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RESEARCH ARTICLE

Population Dynamics of Shortfin Scad (*Decapterus macrosoma*) Bleeker 1851 in Babuyan Channel, Philippines

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ABSTRACT

The study was conducted to determine the status of *Decapterus macrosoma* stocks in the Babuyan Channel. Data were collected from January 2016 to December 2017 following the standard methodology of the National Stock Assessment Program (NSAP). The data were analyzed using the Fisheries Stock Assessment Tool II software and R package. Results showed that the species is available throughout the year and is most productive during summer. Decreased catch landings were affected by environmental, biological, social, economic, and regulatory factors. Beach seine has the largest contribution of catch but has the most number of immature catches. The highest catch per unit effort for all the gears occurs from February to June. Fishing mortality for beach seine (F = 2.98) is higher than the natural mortality (M = 1.76) values, indicating that the species is already experiencing high fishing pressure. *D. macrosoma* exhibited a bimodal mode or recruitment with unequal strengths. Similarly, the observed exploitation ratio (E = 0.63) is beyond the sustainable exploitation level. In order to sustainably manage the species population, introducing environment-friendly gear, banning beach seine, and establishing Marine Protected Areas should be implemented to support species productivity. These are some of the effective management measures being implemented in different parts of the country and found in the study of Cabigas et al. (2012), Valdemarsen and Suuronen (2001), and Hilborn and Ovando (2014).

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1. INTRODUCTION

Round scads represent an important food fish for Filipino people. It is one of the commercially and economically important marine fishery resources and one of the major commodities exported in the Philippines with a volume of 171,306.41 MT. It ranked 3rd in the commercial sector with an annual catch of 120,364.80 MT, contributing 12.7% of the total marine commercial landings. Similarly, it ranked 4th in the municipal sector with an annual volume of 53,941 MT, contributing 5.4% of the total marine municipal landings (DA-BFAR 2018).

In Region 02, no catch of *Decapterus macrosoma* was recorded in 2018 in the commercial sector. However, it ranked 16th in the municipal sector with an annual catch of 107.60 MT, contributing 6.31% of the total marine landings in Region 02. In Babuyan Channel, it ranked 16th in the municipal sector in 2018 with an annual catch of 105.62 MT, contributing to 48.29% of total marine municipal landings in the fishing ground (DA-BFARc 2020).

There are 10,442 total boats operating (DA-BFARa 2020) and 48,685 fisherfolks (DA-BFARb 2020) engaged in fisheries activities in Region 02, in which the Province of Cagayan has the highest number of registered boats and fisherfolks.

Babuyan Channel is one of the major fishing grounds in the Cagayan Valley region, with a higher volume of shortfin scad landings compared to the waters of Batanes and Isabela. However, landings in the region are minimal compared to landings in other fishing grounds in the country, like Palawan, Zamboanga, and Davao Peninsula. Shortfin scad in the Babuyan Channel is a shared catch of almost 7,101 units (DA-BFARa 2020) of municipal boats and 174 units of commercial boats using different types of gears.

Decapterus macrosoma is a small pelagic species belonging to the family Carangidae. It is the most abundant and dominant species among the six species of round scad found in the Philippine waters. The species is present in the fishing ground throughout the year and is commonly caught by ring net, beach seine, multiple hook and line, troll line, simple handline, and gillnet.

While the species is considered one of the country's economically important fish and a popular food fish for most Filipinos, particularly the Ilocanos, the price in the region still ranges from 180.00 to 220.00 pesos a kilo due to low harvest and supply. The stocks are already declining, as observed in different major fishing grounds of the country. The exploitation ratio is already beyond the sustainable level being one of the targeted species by commercial and municipal fishing where high exploitation levels were noted in different parts of the country like Palawan (Ingles and Pauly 1984), Sulu Sea (Lavapie-Gonzales et al., 1997), Tawi-Tawi (Aripin and Showers 2000), Camotes Sea (Belga et al. 2018), Eastern Sulu Sea and Basilan Strait (De Guzman et al. 2018), and Lagonoy Gulf (Olaño et al. 2018). Based on DA-BFARc (2020) available data, a declining catch and catch per unit effort (CPUE) trend for D. macrosoma was observed during the past 11 years in the Cagayan Valley Region starting the year 2007 where a total of 80.30 MT was landed both for commercial and municipal sector (Figure 1). The catch increase was noted in 2016, but the catch per unit effort remains too low.

Population assessment studies were conducted in some areas of the country in some members of the genus Decapterus, including *Decapterus kurroides* Bleeker 1855 (Lavapie-Gonzales 1991), *Decapterus russeli* Cuvier 1833 (Ingles and Pauly 1984), and *Decapterus macrosoma* Bleeker 1851 (Belga et al. 2018) using length-frequency data. However, published studies on population dynamics and fishing patterns still need to be included in Babuyan Channel, Philippines. Thus, the study aimed to determine the seasonality, size distribution, catch per unit effort pattern, and population parameters like mortality, exploitation ratio, and probability of capture.

Resource managers and policymakers can use reference points like B_{msy} and F_{msy} values generated in this study in formulating policies and diversifying management strategies for the healthy and sustainable production of said species in the Babuyan Channel fishing ground. In addition, the result will further serve as regional input in categorizing the status of the species in the Philippine International Union of Conservation for Nature (IUCN) Red List of threatened species.

2. MATERIALS AND METHODS

2.1 Study site

The study was conducted in Babuyan Channel, the major fishing ground in Cagayan Valley Region, covering twelve coastal municipalities in the Province of Cagayan (Figure 2). It lies approximately

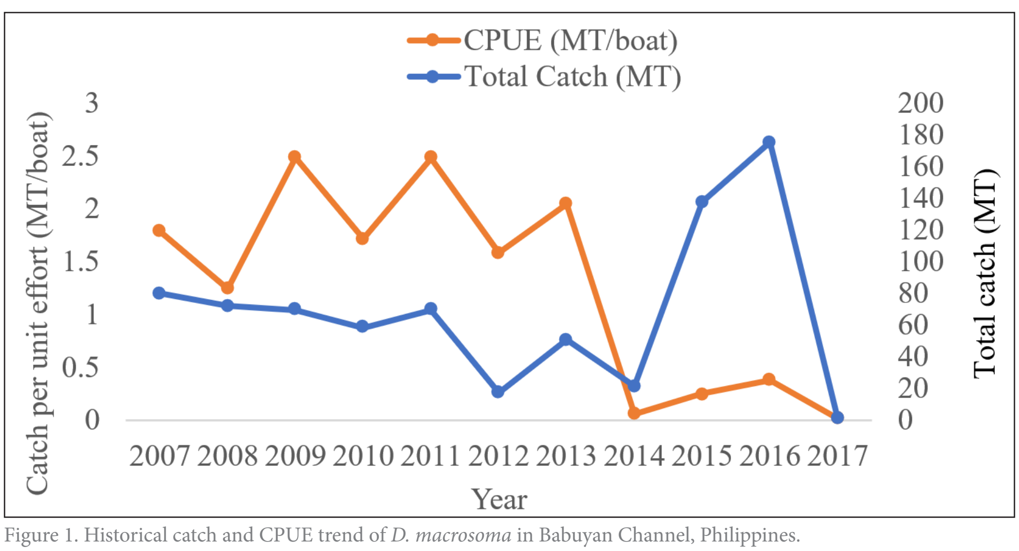

Figure 1. Historical catch and CPUE trend of *D. macrosoma* in Babuyan Channel, Philippines.

