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REPRODUCTIVE CHARACTERISTICS OF MACKEREL SCAD *Decapterus macarellus* (CUVIER, 1833) IN NORTHERN PHILIPPINE WATERS

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ABSTRACT

Mackerel scad *Decapterus macarellus* is a highly valuable species in the Philippines municipal and commercial fishing industry, particularly in northern Philippine waters in the Babuyan Channel fishing ground. The study assesses reproductive characteristics, including the sex ratio, catch seasonality, fecundity, gonadosomatic index (GSI), gonad and sexual maturity (L_m and L_{95}), and length range distribution by gear. Samples were collected in the Babuyan Channel fishing ground from April 2018 to March 2020. The results showed that *D. macarellus* is present throughout the year in the fishing ground, with noted peaks from April to July. An unbalanced sex ratio was found between the females (1:18) and males (1). The mean fecundity was 25,546 eggs. The gonadosomatic index revealed that the spawning season of *D. macarellus* occurs throughout the year, with an observed prolonged spawning and a notable peak during the northeast monsoon. The length at maturity (L_m) was 14.15 cm, and L_{95} was 17.60 cm. Of all the fishing gear for catching the species, beach seines catch most of the juveniles. Management options such as establishing additional Marine Protected Areas to support fish populations and productivity of the species, and reducing fishing effort are recommended to protect and conserve the stock.

How to Cite

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INTRODUCTION

Mackerel scad *Decapterus macarellus* (Cuvier, 1833), locally known as "Baraniti" in the Province of Cagayan, is an economically important species to millions of Filipinos. In Northern Philippines, particularly in the waters of the Ilocos Region and Cagayan Valley Region, mackerel is mostly caught in the waters of the Babuyan Channel (Calicdan et al., 2018) and Lingayen Gulf (Gaerlan et al., 2018) using Gill nets (encircling gill nets, bottom and surface gill nets), and seine nets (beach seine, round haul seine). The traditional fishing grounds of *Decapterus* species in the Philippines are the Sulu Sea, Mindoro Strait, Visayan Sea, Moro Gulf, Lamon Bay, Cuyo Pass, Ragay Gulf, Batangas Coast, Tayabas Bay, Samar Sea, Camotes Sea, Sibuyan Sea, Bohol Sea, and Davao Gulf, while the municipal fishing grounds are in the Northern and Southern Mindanao, Casiguran Sound (Pastoral et al., 2000; Rada et al., 2019), and Manila Bay (Tiews et al., 1971).

In the Cagayan Valley Region, there are 39,868 fisherfolk registered in Cagayan Province, particularly the municipalities bordering the Babuyan Channel (DA-BFAR, 2024), which is higher compared to Batanes Province (1,731) and Isabela Province (1,323). Babuyan Channel fishing ground is one of the major fishing grounds in the Northern Philippines with a higher volume of scad landings compared to the waters of Batanes and Isabela (Villarao et al., 2023), but lower landings compared to the fishing grounds in southern Philippine waters like the Sulu Sea, Visayan Sea, and Moro Gulf (Calvelo, 1992).

In the Babuyan Channel, the stocks of *Decapterus* are shared by 7,101 municipal and 174 units of commercial fishing boats using different gear types (DA-BFAR, 2020). Though it is one of the commercially important species and is caught in large quantities in Philippine waters, the information on its reproductive biology, particularly its spawning and maturity, remains scarce. Several authors have already documented the spawning season of other round scad species in the Philippines (Dela Rosa et al., 2022; Rada et al., 2019; Villarao and Encarnacion, 2023), but the species of *D. macarellus* is not one of them. Instead, studies on *D. macarellus* focused mainly on the meristic and morphometric characteristics and population dynamics of the species. Some studies in other countries attempted to investigate the spawning period and length at maturity of this species, but more studies are needed to determine its specific spawning patterns. The results of this study will serve as a guide for resource managers and policymakers in formulating policies and diversifying management strategies for a healthy and sustainable production of *D. macarellus*. In addition, the result will further serve as regional input in categorizing the status of the species in the Philippines under the International Union for Conservation of Nature Red List of Threatened Species. Results also served as baseline information and significant input by the Fisheries Management Area 1 (FMA-1), Northern Pacific Seaboard in determining the Harvest Control Rules (HCRs) and formulating Harvest Control Measures (HCRs) of *Decapterus* stocks for its sustainable management in FMA 1.

