea, Philippines (Narido et al. 2016). Meanwhile, Ingles and Pauly (1984) reported a 3.2-year life span for *D. macrosoma*. However, Shiraishi et al. (2010) reported that male *D. macrosoma* has a maximum estimated age of 5 years while females have 4 years in waters off Southern Kyushu, Japan. The latter study was situated in a temperate zone, and the authors used the sagittal otolith method to determine the age of the fish.

The estimated F of *D. macrosoma* in Antique was higher than the M , which is an indication of the unbalanced standing of the stock (i.e., fishing pressure threatens the current population of the species) (Narido et al. 2016). The stock is said to be optimally exploited if fishing mortality is equal to natural mortality or when the exploitation level is 0.5 (Gulland 1971). The exploitation rate of 0.60 yr^{-1} of *D. macrosoma* in this study suggests that the stock was overexploited. Furthermore, E was also higher than the optimum exploitation rate ($E_{0.5}$) (0.28 yr^{-1}) and maximum allowable exploitation ($E_{\max}$) (0.42 yr^{-1}) that were estimated by the knife-edge procedure assumption (Fig. 6). These values also suggest high overexploitation of *D. macrosoma* in this fishing ground. The rate of fishing mortality of *D. macrosoma* in this study (2.78 yr^{-1}) was higher than those reported in Tawi-Tawi (1.59 yr^{-1}) (Aripin and Showers 2000). The M in this study was within the range of values observed by Ingles and Pauly (1984), Lavapie-Gonzales et al. (1997), and Aripin and Showers (2000). However, the Z in this study was closely related to the findings of Lavapie-Gonzales et al. (1997) in Leyte Gulf and Moro Gulf or Illana Bay (Table 2). Meanwhile, E in this study was closely related to the results of Aripin and Showers (2000) and Lavapie-Gonzales et al. (1997) in the Camotes Sea (Table 2).

The Philippine neritic fishes have two recruitment pulses in a year with an unequal duration of about 4 and 8 months, which could be correlated to the 5- and 7-months rhythm of monsoon winds in the Philippines (Pauly and Navaluna 1983). The northeast monsoon in Antique blows between November to April, while the southwest monsoon blows from June to October (Hurtado-Ponce et al. 1998). The start of sampling in this study was in April 2019, which was the beginning of the change of monsoons. Following the pattern of monsoons in the Philippines, the recruitment pulse of *D. macrosoma* was short during the southwest monsoon and longer during the northeast monsoon, with the highest peak of 18.07% in December 2019. The fluctuating recruitment

strengths could result from interannual variation of reproductive effort or success and variations in the survival or settlement of larvae and juveniles (King 2007). Aside from biological factors such as predation, upwelling events, and vertical instability may also have critical effects on the survival of fish larvae (Pauly and Navaluna, 1983). *D. macrosoma* was also found to exhibit bimodal recruitment patterns in Tawi-Tawi (Aripin and Showers 2000), and in the Camotes Sea, central Visayas (Belga et al. 2018).

The mean size at first capture (L_c/L_{50}) was 11.41 cm TL. Based on the result of the VBGF model (Fig. 7), an 11-cm TL ranges between the ages of 0.0 to 1.0. This implies that 50% of *D. macrosoma* in Antique were exploited at an early age. This probably resulted from the attractive effect of fish aggregating devices (FAD) on juveniles (Deudero et al., 1999; Monteclaro 2005). Recruitment of juvenile pelagic fishes to FADs is rapid, with shoals reported to be present only a few days after FAD placement (Deudero et al. 1999). Most of the ring net fishers in Antique relied on FADs for their fishing operation; hence, juvenile fishes attracted during the lighting of FADs become vulnerable to capture. Belga et al. (2018) reported *D. macrosoma* was 16.0 cm L_c/L_{50} in the Camotes Sea. Liestiana et al. (2015) found 25.5 cm L_c/L_{50} in Gunungkidol, Yogyakarta, Indonesia. Similarly, Asni et al. (2019) reported 25.5 cm L_c/L_{50} in Makassar waters, South Sulawesi, Indonesia. The length at first capture reported in this study is much lower than the length at first maturity (L_m) of *D. macrosoma* recorded in other parts of the Philippines. For example, in Tablas Strait, Romblon, the L_m of female *D. macrosoma* was 20.36 cm and 24.26 cm for males (Gonzales et al. 2021), while in the Sibuyan Sea, it was 15.29 cm for females and 17.22 cm for males (Rada et al. 2019). Given that the estimated L_c/L_{50} of *D. macrosoma* was smaller compared to L_m of *D. macrosoma*, this result suggests that *D. macrosoma* in Antique were caught before they reached sexual maturity.