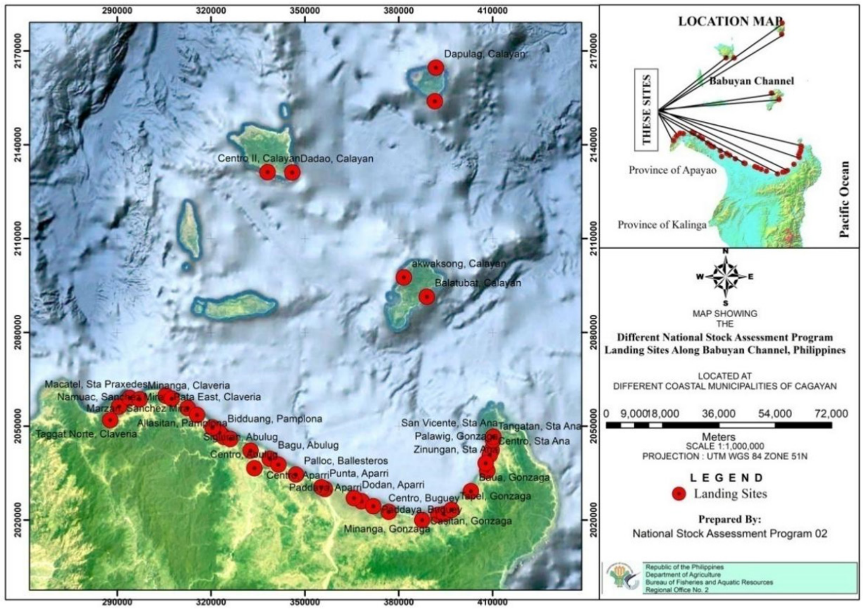

Figure 2. Location of landing centers in Babuyan Channel, Philippines.

between 18°16'00" and 11°35'00" North latitude and 121°02"00" and 121°14'30" East longitude.

The mainland and island of Cagayan have a coastline length of 154 kilometers and an approximate total area of 477,550 square kilometers. The northern part of the channel extends to the islands of Fuga, Camiguin, Dalupiri, Calayan, and Babuyan Group of Islands converging with the Pacific Ocean on the east and the West Philippine Sea on the west.

2.2 Data collection

Data were collected in the established National Stock Assessment Program (NSAP) landing sites within Babuyan Channel, namely Ballesteros, Abulug, Sanchez Mira, Pamplona, Claveria, and Calayan Group of Islands, Cagayan (Figure 1) using six types of fishing gears which includes beach seine, gillnet, multiple hook and line, ring net, simple hand line, and troll line from 2016 to 2017.

The sampling scheme involved monitoring of landed catch, which was done every other two days regardless of Saturday, Sunday, and Holiday. A total of 10–11 sampling days per month per landing site for 30–31 days a month, respectively. Major landing sites were sampled on the first day while minor landing sites were sampled on the second day; the third day is a non-sampling day. The same sampling pattern is followed for the succeeding days until the end of the month. In cases where there are 31 days in a month, the last day is scheduled for the major landing site. Then, on the first day of the month, the enumerators will return to the major landing site at the start of the month (Santos et al. 2017).

Upon fishers unloading their catch, direct interviews with the fishers were conducted to determine the total catch, effort, and the fishing gears used during the operation. All fishing boats unloading their catch were sampled and recorded. Sub-samples were randomly collected from each tub per fisher for length-frequency measurements (cm). The minimum of 50 samples per gear per landing per sampling was not met due to the limited unavailability of catch on most sampling days. Hence, few length-frequency samples were obtained from almost all fishing gears used in the study since the majority of the catch of the gears do not compose of *D. macrosoma* and only the gear beach seine has the highest number of samples for the length-frequency measurement. During sampling, those available samples (i.e., ten pieces) on gear were the only ones being measured and recorded. All data gathered were transferred to the following standard NSAP forms:

a. Form 1 – Monthly Summary Report
b. Form 2 – Fish Landing Survey Form (Catch and Effort)
c. Form 2a – Landing Catch and Effort Monitoring (Weight Measurement)
d. Form 2b – Landing Catch and Effort Monitoring (Length Measurement)
e. Form 3 – Actual Length Frequency Tally Sheet

The information recorded in the following forms was eventually encoded in an Excel spreadsheet for processing and analysis.

Total length (TL) was determined to the nearest 0.1 cm, and the length data were grouped at 0.5 cm intervals since the species are small pelagic and subsequently analyzed using the Fisheries Stock Assessment Tool (FiSAT) II software (Gayanilo et al. 2005). Only the species' landed catch and length data were collected since a separate study on the species' reproductive biology is being conducted for the length at maturity (L_m) and spawning potential ratio (SPR) of the species in the Babuyan Channel.

2.3 Data processing and analysis

Production was estimated by following the procedure of Stamatopoulos (2002):

Catch = CPUE x Effort

Where: Catch (total) – refers to all species taken together and usually computed within the logical context of a) a limited geographical area or stratum, b) a given reference period (i.e., a calendar month), and c) a specific boat or gear category. CPUE is the computed catch per unit effort. It is an overall average deriving from sampling and expressing how much fish (all species) a unit effort catches. Effort is the total number of boats landed. Since the catch of the gears is a mixed composition of species, species composition is also computed.

Species = SP x Catch

Where: species catch is the estimated catch for each species. SP is a fraction of the total catch corresponding to a species and is formulated from the proportion of a species found in the samples, and catch is the estimated total catch computed earlier. However, only the estimated catch of *D. macrosoma* was presented and used in this study.

After the CPUE and effort were computed, data was raised using the following formula (Santos et al. 2017).

$$\text{Raising Factor} = \frac{\text{Weight of each species group}}{\text{Total sub} - \text{sample weight}} \text{x Total Catch (weight) of the boat}$$

2.4 Seasonal pattern

Monthly raised catch was used to determine the seasonal pattern of the species regardless of the fishing gear used. This was done by summing the catch of all fishing gears catching *D. macrosoma* in at month.

2.5 Length distribution

Length frequency measurements of the species caught by ring net, multiple hook and line, troll line, simple handline, beach seine, and gillnet were encoded in an Excel spreadsheet. A raising factor was used in raising the catches of the total boat landed and length frequencies with the same fishing gear per sampling (Santos et al. 2017).

$$\text{Raising Factor} = \frac{\text{Weight of each species group}}{\text{Total sub} - \text{sample weight}} \text{ x No. of length frequency}$$

The raising of sub-sample catch for the length frequency was done since monitoring was only conducted for 10 to 11 days per landing center. These length frequencies were also used in the processing of population parameters in FiSAT Software.