MATERIALS AND METHODS

Study site

The study was conducted in the Babuyan Channel, encompassing 12 coastal municipalities in Cagayan Province, Philippines (Figure 1). Geographically, the area spans from 18° 16' 00" to 19° 35' 00" North Latitude and from 121° 02' 00" to 121° 14' 30" East Longitude. The Cagayan mainland and islands have a combined coastline of 154 km and cover approximately 477,550 km^2. The channel extends northward to Fuga, Camiguin, Dalupiri, Calayan, and Babuyan Islands, connecting the Pacific Ocean (East) and the West Philippine Sea (West) (Villarao et al., 2023).

Samples of *D. macarellus* were collected in the municipality of Sta Ana (Tangatan, Palawig, Centro and Casambalangan), Gonzaga (Amunitan, Tapel, Batangan, and Minanga), Buguey (Paddaya and San Isidro), Aparri (Centro, Punta, Dodan and Macanaya), Abulug (Centro and Siguiran), Sanchez Mira (Masisit and Tokitok), Pamplona (Nagtupacan and Bidduang), Claveria (Taggat and Minanga).

Data collection

Data were collected at the established National Stock Assessment Program (NSAP) landing sites along the Babuyan Channel, Philippines (Figure 1) using beach seine, bottom set gillnet, troll line, drift gillnet, encircling gillnet, bottom set longline, round haul seine, and multiple hook and line from April 2018 to March 2020, following the NSAP standard methodology described by Santos et al. (2017). All fishing boats unloading catch of *D. macarellus* were sampled and recorded. A minimum of ten (10) samples per month per gear were collected, measured, and dissected by the trained National Stock Assessment Program enumerators. From each type of fishing gear landed, enumerators bought a sub-sample (minimum of 1 kilo) that was randomly taken from the tub, measured and weighted. This information was encoded in a prescribed form. The form, together with the samples that were already properly coded based on the sample numbers that already appeared in the form, was submitted to the laboratory for dissection and counting of eggs.

Total lengths (in centimeters) and body weights (in grams) were measured and recorded. Individual gonad weights (GW: weight of both lobules) were recorded in grams (g). The procedure of gonad fixation by Villarao et al. (2024) was followed. Parts of the gonads were fixed in a 10% formalin solution and later transferred to a 70% alcohol solution for fecundity and GSI determination. Fish body lengths were measured to the nearest 0.1 gram. This

