DOI: 10.31398/tpjf/28.2.2020C0014

RESEARCH ARTICLE

Stock Assessment of the Blue Swimming Crab *Portunus pelagicus* (Linnaeus, 1758) in Stock Enhancement Sites of Danajon Bank, Central Philippines

Bruna T. Abrenica[1], Mary Jane M. Fajardo[1], Johnson S. Paran[1], Mario N. Ruinata[1], Marinelle S. Espino[2], Allan L. Poquita[1]

[1]*Bureau of Fisheries and Aquatic Resources Regional Office 7, Cebu City*
[2]*Philippine Association of Crab Processors, Inc. (PACPI), Mandaue City, Cebu*

ABSTRACT

The stock status of Blue Swimming Crab (BSC), *Portunus pelagicus*, locally known as *lambay*, in Danajon Bank was assessed from June 2019 to September 2020 to monitor the impact of the BSC stock enhancement initiative by the Philippine Association of Crab Processors, Inc. (PACPI) in collaboration with BFAR 7. The stock was assessed based on the indicators, namely, catch per unit effort (CPUE), exploitation rate (E), average size, length at first maturity (Lm), and Spawning Potential Ratio (SPR). Data analysis was done using FAO-ICLARM Stock Assessment Tools (FiSAT) II software and the Barefoot Ecologist's Toolbox for the Length-based Spawning Potential Ratio (SPR). Results show that BSC dominated the monitored landings accounting for 66% of the overall catch harvested mainly by crab pot and crab net. Higher CPUEs were obtained in the months of July, June, May and August with annual mean observed to be higher than the previous assessment conducted by ECOFISH in Danajon Bank particularly for crab pot. Population characteristics revealed that male crab grew slightly faster having higher asymptotic length ($L\infty$ =21.65cm Carapace Width or CW) and growth constant ($K=1.3^{yr-1}$) than female ($L\infty$ =21.40cm CW, $K=1.28^{yr-1}$). Sex ratio of male to female was at 1:1.28 indicating plenty of female crabs were captured than male. Gravid crabs were abundant in May, December, April and October. Recruitment pattern showed two pulses with primary peak occurred in April and May and secondary pulse happened in August and September. Encouraging performance indicator noted from this assessment was on the bigger probability of capture sizes and mean length of commonly caught BSC falling above the recommended catchable size of 10.2 cm CW pursuant to DA-DILG JAO No. 1 s. 2014. Maturity size (Lm) was estimated at 10.54 cm CW, though smaller than the previous reported Lm values in Danajon but still within the threshold. The estimated SPR was 26%, higher than 20% limit reference point but slightly lower than 27% recorded in the assessment done by ECOFISH Project in 2014 to 2015. The present SPR though lower than 30% precautionary threshold however higher than 21% generated in Visayan Sea Region 7 for the same period. The higher SPR in Danajon Bank compared to Visayan Sea maybe credited to the effect of stock enhancement activity implemented in the area, though observation is not yet conclusive. On the other hand, unfavorable indicators were seen on high exploitation rate (E), high exploitation at yield per recruit some of which already breached the optimum level, consequently subjecting Danajon Bank to high fishing pressure. It is recommended to continue the BSC stock enhancement program of PACPI and BFAR 7 taking consideration some strategies for improvement specified in the recommendations.

*Corresponding Author: *rona_abrenica@yahoo.com*
Received: *August 6, 2021*
Accepted: *September 27, 2021*

Keywords: *assessment, blue swimming crab, Danajon Bank, stock enhancement*

1. INTRODUCTION

The *Portunus pelagicus* (Linnaeus, 1758), locally known as *lambay* in Bisaya and *alimasag* in Tagalog, is considered as one of the major fishery resources of the country. This species is widely distributed in the coastal waters of the Philippines, particularly in nearshore shelf areas at depths above 70 meters. Juvenile BSC inhabit the shallow waters mostly in seagrass, seaweeds, and algal beds, while the mature ones are found in sandy substrates at deeper waters of up to 20 meters isobaths (Ingles 1996). Male and female BSC can easily be distinguished externally by their color pattern. Female BSC is patterned with brown spots, while male BSC has blue spots. BSC can be harvested using various gears, namely crab pot, crab lift net, gill net, fish corral, municipal trawl, push net, and seine net.

The BSC fishery is a significant commodity in the Philippines because of its high demand among the export industry (Ingles 2004). Based on 2009 Fisheries Statistics, the BSC fishing industry ranks 20 among the highest fishery commodity. Likewise, it ranks 4th as the most important fishery export of the country in terms of value (39,171 USD or PHP 1,852,785) of processed or frozen crab meat and fat. The export volume and value of processed or frozen crab meat and fat contributes 5.80% of the total fish and fishery product exports reported in that same year. In 2011, data showed that the blue swimming crabs harvested by the municipal fishery sector account for 95.38% (27,920.67 MT) while the commercial fishery contributes only 4.62% (1,353.53 MT). The percentage share of the total volume of BSC harvested in 2011 accounts for 1.34% of the annual fishery production (Yap et al. 2020).