The most basic parameters of fish population dynamics are strongly related to maximum length (Allen 1971; Pauly 1980; Welcomme 1999; Binohlan and Froese 2009). The size structure of the fish changes and reduces the mean length because of commercial fishing (Beverton and Holt 1957). Due to continued overfishing, commercial stocks exerted high mortality rates; hence, there is little chance for a few individuals to survive and reach maximum size (Myers and Worm 2003; Binohlan and Froese 2009). As a result, it has become difficult to observe the maximum size of fished populations (Binohlan and Froese 2009).

However, L_{max} can be estimated using the model of Binohlan and Froese (2009), and this was applied in the study to establish the predicted L_{max} of the species in the fishing ground.

$$\text{Log } L_{max} = 0.2602+0.9928*\log (L_m)$$

The 95% confidence limit for the mean L_{max} from the formula was:

$$\boldsymbol{log\ Lmax\ lower = 10\ [log\ Lmax - t * s * \sqrt{(1/n)}]}$$
$$\boldsymbol{log\ Lmax\ upper = 10\ [log\ Lmax + t * s * \sqrt{(1/n)}]}$$

The 95% prediction limit was obtained using the formula:

$$\boldsymbol{log\ Lmax\ lower = 10\ [log\ Lmax - t * s * \sqrt{(1 + 1/n)}]}$$
$$\boldsymbol{log\ Lmax\ upper = 10\ [log\ Lmax + t * s * \sqrt{(1 + 1/n)}]}$$

Where L_{max} can be replaced by L_m, T is the value of the t-distribution corresponding to alpha 0.025 and n-2 degrees of freedom, s is the standard deviation and n is the sample for the fish group.

2.6 Catch contribution per gear

Catch data was used to determine the percentage catch contribution per gear. This was obtained by summing the total catch of all gears divided by the total catch of specific fishing gear multiplied by 100%.

2.7 Catch, effort, and catch per unit effort (CPUE)

Nominal CPUE was computed by dividing the total catch over the fishing effort. The nominal CPUE computed along with other data collected, such as year, month, fishing gear, and location, were processed and analyzed in R software and standardized using the Generalized Linear Model (GLM). The calculation was made and based on the GLM Model to filter biases in the computed nominal CPUE since confounding factors might affect or influence the catch rate calculation.

$$CPUE = (mean) + [month] + [location] + [fishing\ gear] + \varepsilon$$

Where CPUE is the log nominal CPUE plus the constant of 10% of the nominal CPUE. The 10% was adopted to fit the model as recommended by Annon (1996) cited by Campbell (1996) and Lee (1998). Mean is the mean nominal CPUE and ε is the error term assumed as the normal distribution with zero mean and variance. Months were from January to December; location is where the fishing activities occur and fishing gears were the gears used in catching *D. macrosoma*. Month, location, and fishing gear are all independent variables used.

Meanwhile, five-year historical data on catch and CPUE for beach seine from 2012 to 2016 were processed for the Catch Maximum Sustainable Yield (CMSY) and Bayesian Schaefer Model (BSM) methods for verification of results from FiSAT II and for use in establishing management options. CMSY and BSM are new stock assessment methods used to generate Reference Points (RPs) such as biomass, (B_{msy}), Maximum Sustainable Yield (MSY), fishing maximum sustainable yield (F_{msy}), and others that are highly sought by fisheries managers for decision making.

The following formula was used to compute CMSY and BSM (Palomares and Froese 2017).

$$\mathbf{Bt+1 = Bt + r\,Bt\left(\frac{Bt}{k}\right) - Ct}$$

Where Ct was the catch in year t, B = CPUE / q, q was the catchability coefficient. If the CPUE is unknown, a prior range for r was derived from life history traits, a prior range for k was derived from the maximum catch, and the prior ranges for Bt/k (beginning and end of catch time series) were derived from expert knowledge. All r-k combinations that were compatible with the life history traits (r, M, K), catches (Ct) and the expert knowledge (Bt/k) were identified by Monte-Carlo approach.

2.8 Population parameters

Using the FiSAT II software, Von Bertalanffy Growth Function (VBGF) like asymptotic length (L_∞) and growth coefficient (K) was estimated using the ELEFAN I (Electronic Length Frequency Analysis) (Pauly and David 1981). A total of 3,431 unraised length-frequency data of *D. macrosoma* were collected from all fishing gears from January 2016 to December 2017. However, only the data of beach seine (1,926 unraised) were processed in this study since it has the most number of collected length-frequency data, with more than six months of data and represents all the length values from other fishing gears in this study.

Initially, length data was validated to double-check if there were outliers in measurements and encoding of length data. This was done by comparing the encoded length data to the hard copies and scanned reports submitted by field enumerators. Species verification was also conducted to minimize and prevent errors of misidentification of the species *D. macrosoma* to *D. macarellus*.

Before processing length-frequency for beach seine, data cleaning was conducted to verify and eliminate the lengths with extreme values. Lengths with values of 32 cm above and 10 cm below were no longer included in the processing of population parameters due to uncertainty of the species identified and some already exceeded the required length ranges of the species as indicated in FishBase. The predicted L_{max} of the species, based on Binohlan and Froese (2009) model, is up to 31.46 cm and was also one of the bases for eliminating the extreme lengths. Estimating population parameters and data were combined for both years to find the best L_∞ and K and give a better stock assessment result for the species since there are months in year 1 and year 2 when the species is not present.

Population parameter was computed using the formula:

$$Lt = L\infty\ (1 - e\ {-k}\ (t\text{-}t_o))$$

The estimates of L_∞ and K value were used to estimate the growth performance index (Φ') (Pauly and Munro 1984) using the equation:

$$\Phi' = 2\log 10\ L_\infty + \log 10 K$$

Where Phi (Φ') = growth performance index,
L_∞ = Asymptotic length
K = Growth coefficient of the VBGF
The age at zero length (t_0) was calculated from Pauly's empirical equation given below:

$$\log(-t_0) = -0.392 - 0.275 \log L_\infty - 1.0381\ K$$

Where t_0 = age at zero length
L_∞ = Asymptotic length
K = Growth coefficient.

Further, natural mortality (M) was calculated by Pauly's empirical formula (Pauly 1984) by taking the mean sea surface temperature as 28ºC (mean annual habitat temperature of the water in which the stocks live).

$$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T)$$

Where L_∞ = Asymptotic length, K = Growth coefficient and T = Sea surface temperature
Total mortality (Z) was calculated from length converted catch curve using FiSAT software. Fishing mortality (F) was estimated by Pauly as:

$$F = Z - M$$

Where F = Fishing Mortality, Z = Total Mortality,
M = Natural Mortality
Further, the exploitation ratio (E) was estimated by the relationship of Gulland (1971)

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

Where F = Fishing Mortality, Z = Total Mortality, E = Exploitation ratio

To estimate the capture probabilities, catch curve was extended using the logistic transformation of L_{25}, L_{50}, and L_{75} (lengths at which 25%, 50%, 75% of *D. macrosoma* will be vulnerable to the gear). The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length frequency data as described in FiSAT II.