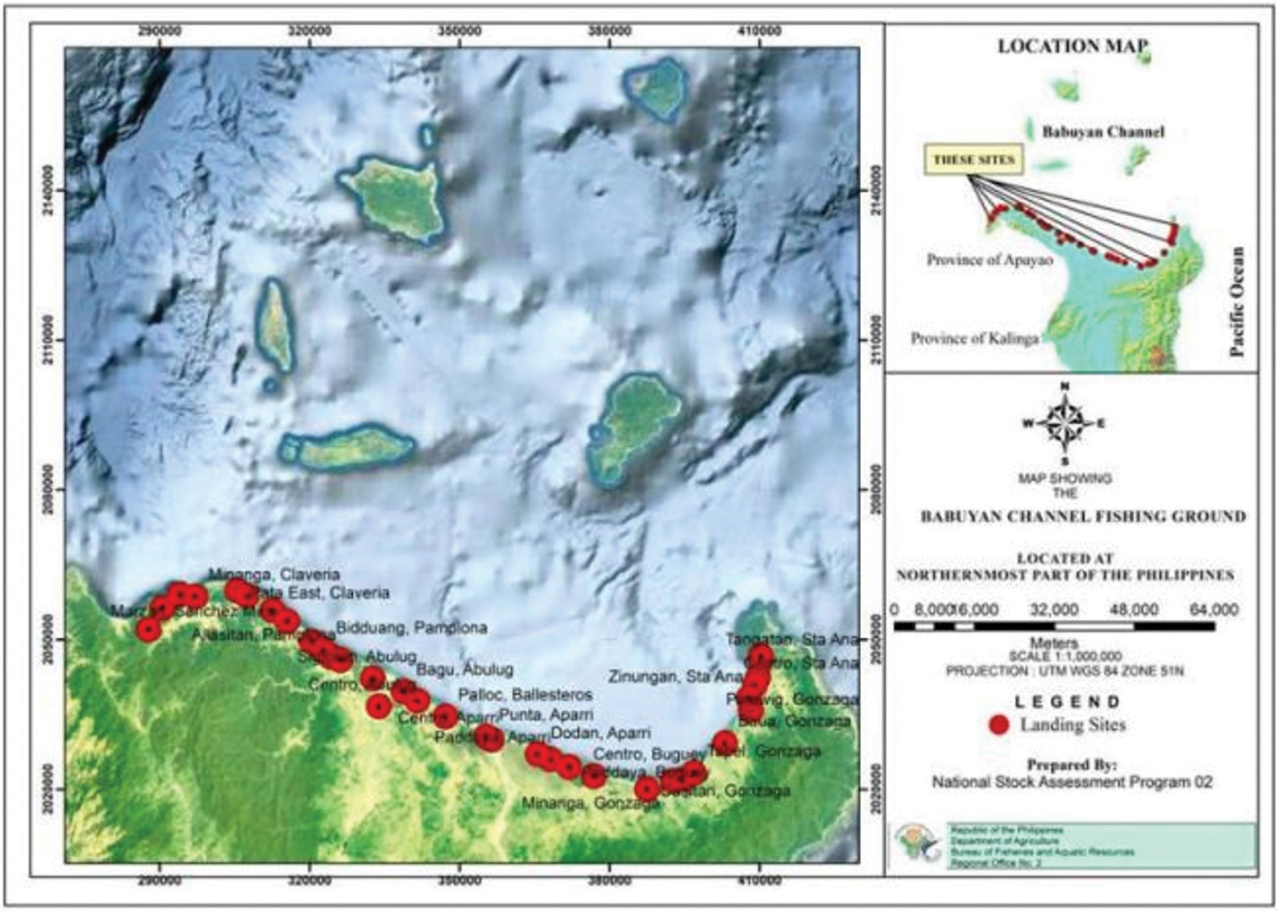

Fig 1. Map of the Babuyan Channel, Philippines showing the location of sampling sites (red dots)

information was recorded in NSAP forms and eventually transferred to an Excel spreadsheet for data verification, checking, processing, and analysis.

Data processing and analysis

Sex ratio

Sexual stages were classified using the five-point scale introduced by Ismen (2002). Monthly sex ratios were computed and expressed as the proportion of females to the total number of juveniles and males following the formula of Sheng-Ping et al. (2003), expressed as:

$$Sex\ ration = F_n / n$$

where F_n is the monthly count of females and n is the monthly total number of samples.

Seasonality

Volume (in kg) of sub-samples was used in determining the seasonal abundance of *D. macarellus* per month (Villarao et al., 2024). Collected data from all fishing gear were pooled to come up with a better presentation of seasonal abundance.

Fecundity and GSI estimation

Mature/developed (Stage III) and Gravid/Spawning (Stage IV) female gonad samples were used in determining the fecundity of *D. macarellus*. Gonad proportions were sampled from the upper lobe, middle lobe, and lower lobe of each gonad calibrated at 0.05 grams. The total number of eggs was estimated from the total number of eggs collected from the three lobes over the total weight of the gonad. The equation used by Shimose and Tachihara (2005) was also used by Villarao et al. (2024) to calculate the gonadosomatic index (GSI):

$$GSI = GW \times (100 / PW)$$

where *GW* is the total weight of the individual gonads and *PW* is the total wet body weight of the individual sample. Relative gonadal frequency distribution was analyzed monthly using the count of the juveniles and females per stage, which was then converted to percentages.

Gonadal frequency pattern

The gonadal frequency pattern was tabulated using the count of juveniles and females per stage. These counts were converted to percentages for the relative frequency distribution per stage. The relative gonadal frequency distribution was computed monthly.