However, a report on the exploitation of crab resources was already determined in the early '90s. The BSC catch is steadily declining in volume and crab size. The reduction of blue swimming crab is believed to be due to fishery problems like overharvesting by effective fishing gears, destruction of nursing and breeding ground, crabbing the ovigerous female (Kunsook et al. 2014), and laxity in the implementation of regulatory policy to protect the resource (Mesa et al. 2018).

In the Philippines, the Visayan Sea and Guimaras are considered the most critical crabbing areas, containing about half of the country's picking stations (Mesa et al. 2018). In Central Visayas, the Danajon Bank double barrier reef, located off northern Bohol Island and southern part of Camotes Sea, is also considered a significant fishing ground of crabbers in Bohol province. Blue swimming crab is among the abundant stocks and has become a source for the livelihood of marginal fisherfolk living in coastal areas. Danajon Bank is not only a sporadic geologic formation. It is also considered one of the richest areas of marine biodiversity in the world and a place where marine life all over the Pacific first evolved (Ready 2014).

Several studies have been conducted in Danajon Bank. It was one of the eight marine key biodiversity areas (MKBAs) of the ECOFISH, a DA-BFAR project supported by USAID. The study aimed to increase fisheries biomass and employment from sustainable fisheries in the MKBAs primarily through promoting and institutionalizing an Ecosystem Approach to Fisheries Management (EAFM) (ECOFISH 2015). Part of the project activities was the Pilot Assessment of the Blue Swimming Crab (*Portunus pelagicus*) estimation of spawning potential ratio (SPR) conducted from May 2014 to May 2015 in five selected areas. The study was carried out in collaboration with the Philippine Association of Crab Processors, Inc. (PACPI). Some results of the ECOFISH BSC assessment were used as a basis for comparison of the present results.

For this particular study, the assessment of BSC was conducted in the five dispersal sites of hatchery-bred blue swimming crab produced from the BSC stock enhancement project of PACPI and BFAR-7. The production of blue swimming crab in the Multi-Species Hatchery of BFAR 7 intended for stock enhancement purposes was implemented from October 2017 up to the present.

Stock enhancement is defined as the release of cultured juveniles into wild populations to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitations (Bell et al. 2008). It involves mass releases of juveniles that feed and grow on natural sustenance in the marine environment and subsequently become recaptured and add biomass to the fishery. The collaborative project of PACPI and BFAR 7 has aimed to restock the blue swimming crab in selected sites of Danajon to augment the blue crab production. Therefore, the hatchery-bred BSC were dispersed to areas where blue crabs are naturally occurring. The assessment was purposely conducted to monitor the impact of BSC stock enhancement activity relative to the biological status of blue swimming crab in the dispersal areas. The stock was assessed based on the indicators, namely: catch per unit effort (CPUE), Exploitation rate (E), length at first maturity (Lm), and Spawning Potential Ratio (SPR).

This report presents the stock status of Blue Swimming Crab (BSC) (*Portunus pelagicus*) monitored in the five BSC stock enhancement sites of Danajon Bank, Central Philippines, from June 2019 to September 2020.

2. MATERIALS AND METHODS

2.1 Study Site

Danajon Bank is considered a double barrier reef in the Philippines (Pichon 1977) and one of just six double barrier reefs in the world (Green et al. 2004). Having a broad area of 272 km^2 with a coastline of 381 km, it provides livelihood for many generations.

It comprises a jurisdiction of 17 coastal municipalities covering four provinces (i.e., Bohol, Cebu, Leyte, and Southern Leyte), underlying a rich and productive area of fisheries and marine resources. It is also one of the breeding areas and shelters of different marine species (Green 2004). This includes reef fishes, small pelagics, and also invertebrates such as blue swimming crab. Moreover, the reef is very abundant in seagrasses that can be considered that all its species in the Philippines can be found in the area (Courtney et al. 2017).

For this study, five landing sites around Danajon Bank, Bohol part were established as monitoring sites which were also the BSC stock enhancement sites, namely: Guindakpan, Talibon; Suba Jao Island, Talibon; Guintaboan, Ubay; Corte Baud, Getafe; and Aguining, CPG (Figure 1).