Similarly, the length data of beach seine was also re-run using the Length Based Bayesian model (LBB) of the R program software to double-check the estimated values (L_∞, K, M, Z/K, M/K and E) generated in FiSAT. This will give more confidence in the result of the data being processed and analyzed in FiSAT.

3. RESULTS

3.1 Seasonal abundance

Seasonality of catch was determined based on the abundance (in volume) and occurrence (in frequency) of the species from various fishing gears used in catching *D. macrosoma* in the Babuyan Channel from 2016 to 2017. Seasonal abundance showed that the species is available throughout the year. In 2016, the bulk of *D. macrosoma* catch was observed from January until April. A drop in the catch was observed in the month of May and a slight increase was noted in June. Though these months (March to May) are considered summer months and the favorable fishing season for the fisherfolks to catch *D. macrosoma,* an abrupt decrease in the catch was noted in the year 2017 (Figure 3). The low catch was observed from February until May and from August to October. Only in the months of June and July in year 2 has the highest recorded landed catch with 0.47 MT and 0.42 MT, respectively. The observed peak in year 2 differs from the observed peak in year 1, while the observed landed catch in year 2 was far below the observed catch in year 1.

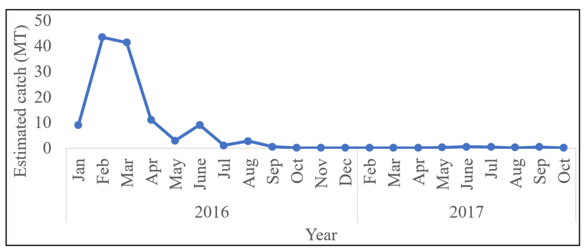

Figure 3. Seasonal abundance of shortfin scad (*Decapterus macrosoma*) in Babuyan Channel, Philippines.

3.2 Length distribution

Length frequency data for all gears were validated and L_{max} was established following the Binohlan and Froese (2009) model. The largest L_{max} observed in the study was 32.8 cm, however, this measurement seems too big for the species and questionable since most of the recorded and published length for this species was only up to 29.5 cm (Lavapie-Gonzales et al. 1997; Belga et al. 2018; Magallanes et al. 2022; FishBase 2022). Applying the equation of Binohlan and Froese (2009), the species of *D. macrosoma* in the Babuyan Channel that matures at 17.64 cm would predict an L_{max} of 31.46 cm. The obtained variance was 17.39 with a standard deviation of 4.17. The predicted L_{max} in the study was used to plot size frequency distribution. Therefore, the analysis did not include all the lengths observed exceeding the predicted L_{max}.

Species caught by beach seine have a midlength ranging from 5.5 cm to 31.5 cm upon eliminating the values exceeding the predicted L_{max} of the species. While species caught by ring net have a midlength ranging from 10.5 cm to 27.5 cm. It was noted that most of the species caught by beach seine and ring net have a midlength of 17.5 cm. Midlength for multiple hook and line was 13.5 cm to 22.5 cm of which most of the species caught at 18.5 cm (Figure 4.)

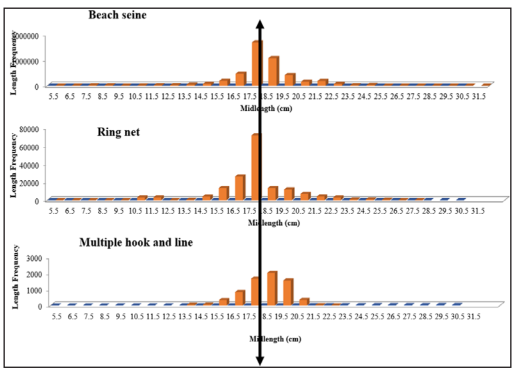

Figure 4. Length distribution of shortfin scad (*Decapterus macrosoma*) caught in Babuyan Channel, Philippines using beach seine, ring net and multiple hook and line from January 2016 to December 2017.

Troll line, on the other hand, has a midlength of 13.5 cm to 25.5 cm with most species caught at a midlength of 14.5 cm. Gillnet has a midlength ranging from 14.5 cm to 29.5 cm with most species caught at 20.5 cm. While simple handline has a midlength of 23.5 cm to 26.5 cm with most species caught at 24.5 cm (Figure 5).

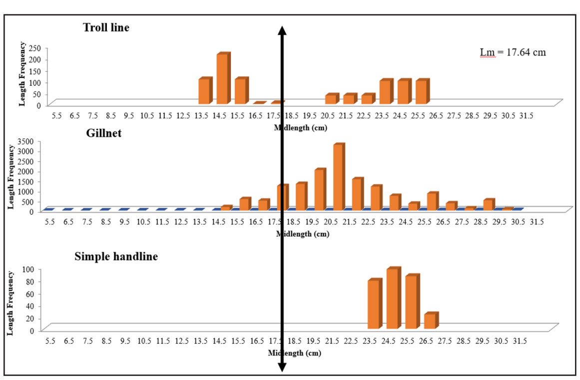

Figure 5. Length distribution of shortfin scad (*Decapterus macrosomia*) caught in Babuyan Channel, Philippines using troll line, gillnet, and simple handline from January 2016 to December 2017.

Further, it can be noted that the result of NSAP on the reproductive biology of *D. macrosoma* in Northern Palawan showed a length at maturity of 16.3 cm in 2013 to 2014, 17.85 cm in 2015 to 2016, and 19.39 cm in 2016 to 2017 (DA-DILG 2015 cited by Rada et al. 2019). Similarly, the species observed L_m was 17.64 cm in the Babuyan Channel from 2018 to 2020 (Villarao et al. unpublished). The values obtained in the Babuyan Channel were used as a reference in estimating the percentage of immature and mature species in the Babuyan Channel since it is the latest study conducted on the fishing ground.

Notably, most of the lengths caught by beach seine were immature, accounting for 56.62% and only 43.38% were mature. Ring net caught 74.46% immature and 25.54% mature. The same observation was also noted for the troll line, where the catches comprised of 51.30% immature and only 48.70% mature. However, most of the catch of gillnets and simple handlines were mature, comprising 83.35 % and 100%, respectively.

3.3 Catch contribution per gear

Figure 6 shows the six types of fishing gears used in catching shortfin scad of which beach seine has the largest catch contribution (84.20%), followed by ring net (10.31%), gillnet (4.60%), multiple hook and line (0.58%), troll line (0.19%), and simple handline (0.11%).