Length at first maturity

The length at which 50% of all individuals were sexually mature (L_m) was estimated from the proportion of mature individuals in each of the one (1) cm length class intervals

and the fitted logistic curve (Sparre and Venema, 1992) as follows:

$$P = \frac{1}{1 + 1\exp(S_1 + S_2 \times L)}$$

where P is the proportion of mature individuals within a length class, S_1 is the absolute intercept, S_2 is the absolute slope, and L midpoint length. The slope (a) and intercept (b) were computed in Excel to find a better estimation of the fit of the logistic curve.

Length ranges of D. macarellus

Comparisons of length frequency distribution caught by different fishing gear were made to determine the type of fishing gear for catching small, bigger, and a wide range of sizes prior to the first maturity. Length frequency measurement of *D. macarellus* caught by various fishing gear was encoded in an Excel spreadsheet. The generated L_m value in this study was used as a baseline in determining the percentage of immature and mature stocks.

RESULTS AND DISCUSSION

Sex ratio

A total of 1,603 samples were collected and dissected during the study, of which 598 were male (37.31%), 621 were female (38.73%), and 384 were of undetermined sex (23.95%) (Table 1).

Table 1. Sex ratio of *Decapterus macarellus* in different months during the study period

Months	Female (N)	Male (N)	Sex Ratio (F: M)
January	79	101	0.78:1
February	27	37	0.73:1
March	15	11	1.36:1
April	128	62	2.06:1
May	50	64	0.78:1
June	103	101	1.02:1
July	86	62	1.39:1
August	45	67	0.67:1
September	40	59	0.68:1
October	17	14	1.21:1
November	8	4	2:01
December	23	16	1.44:1
Overall sex ratio	621	598	1.18:1

As observed, males were outnumbered by females except in January to February, May, and August to September, while equal sex ratios were observed in March, June, July, and October to December. The overall sex ratio was 1.18:1, indicating that for every male there are 1.18 females during the study period. An unbalanced sex ratio is also found in the Babuyan Channel for the species of *Decapterus macrosoma* (Villarao et al., 2024), and *D. macarellus* in the waters of the Banggai Islands, Central Sulawesi (Dahlan et al., 2015) and in Majene waters in West Sulawesi, Indonesia (Tenriware et al., 2023). Some studies on *Decapterus* species also noted a balanced sex ratio of 1:1 (Ongkers et al., 2016; Genisa, 1998; Faizah and Sadiyah, 2020; Ajub et al., 2022). The observation of Tiews et al. (1971) indicates that the sex ratio differs with area and species. Hence, it can be presumed that the species *D. macarellus* in the Babuyan Channel differs from other environments because of its geographical location and the condition of the environment, which is also coupled with various anthropogenic factors (fishing pressure) that might affect the unbalanced sex ratios observed.

Catch seasonality

The catch seasonality of *D. macarellus* in the Babuyan Channel during the study shows an increasing trend from March to May, with the highest peak in June, and then declining from July to September. It can be noted that the highest landings of all marine species in the Babuyan Channel were only observed during the summer months, and started to decline as the southwest monsoon and northeast monsoon entered the Philippines (Calicdan et al., 2018). During this season, the fishing activity of the fishers is highly affected by the changing environmental conditions. Hence, there are minimal to no fishing operations during the season. This is also coupled with the changing of fishing gear used due to the seasonal abundance of target species, seasonal variations, fuel efficiency, cost, market demand for the species during the season, and compliance of fishers with fishery regulations. The species was also noted to be present throughout the year in Philippine waters (Gaerlan et al., 2018), and the peak of landings observed in this study also coincides with the peak of its congeners (*D. macrosoma*) in the Babuyan Channel (Villarao et al., 2023) and the Camotes Sea (Belga et al., 2018). The findings were also further supported by the observation of Trinidad et al. (1993), wherein the highest production of *Decapterus* species in the Philippines happened between March and June, following the end of the northeast monsoon and the beginning of the southwest monsoon. This was also further supported by the study of Pastoral et al. (2000) that the seasonal distribution of *Decapterus* species indicates that the lowest catch rate was noted during the onset of the northeast monsoon, and the peak was revealed during summer months (April-June) (Figure 2). The seasonality is highly affected by monsoon seasons in the fishing ground. According to Yesaki (1983), as cited by

Trinidad et al. (1993), the Philippines is a tropical country where primary and secondary production do not show strong seasonal fluctuations. The biological production of small pelagics is highly seasonal, being influenced by environmental conditions, most probably by monsoon winds (Pauly and Navaluna, 1983; Navaluna and Pauly, 1988; Dalzell and Corpuz, 1990).