Fish growth may be negative or positive, temporary or permanent (Busacker et al. 1990). If a fish exhibits negative allometry, it is much slender and grows faster in length than weight; positive allometry results in a fish that is stouter as it grows faster in weight than length; whereas isometry allows fish to increase in length and weight at the same rate (King 2007; Riedel et al. 2007). Our results show that the length and weight relationship of *D. macrosoma* in Antique were statistically significant ($p < 0.05$), and the correlation coefficient confirmed that length and weight were positively correlated. The high coefficient

of determination values found in the assessment of LWRs during the whole year is an indication of the good quality of the prediction of linear regression for the analyzed fish species, and extrapolation in the future catches can be done in that geographical spot for the size range (Jisr et al. 2018). Although there were months when *D. macrosoma* exhibited positive allometry (September, January, and February), *D. macrosoma* was growing isometrically as a general pattern in the waters off Antique, which implies a good condition. However, the variation in growth pattern could indicate variation in sexes, the maturity of the fish samples, location, season, and food availability (Le Cren 1951; Froese 2006; Pattikawa et al. 2017). Other reports showed that *D. macrosoma* found in the eastern water off Ambon Island, Maluku, Indonesia has positive allometric growth (Pattikawa et al. 2017); however, negative allometric growth was recorded off Aceh waters (Afdhila et al. 2019), and both negative and positive allometric growth in Banda waters, Maluku Province (Senen et al. 2011). Isometric growth of *D. macrosoma* was also reported in the Java Sea (Prihatini et al. 2017) and the Masalima Sea around Makassar Strait, Indonesia (Ahmadi 2020). A relative condition factor (Kn) value greater than 1 indicates the generally good condition of the fish (Le Cren 1951). In the present study, the monthly condition factor ranged from 0.99 to 3.39 (mean=1.23), which suggests that the waters off Antique are suitable for *D. macrosoma* growth. Perhaps the food availability in this fishing ground is sufficient to sustain the fish's growth performance, just as reported in Banda Aceh (Afdhila et al. 2019). However, various biotic and abiotic factors which can affect the fluctuation of condition factors of fish (Murphy et al. 1991; Blackwell et al. 2000; Muchlisin et al. 2010) need to be investigated.

5. CONCLUSION

Decapterus macrosoma in Antique had a fast growth rate but a short life span. Furthermore, its growth pattern was generally isometric, indicating a normal growth not disturbed by environmental perturbances. The preceding was supported by the relative condition factor revealing that *D. macrosoma* is well suited to this environment. *D. macrosoma* exhibited bimodal recruitment events, but this species

was caught in the first year of its life, which probably resulted in growth overfishing. Also, the values reported for mortality, exploitation rate, and length at first capture suggest that the *D. macrosoma* stock in these waters faces a high rate of overexploitation and fishing pressure. These results offer important information that can be used for the management and sustainable utilization of *D. macrosoma* in southern Panay waters.

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AUTHOR CONTRIBUTIONS

Magallanes S: Conceptualization, Investigation, Methodology, Formal analysis, Data curation, and Writing Original draft preparation, Editing of manuscript. **Monteclaro H:** Conceptualization, Supervision, Validation, Writing, Review and editing of manuscript. **Gonzales B:** Validation, Review and Editing of Manuscript. **Quinitio G:** Validation, Writing, Review and Editing of Manuscript. **Mediodia D:** Validation, Review and Editing of Manuscript.

CONFLICT OF INTEREST

To the best of our knowledge, no conflict of interest exists.

ETHICS STATEMENT

This study did not deal with live animals nor humans as subjects.

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