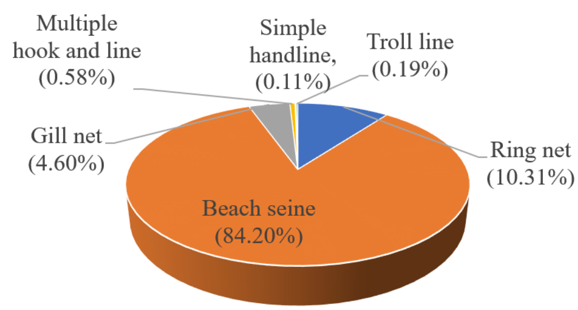

Figure 6. Percentage contribution of fishing gears used to catch shortfin scad (*Decapterus macrosoma*) in Babuyan Channel, Philippines from January 2016 to December 2017.

3.4. Catch, effort, and CPUE

Figure 7 shows the monthly catch, effort, and standardized CPUE of beach seine, ring net, multiple hook and line, troll line, gill net, and simple handline. Notably, catch, effort, and CPUE for specific fishing gears were not observed throughout the year since most of the fishing gears used in the fishing ground are highly seasonal based on the targeted species and the environmental conditions.

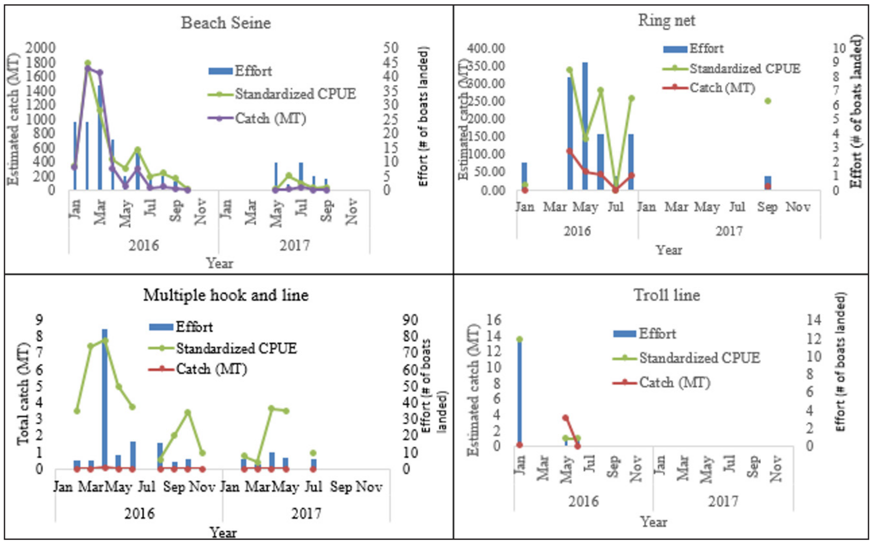

Figure 7. Catch, effort and catch per unit effort of beach seine, ring net, multiple hook and line, troll line, gill net, and simple handline in Babuyan Channel, Philippines from January 2016 to December 2017.

The highest CPUE for beach seine in year 1 was observed in February (1,789.95 MT/boat) while, in year 2, it was noted in July (102.98 MT/boat). As observed, CPUE in February started to decrease from March until October. In year 2, fluctuating CPUE was observed. For ring net in year 1, the highest CPUE (258.02 MT/boat) was observed during June. In year 2, only in the month of September has an observed CPUE (251.20 MT/boat). As observed in year 1, the CPUE of the gear is fluctuating while the catch is decreasing. Gillnet has the highest CPUE observed in July (48.96 MT/boat) in year 1 and September (0.03 MT/boat) in year 2 with a fluctuating CPUE and catch. Multiple hook and line have the highest CPUE recorded in April both for year 1 and year 2 with an observed CPUE of 7.78 MT/boat and 3.65 MT/boat, respectively. CPUE and catch are fluctuating. CPUE for simple handline was only observed in year 1 in the month of September with 2 MT/boat. In January, the highest CPUE for the troll line in year 1 was noted with 13.66 MT/boat. For simple handline and troll lines, the CPUE trend cannot be determined due to a limited number of landings for said gears during the 2-year study period. With all the fishing gear used, it was observed that there were fish landings in the months of November and December in year 2 of the study, but no *D. macrosoma* had been unloaded.

3.5 Population parameters

Only population parameters of beach seine were assessed in this study since the gear already covers the ranges of sizes caught by other fishing gear. Length data of beach seine for the two-year period were pooled to come up with a greater number of length frequencies and to cover the months where the species length is not available during the first and or the second year. The observed VBGF asymptotic length (L_∞) of *D. macrosoma* was 27.83 cm with a growth coefficient (K) of 0.95 and a growth performance index of 2.86. The L_∞ observed was close to the values obtained in LBB which was 26.58 cm.

Interestingly, based on CMSY and BSM analyses using the five-year historical data on catch and CPUE for beach seine from 2012 to 2016, the CMSY exploitation rate has a similar trend to the CPUE exploitation rate. The result of CMSY methods shows that the catch of the species in the last two (2) years is already above the target MSY (32 MT) for the species. The MSY was 120 MT in 2015 and 89.8 MT in 2016 which are far above the target (Figure 8). The results of the exploitation (F/F_{msy}) and relative stock size (B/B_{msy}) also corroborate the result of the FiSAT obtained in this study. In 2015 to 2016, the F/Fmsy is greater than 1 (>1), showing an ongoing overfishing, and the B/B_{msy} is within the 0.5–1 level, showing also that the species is already outside the safe biological limits. Generally, *D. macrosoma* are already fully overfished and can no longer produce the target MSY based on the definition of fish stock status, specifically on B/B_{msy} and F/F_{msy} in the final year of time series of Froese et al. (2016) and Froese et al. (2018).

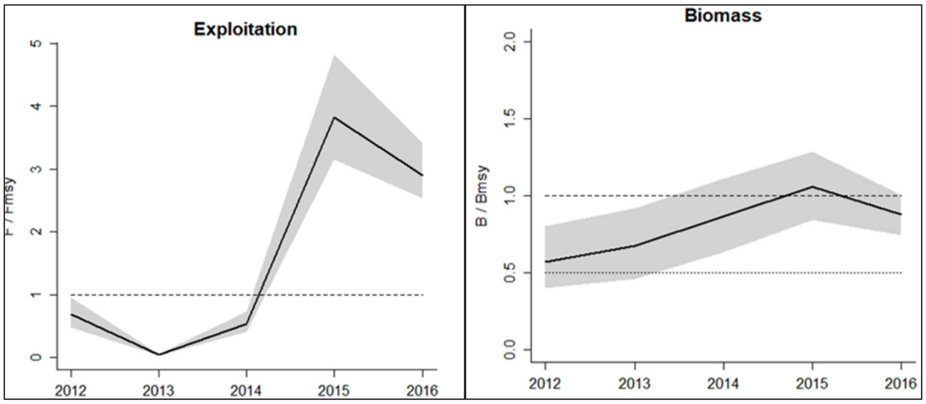

Figure 8. CMSY analysis of exploitation and biomass of *D. macrosoma* in Babuyan Channel, Philippines.