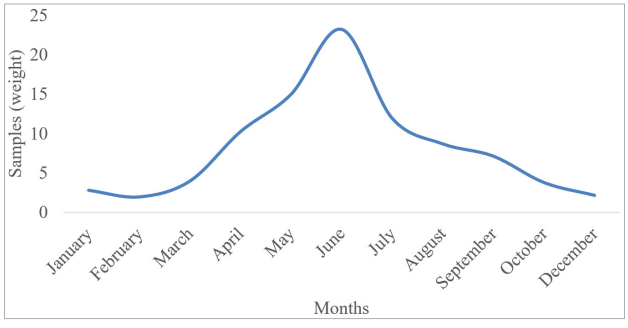

Fig 2. Catch seasonality of *Decapterus macarellus* in the Babuyan Channel, Philippines

Fecundity estimate

A total of 207 samples of *D. macarellus* in Stages III and IV females were studied for fecundity. The observed length at minimum (L_{min}) was 15.10 cm, and the length at maximum (L_{max}) was 29.9 cm, with a corresponding body weight of 219 grams and 31 grams, respectively. The highest absolute fecundity observed was 85,996 for an ovary weighing 5.85 grams, while the lowest absolute fecundity was observed as 250 eggs for an ovary weighing 0.019 grams. The mean fecundity recorded was 25,546 eggs.

Notably, fecundity estimates of *D. macarellus* in the study are the first record for the species in Philippine waters. However, there are already fecundity studies for other species of *Decapterus* in the Philippines. The mean fecundity obtained for *D. macarellus* in this study was 25,546 eggs, which is relatively low compared to the species of *Decapterus kurroides* in Iligan Bay with 197,672 eggs (Dela Rosa et al., 2022), 152,123 eggs of *D. russelli* in Northwest Coast India (Poorjay et al., 2015) and 106,000 eggs of *Decapterus* species in Philippine waters (Tiews et al., 1971). The variation of fecundity could be due to environmental conditions and the size of a fish.

Gonadosomatic index (GSI)

Mature males and females were found from January to December, with the highest GSI occurring in August (female = 2.44; male = 1.64) and November (female = 4.78; male = 1.25), and extended up to February. This only implies that the reproductive season of *D. macarellus* occurs throughout the year, with spawning peaks from August to November and a small peak in February (Figure 3). This spawning season occurs during the cold season (October to December) and the onset of the hot season (February) in the fishing ground with the highest spawning peaks during the cold season.

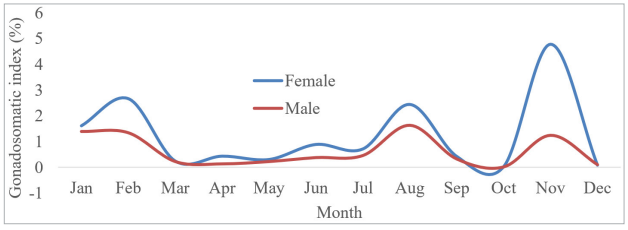

Fig 3. The spawning season of *Decapterus macarellus* in the Babuyan Channel, Philippines