3.6 Mortality and exploitation ratio

Combining data from both years, the analysis of the converted catch curve generated a mortality estimate of Z = 4.74. The natural mortality (M) was estimated (for T = 28°C) at 1.76 with fishing mortality (F) of 2.98 and the current exploitation (E) level was computed at 0.63 (Figure 9).

The relative yield per recruit (Y'/R) analysis using selection Ogive was used to determine the exploitation status for the gear. Figure 10 shows the exploitation status generated by the ratio of the current exploitation rate E = 0.63 to the E_{max} = 0.749 is 0.841(E/E_{max}) which implies that *D. macrosoma* in Babuyan Channel is already beyond the maximum level of exploitation using beach seine.

To double-check and further verify the results generated in FiSAT, data were also processed using the LBB of the R program software. The results obtained for M/K were 1.52, F/K of 1.08, and Z/K of 3. The values were also high as compared to the values obtained in FiSAT. The generated value for Y/R' was 0.019 with a B/B_0 of 0.081 and B/B_{msy} of 0.22. Based on the calculated values, it can be observed that B/B_0 is less than B/B_{msy} ($B/B_o < B/B_{msy}$) indicating also that the stocks are overfished. The same results were obtained from the CMSY analysis and FiSAT.

3.7 Probability of capture

The result of the converted catch curved using the logistic transformation showed that sizes 13.78 cm (L_{25}), 14.70 cm (L_{50}), and 15.61 cm (L_{75}) are vulnerable to the gear (Figure 11). *D. macrosoma* showed year-round recruitment patterns having two peak periods with unequal strength (Figure 12). Major peak was observed to occur in March and April, and the minor peak to occur in August to October.

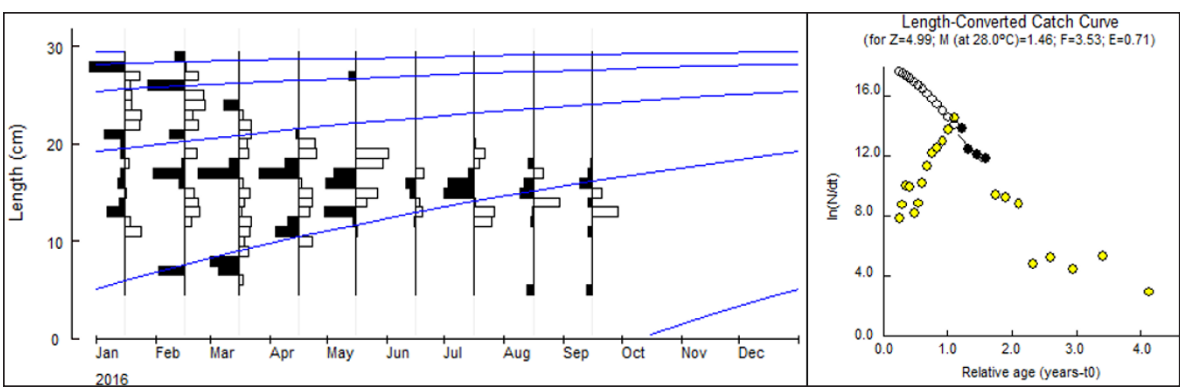

Figure 9. Length frequency plot and length converted catch curve of shortfin scad (*Decapterus macrosoma*) caught by beach seine in Babuyan Channel, Philippines.

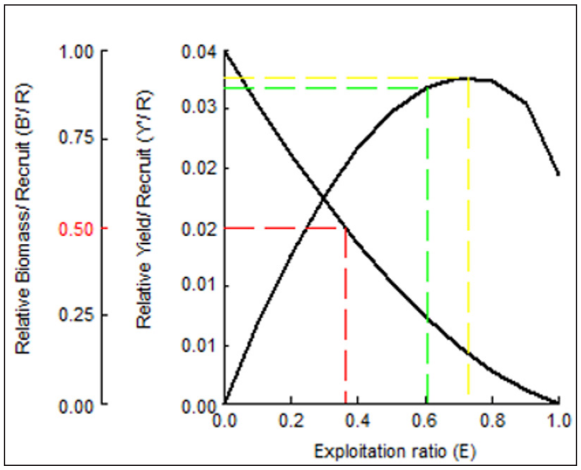

Figure 10. Relative yield per recruit (Y'/R) of beach seine in Babuyan Channel, Philippines.

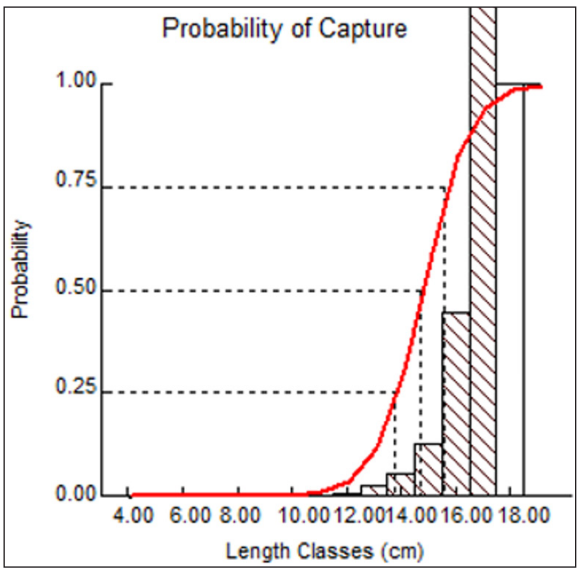

Figure 11. Probability of capture for beach seine in Babuyan Channel, Philippines.

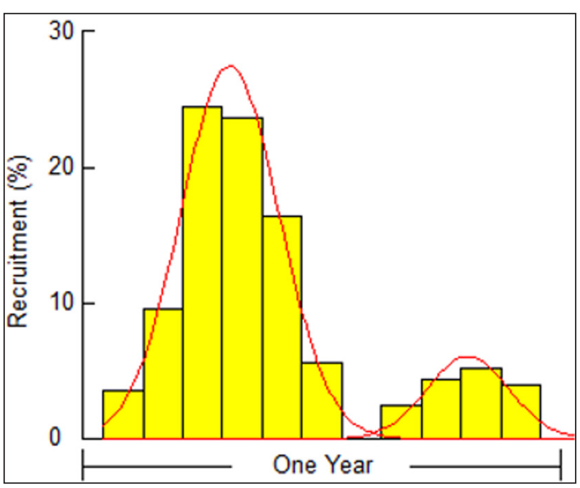

Figure 12. Recruitment pattern of beach seine in Babuyan Channel, Philippines.

4. DISCUSSION

Seasonality of the species in the Babuyan Channel is highly influenced by southwest and northeast monsoon and transition winds that regularly occur every year. *D. macrosoma* were most abundant during the months of February to April and June, before the onset of the southwest monsoon (June to October), and least observed during the northeast monsoon. In the study of Belga et al. (2018), the highest peak of *D. macrosoma* in the Camotes Sea was observed in April which prevails until June and no more secondary peak was observed after that. This is further supported by the observation of Trinidad et al. (1993), wherein the highest production of its congeners in the Philippines happened between March and June ensuing the end of the northeast monsoon and the beginning of the southwest monsoon. The study made by Pastoral et al. (2000) on the seasonal distribution of catch from one year indicates that the lowest catch rate was noted during the onset of the northeast monsoon in November and December, while the peak was revealed in the summer months of April to June.

Moreover, the decrease in landed catch in 2017 could not only be attributed to the lesser number of boat landings catching *D. macrosoma* from 194 in 2016 to only 40 units of boats landed in 2017. Based on the 2017 NSAP gear inventory, there were 334 units of fishing gear catching *D. macrosoma*. The low catch could be the effect of strict implementation of the Republic Act 8550 as amended by Republic Act 10654 (An Act to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing) on the operation of unlicensed fishing gears, particularly ring nets (Sec. 86 of R.A. 10654). Buguina S. (March 9, 2020, Personal communication) showed figures on the number of enforcement activities conducted in the area in 2015, 2016, and 2017 with the increasing number of seaborne operations from 150, 276, to 315, respectively.

Furthermore, the landed catch of *D. macrosoma* has been observed to be low in the landing areas. It can be noted that in previous years, the majority of the catch was composed of *D. macrosoma*. However, in the year 2017, it was observed that the catch of said species is beginning to decline, and other small pelagic species like *Amblygaster, Selar*, and other species of *Decapterus* dominated the catch of gears.

Aside from the strict implementation of R.A. 10654 (particularly Sec. 86), the sudden change of weather conditions and frequent occurrence of a typhoon in the area might also affect fishing trips and the number of hours expended by the fishers when they were already out at sea or prevent them from leaving the harbor. In the study of Calicdan et al. (2018) in Babuyan Channel, it was observed that the increase in production is reflected by the increased number of efforts exerted by fishers. Notably, during summer which is also a peak of fishing and good weather conditions, fishers extend their fishing hours and hauling activities. Ring netters operate eight hours a day with twohauls during peak season and five hours a day with only one haul during the lean season. For beach seine, during peak season, the operating time is six hours a day while three hours a day during the lean season. The decrease in production might be further aggravated by environmental factors (i.e., weather conditions), social (i.e., conflict with other users), and economic (i.e., increased fuel price) that the fishers encountered. Guillen and Maynou (2016) stated that the main reasons for the decrease in economic performance and fishing activity of fishers are increases in fuel prices together with low prices of fish and low fish productivity. The author also further concluded that fuel cost can represent 50% of the total fishing cost, so fishing performance is very dependent on the fuel price. It was further proved by Rezaee et al. (2016) that weather factors like wind speed and fishing activity levels (i.e., extreme weather conditions usually resulted in decreased fishing activities) have a strong relationship.

The sudden decrease in production in 2017 could not only be attributed to boat landings, strict implementation of fishery laws, and other environmental, social, and economic factors but might also be due to the low productivity of the species. Enumerators observed that in 2017 most of the catch consisted mainly of small pelagic species like *Engraulids* and *D. macarellus* species. The noted production of *D. macrosoma* in that year is minimal compared to 2016. It was also observed that starting in 2017, most of the round scad being sold at the market in Cagayan Province mainly came from Ilocos Region.

The result of length frequency distribution implies that most beach seine, ring net, multiple hook and line, and troll line are the fishing gears that caught the species before maturity. It can be noted that beach seine and ring net have the most immature species caught, which could be associated with the specification of the fishing gear being used. Most of the beach seine used in the area has a mesh size of 1.5 inches (9 knots), 1 inch (13 knots), and 0.5 inches wherein the bunt is made up of a mosquito net and is deployed and operated 600 meters away from the shore. On the contrary, the ring net used in the area has a mesh size of 6, 18, 22, and 32 knots and is operated in municipal waters. De Peralta N. (February 27, 2020, Personal communication) stated that no gear modification has been made for beach seine in the area since 2000. The use of fishing gear is highly seasonal due to weather conditions, moon phases, and the seasonality of fish on the fishing ground.

Of all the fishing gears used, beach seine has the highest percentage of catch compared to other gears used in the area. It can be noted that beach seine is a demersal gear but most of the catches are *D. macrosoma*, a pelagic species. Based on previous studies, the species composition of beach seine depends on the fishing time (Monteclaro and Abunal 2013). Beach seine also captures mostly juvenile slipmouths, anchovies, and sardines (Beckley and Fennessy 1996) and other clupeid species (Davies et al. 2009) which are also small pelagic species.

The highest CPUE occurs before and after the summer season from January to June. These months are the peak of fishing in the fishing ground, the only months favorable for fishing activities. Fluctuating CPUE and decreasing catch for ring net and beach seine could be attributed to the low catch of *D. macrosoma*. Most of the catch is composed mainly of tuna and tuna-like species, and *Engraulids* for ring net. The majority of the catch of beach seine particularly in year 2 were other species of *Decapterus, Leiognathus, Carangoides, Selaroides, Engraulids, and Rastrelliger*. Other factors could also affect the CPUE and catch of fishers like environmental conditions (typhoon and bad weather) along with other biological (species abundance), social (high cost of fuel) factors, and other law enforcement activities being implemented particularly for unlicensed commercial gears. The location of the landing site or the fishing area, the boat's gross tonnage, and the type of fishing gear used could also affect the CPUE. The study of Sulishtyaningsih et al. (2020) showed that the variation of CPUE was influenced mainly by year and quarter, while season and fleet size (GT) showed less impact on the catch.

The estimated growth performance and K values computed were quite close to the values obtained in Moro Gulf/Ilana Bay, Leyte Gulf, Camotes Sea (Lavapie-Gonzales et al. 1997), and Palawan (Dalzell and Ganaden 1987). L_∞ recorded in Palawan and Manila Bay (Dalzell and Ganaden 1987), Visayan Sea (Aprieto and Villoso 1979) and Guimaras Strait (Dalzell and Ganaden 1987), ranges from 30 cm to 33 cm.

As observed, larger species were mostly caught in the islands of Calayan and Camiguin. Further, species validation and verification were conducted to confirm if there was a misidentification of species between *D. macrosoma* and *D. macarellus*. Based on the samples being presented by the enumerators and their morphometric characteristics, it was found that the species being measured and recorded was *D. macrosoma*.

Meanwhile, the results of mortality parameters were compared with the available data in earlier studies which showed that Z estimates of the species from this study (Z = 4.74) were slightly higher than those estimates obtained by Aripin and Showers (2000) in Tawi-Tawi (Z = 3.49), De Guzman et al. (2018) in Eastern Sulu Sea and Basilan Strait (Z = 3.53), Calicdan et al. (2018) in Babuyan Channel (Z = 3.14 to 4.81) but lower than the observed values of Belga et al. (2018) in Camotes Sea (Z = 5.44) and Olaño et al. (2018) in Lagonoy Gulf (Z = 7.55).