The spawning pattern of *D. macarellus* in the Babuyan Channel is similar to its congener *Decapterus macrosoma* in Philippine waters, where the spawning peaks occur during the northeast monsoon (September-January) and the southwest monsoon (February-May) (Villarao et al., 2023). However, different spawning patterns were observed in the major fishing grounds of the country, where the peak spawning of its congeners occurs in January to April in Manila Bay (Lopez, 1996) and in February and August to October in Romblon (Rada et al., 2019). Two spawning peaks (from December to February and from April to June) were also observed in Tablas Island, Romblon (Gonzales et al., 2021). Hence, this only shows that *Decapterus* species in Philippine waters spawn throughout the year with two reproductive activity peaks, which happen during the cold and hot seasons or the northeast and southwest monsoons in the fishing ground. The pattern of spawning season in the Babuyan Channel could be affected by various ecological, biological, and environmental conditions. The presence of the Kuroshio current and the occurrence of a natural closed season in the area could affect the reproductive behavior and spawning season of *D. macarellus* in this study. However, it can be noted that the reproductive timing agrees with that of other tropical marine fishes, which, according to Lowe-MacConnell (1979, 1987) and Longhurst and Pauly (1987), vary by species, spawning throughout the year or having well-defined breeding seasons. This only implies that variations in the reproductive characteristics of the species differ among habitats, as revealed by Ohshimo et al. (2006). Some studies also indicate that environmental factors have also influence on the biological characteristics of the species (Yoneda, 2006). The bio-physical factors like water temperature (Lopez, 1996), food availability (Gayanilo et al., 2005), lunar cycles (Lopez 1996), salinity and water quality (Gayanilo et al., 2005), and genetic variation (Gayanilo et al., 2005) also affect the spawning pattern of the species.

Meanwhile, the Babuyan Channel experiences a natural closure period during the northeast monsoon, which occurs from September to January, resulting in a significant reduction in fishing pressure. The decline in fishing activity coincides with critical reproductive phases of *D. macarellus*, potentially influencing the spawning dynamics within the fishing ground. Additionally, the presence of the Kuroshio current in the region may further impact the spawning period of *D. macrellus* by

altering water temperatures and nutrient availability. High fishing pressure on all commercially important marine species in the Babuyan Channel, as noted by Calicdan et al. (2018), including various species within the genus *Decapterus*, represents a key factor that may affect the species' spawning patterns. The consistent observation of a five-point scale of gonadal maturity for *D. macarellus* throughout the year suggests that the species possesses a flexible reproductive strategy, allowing it to adapt to varying environmental conditions and fishing pressure. Hence, these variations in the reproductive timing of *Decapterus* population in the area and nearby fishing grounds may be attributed to the factors mentioned earlier.

Gonadal stages of maturity

Figure 4 shows the gonadal stages of maturity of *D. macarellus* in different months during the study period. The five-scale gonadal pattern was used in determining the gonadal maturity of the samples. As observed, the presence of a five-point scale of gonadal maturity throughout the year could be attributed to the biological characteristic of the species having a flexible reproductive strategy. Juveniles are present throughout the study period, with a peak during the occurrence of the northeast monsoon (July-December) in the Babuyan Channel. Stage III samples were noted throughout the year, where most of the mature individuals were present in January to February and in April to June. Stage IV samples were noted to be abundant during January, June, and March. Most of the stage V samples (spent/resting) spent their eggs in July and January.

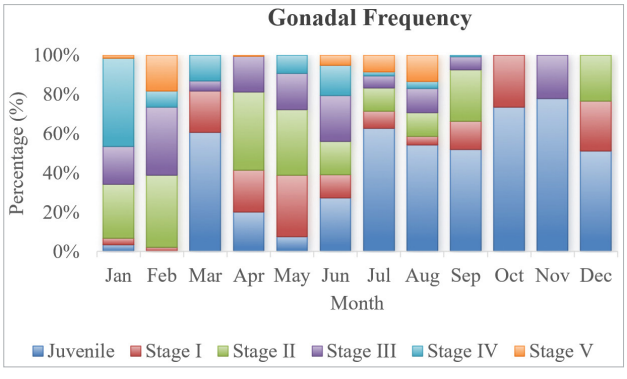

Fig 4. Frequency of occurrence of the gonadal stage of maturity of *Decapterus macarellus* in the Babuyan Channel, Philippines

Notably, the prolonged spawning season observed for the species may be associated with the availability of planktonic prey (Chang et al., 2009; Jose et al., 2015), other nutrients present in the fishing ground, and the zooplankton biomass and composition in the area.

Sexual maturity

The observed length of female *D. macarellus* ranges from 6 cm to 29.8 cm, while the male ranges from 10.6 cm to 29.9 cm. The computed length at maturity (L_m) of *D. macarellus* stocks in the Babuyan Channel fishing ground was 14.15 cm with L_{95} of 17.60 cm (Figure 5). Variations of length at maturity were documented in different environments, such as Sulawesi, Indonesia (Retnoningtyas et al., 2024) and Majene waters in West Sulawesi, India (Tenriware et al., 2023), which are much larger than the result of this study. However, the congeners of this species (*Decapterus macrosoma*) had a close length at maturity values in the Babuyan Channel (Villarao and Encarnacion, 2023), Romblon, Philippines (Rada et al., 2019), Palawan (DA-DILG, 2015, cited by Rada et al., 2019).

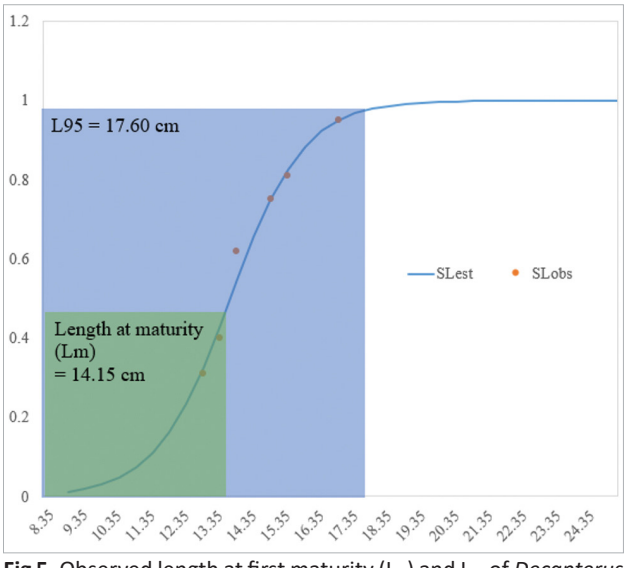

Fig 5. Observed length at first maturity (L_m) and L_{95} of *Decapterus macarellus* in the Babuyan Channel, Philippines

Length range distribution by fishing gear

Pooling all the data for two years to come up with better length ranges, the fishing gear beach seine has length ranging from 9.5 cm to 29.5 cm, bottom set gillnet from 13.5 cm to 25.5 cm, bottom set longline from 22.5 cm to 27.5 cm, drift gillnet from 16.5 cm to 27.5 cm, multiple hook and line from 17.5 cm to 27.5 cm, round haul seine from 23.5 cm to 29.5 cm, ring net from 16.5 cm to 24.5 cm, and troll line from 13.5 cm to 29.5 cm (Figure 6). The observed minimum length for all fishing gear catching *D. macarellus* for the two-year study period was 9.50 cm, and the maximum length was 29.9 cm. Using the length at maturity generated in this study (14.15 cm), it can be presumed that the species were already caught after maturity (100% mature) by most of the fishing gear used in the study. Only the beach seine is catching immature *D. macarellus*, which accounts for 14% of juveniles and 86% are mature.

Generally, the variations in length could be highly affected by some environmental influences in the fishing ground. The channels' unique environmental conditions, such as water temperature, nutrient availability, and ocean currents, may impact the growth and maturity of the species.

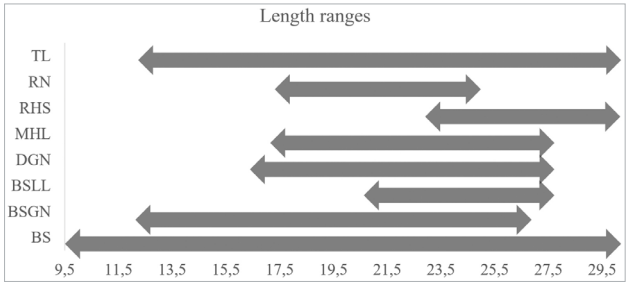

Fig 6. Length range distribution (cm) of *Decapterus macarellus* caught by beach seine, bottom set gillnet, bottom set longline, drift gillnet, multiple hook and line, round haul seine, ring net, and troll line

In addition, the high fishing pressure in the fishing ground, particularly on the genus *Decapterus* could highly influence the smaller maturity sizes documented since intense fishing activities in the channel could lead to earlier maturity as smaller fish are more likely to be caught. It can be noted that in the study by Calicdan et al. (2018), all top commercially important species, including the species of *Decapterus* were already experiencing high fishing pressure since 2009. This could also be the result of the smaller number of samples obtained since the species is highly seasonal in the fishing ground where the fishing gear used to catch the species is not used throughout the year. The fishers shift to different fishing gear depending on the season, environmental conditions, and the target species.