Higher fishing mortality values than natural mortality values obtained imply that the species is already experiencing high fishing pressure. According to Gayanilo and Pauly (1997), Z/K = 1 is a rule of thumb for a stock to be growth-dominated; whereas, if it is more than two (2), it is considered fishing mortality-dominated. Hence, high mortality estimates in this study indicate that the stock is highly fishing mortality-dominated.

For the Yield per Recruit, Beverton and Holt (1959) indicated that the M/K ratio should usually fall in the range of 1–2.5 which is often become a tool to verify the accuracy of the natural mortality estimates. It was revealed that the values obtained in this study using the LBB and FiSAT were 1.52 and 1.85, respectively, indicating that natural mortality in this study was considered reasonable. A high exploitation ratio was also noted for the species for the whole length groups, indicating that the species in the fishing ground is already beyond the sustainable level of exploitation. Gulland (1971) pointed out that a stock is optionally exploited if fishing mortality equals natural mortality; F_{opt} = M or E=0.5; hence higher than 0.5 suggests overexploitation.

To double-check and verify the result, data were processed to CMSY and it obtained a high exploitation rate (above 1) from 2012 to 2016 and some CMSY points were not within the equilibrium suggesting that overfishing and shrinking of biomass is occurring. High fishing mortality and exploitation values were previously observed in the study of Calicdan et al. (2018) in Babuyan Channel from 2009 to 2013. However, mortality values obtained before were lower than those obtained in the present study.

Same observations on high exploitation values for shortfin scad were also recorded in different major fishing grounds in the country, particularly in the Southern Region like in Palawan, Manila Bay (Ingles and Pauly 1984), Camotes Sea, Sulu Sea, and Moro Gulf (Lavapie-Gonzales et al. 1997); Tawi-Tawi (Aripin and Showers 2000), Camotes Sea (Belga et al. 2018), Moro Gulf (Olaño et al. 2018), and Eastern Sulu Sea and Basilan Strait (De Guzman et al. 2018). The result of E values in this study further corroborates the result found in nearby fishing grounds like in Lingayen Gulf (Gaerlan et al. 2018) in Region 1 and other major fishing grounds in the country that are mentioned earlier.

Notably, L_{25}, L_{50}, and L_{75} values computed earlier in the study of Calicdan et al. (2018) became smaller in this study. The declining L_{25}, L_{50}, and L_{75} values of *D. macrosoma* in Babuyan Channel could be attributed to heavy fishing pressure on the fishing ground as reflected by the high fishing mortality values obtained. L_{50} showed that 50% of the species at 14.04 cm are vulnerable to the gear in which the length at maturity in FishBase (2022) was 17.6 cm and 17.64 cm in Babuyan Channel (Villarao et al. in press). This only shows that the species have yet to reach maturity or spawn before they are caught and contribute to production. The smaller sizes obtained by Pauly (1998) and Froese (2006) for roughear scad were attributed to the effect of fishing pressure resulting in growth overfishing or differences in environmental factors, particularly water temperature and food availability.

Results of the recruitment pattern in this study showed a dual mode of recruitment with unequal strength. This also conforms to the study of Aripin and Showers (2000); Belga et al. (2018) and Ramos et al. (2018). Ingles and Pauly (1984) cited by Ramos et al. (2018) reported that the recruitment pattern of most of the Philippine stocks has two pulses generated each year.

5. CONCLUSION

The seasonality of *D. macrosoma* in the Babuyan Channel is highly influenced by the monsoon season in which the highest production was observed during summer. The noted decrease and increase in the catch for *D. macrosoma* and fluctuating catch per unit effort could be attributed to the lesser number of landings observed from year 1 to year 2 of the study. This could be due to strict implementation of the fishery law (RA 10654), the visibility of the fishery law enforcers in the area where unlicensed ring netters are operating, and low catch or productivity of the species. This is also coupled with the sudden change in weather conditions, high fuel price costs, and increased efforts exerted by fishers. The majority of the catch of beach seine, ring net, multiple hook and line are immature. The higher L_∞ values obtained could result from larger *D. macrosoma* recorded than the observed length ranges in FishBase. The estimated fishing mortality value obtained is higher than the natural mortality values indicating that the species is already experiencing high fishing pressure. The estimated exploitation ratio observed is already higher than 0.5 level but also exceeded the values of E_{10}, E_{50}, and E_{max} implying that the level of exploitation is already beyond the sustainable level.

Hence, for management purposes, environment-friendly fishing gear should be introduced. An example of environment-friendly fishing gear is hook and line because of its characteristic of being selective, thus, diminishing the catch of endangered species that can be caught unintentionally and reducing the catch of juvenile fish species. Likewise, gill nets can be an environment-friendly fishing gear as long as the mesh size is legal for sustainable catching to avoid juvenile fish species. However, it is also recommended to conduct a "right-sizing" of fishing effort to identify the specific measures for the persistent fisheries issues and problems in the area as a way forward.

Banning beach seine could also be considered as one management option due to its destructive effect because of its fine mesh cod-end mesh size. However, if this regulation is imposed, it will affect the fishers' economic well-being and could inevitably pose serious repercussions on the fisheries workers who are highly dependent on fishing using this type of fishing gear for their livelihood. Though the loss of livelihood and income will cast down over the favorability of this regulation, the fisheries workers of the beach seine fishery could be given alternative livelihood (i.e., fish caging, aquaculture production, and processing activities), gear modification or they could be given fishing gears and boats of their own to operate in order to alleviate the impact of banning the beach seine and mitigate income loss.

Similarly, Marine Protected Areas (MPAs) in all coastal municipalities within the Babuyan Channel should be established and expanded to further support the species population and productivity. Though MPAs have already been established in some parts of the Province of Cagayan, areas still need to be protected. Some of these are the Fuga reef, Calayan reef, Patunungan reef in Sta. Ana and Camiguin reef. These are the priority areas within the Babuyan Channel fishing ground that still need further protection since it is also where a large chunk of the fish population and landings come from. If this measure were implemented, this would affect the income of the marginal fishers. However, the number of fishers affected can only be determined if there is an inventory of fishers and the actual boat and gear inventory in the area.

Meanwhile, the close season could not be considered a viable option in the area because of the natural close season occurring in the fishing ground since typhoons and bad weather conditions were frequently observed after the summer season.

On the other hand, a reproductive biology study is also needed to further investigate the peak of spawning season, sex and maturity data, and the relationship between seasonality with the occurrence of monsoon and unfavorable weather conditions which will serve as the basis for stock management.

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AUTHOR CONTRIBUTIONS

Villarao MC: Conceptualization, Methodology, Formal Analysis, Writing-draft preparation, and Editing the manuscript. **Gumiran E**: Data processing and analysis. **Encarnacion AB**: Conceptualization, Supervision, Formal Analysis, Review, and Editing of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no competing and conflict of interests.

ETHICS STATEMENT

Additional informed consent was obtained from all individuals for whom identifying information is included in this article.

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