CONCLUSION

The seasonality of *Decapterus macarellus* in the Babuyan Channel is highly influenced by several factors, such as the monsoon season (northeast and southwest). The spawning and seasonality of *D. macarellus* in the fishing ground can be attributed to specific environmental conditions, such as natural closures, where fishing pressure is mitigated, thereby influencing the spawning dynamics of the species. The presence of the Kuroshio current in the fishing could also impact the spawning period of the species by influencing the water temperatures and nutrients. The presence of mature spawners and juveniles throughout the year is an indication that the Babuyan Channel is a spawning area of *D. macarellus*. The majority of the catch of all fishing gear used in the study is mature. However, the length at maturity generated in this study was smaller compared to the length at maturity obtained in other countries, but very close to the maturity of its congeners in the Philippines. This could be the result of excessive fishing pressure on the stock. Therefore, it is recommended that further studies on reproductive biology with a larger number of samples be conducted to validate the result. Population dynamics of the species should also be conducted to determine the current status of the stock in the fishing ground. For management purposes, a close season in the fishing ground is not a viable option since the area has its own natural close season (from September to January) because of the northeast monsoon. Additional Marine Protected Areas should be established in Calayan, Camiguin, Fuga, Claveria, Sanchez Mira, Pamplona, Ballesteros, Aparri, Buguey, Gonzaga, and Sta Ana in Cagayan Province to provide additional refuge for spawning and juvenile *D. macarellus*. Fishing effort reduction (i.e. number of fishing days, vessels) could be considered to protect and conserve the habitat of the stock, particularly coral reefs.

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REPRODUKTIVNE KARAKTERISTIKE SKUŠE *Decapterus macarellus* (CUVIER, 1833) U SJEVERNIM FILIPINSKIM VODAMA

SAŽETAK

Skuša *Decapterus macarellus* je vrlo vrijedna vrsta u filipinskoj komercijalnoj ribarskoj industriji, posebno u sjevernim filipinskim vodama ribolovnog područja Babuyan kanala. Ova studija procjenjuje reproduktivne karakteristike, uključujući omjer spolova, sezonski ulov, plodnost i gonadnosomatski indeks (GSI), gonade i spolnu zrelost (L_m i L_{95}) te dužinsku raspodjelu prema alatu uzrokovanja. Uzorci su prikupljeni u ribolovnom području Babuyan kanala od travnja 2018. do ožujka 2020. godine. Rezultati su pokazali da je *D. macarellus* prisutan tijekom cijele godine u ribolovnom području, s uočenim vrhuncima pojavljivanja od travnja do srpnja. Utvrđen je neuravnotežen omjer spolova između ženki (1:18) i mužjaka (1). Prosječna plodnost bila je 25 546 jaja. Gonadosomatski indeks otkrio je da se sezona mriještenja *D. macarellus* događa tijekom cijele godine, s uočenim produljenim mriješćenjem s značajnim vrhuncem mriještenja tijekom sjeveroistočnog monsuna. Duljina u zrelosti (L_m) bila je 14,15 cm, a L_{95} od 17,60 cm. Od svih ribolovnih alata kojima se lovi ova vrsta, utvrđeno je da mreža potegača izlovi većinu mlađi. Kako bi se zaštitio i očuvao stok, predlažu se opcije upravljanja poput uspostavljanja dodatnih zaštićenih morskih područja za podršku produktivnosti ove vrste i smanjenja ribolovnih napora.

Ključne riječi: reproduktivna biologija, gonadosomatski indeks, Babuyanski kanal

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