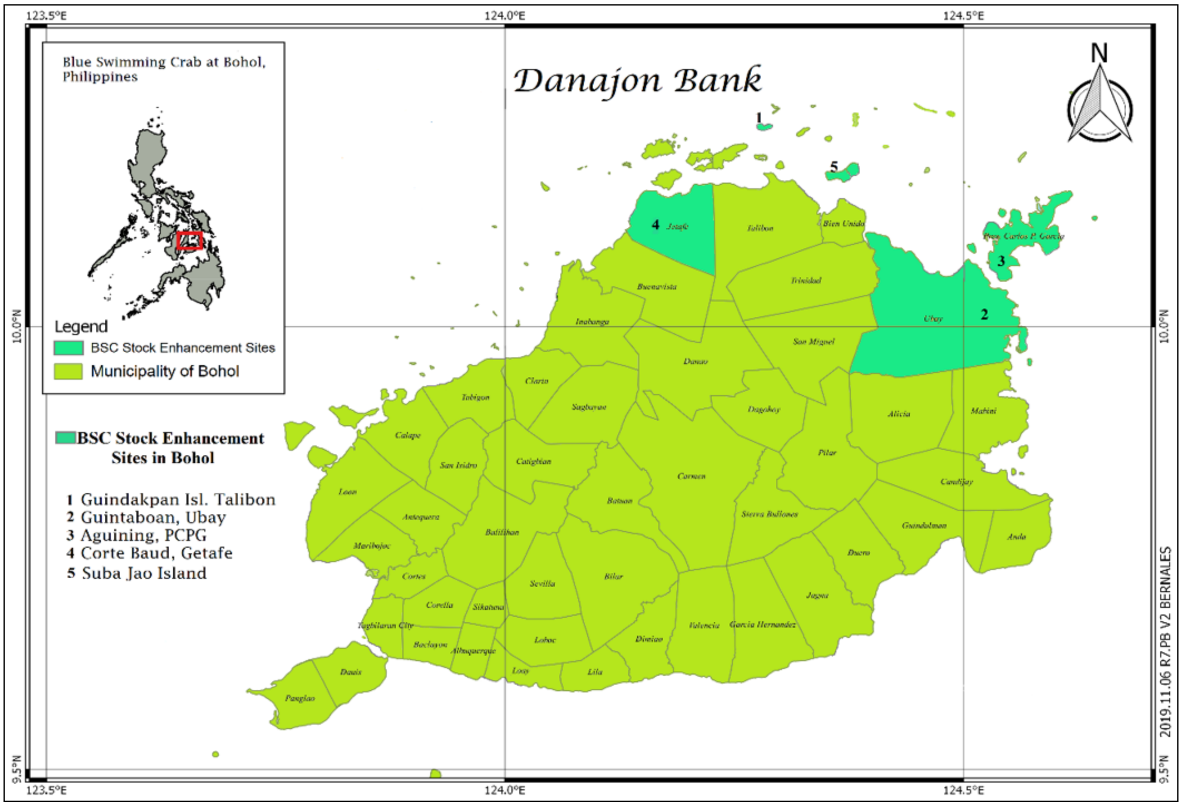

Figure 1. Map of Danajon Bank showing the BSC stock enhancement sites established for BSC catch monitoring from June 2019 to September 2020. The same areas were also sampled for reproductive biology study from October 2019 to September 2020.

The areas, as mentioned earlier, were stocked with hatchery-bred blue swimming crab produced from BFAR 7 hatchery facility in Sinandigan, Ubay, Bohol. A total of 1,202,439 individual Instar 4 BSC and 227,301 crablets were dispersed. Asynchronous stocking of hatchery-bred BSC in Danajon was done from December 2017 up to December 2020. In addition, catch monitoring was carried out from June 2019 to September 2020.

2.2 Catch, Effort and Length Data Collection

Data collection followed the standard method used by the National Stock Assessment Program (Santos et al. 2017). Sampling was carried out by trained enumerators who monitored the landed catch in their assigned site every other two days regardless of weekends and holidays. Enumerators assigned should have a total of 21 sampling days if the month has 31 calendar days and 20 sampling days for a month having 30 calendar days, for a mean of 20 days sampling frequency per month. Enumerators were tasked to monitor and collect the catch information from all kinds of gears catching the blue swimming crab. Information gathered includes the name of the landing site, date of sampling, fishing gear type, type of fishing boat, number of pot or trap, number of fishing time, number of hauls, and fishing trip per day of the actual operation. In addition, the landed catch was categorized by species, with each bycatch being reported separately from BSC. Finfishes were identified using NSAP training modules developed by NFRDI, published textbooks (i.e., Masuda et al. 1984; Randall et al. 1997; Rau and Rau 1980), journals, and Fishbase. The length measurement was done by determining individual carapace width (CW) in a centimeter (cm) scale by measuring from the tip of spines on both sides of the carapace using a caliper or other measuring materials. A range of 15 - 30 individual lengths of BSC was taken every sampling day, and corresponding maturity stages were determined externally.

2.3 Stages of Maturity

A separate sampling was done for reproductive biology and the determination of maturity stages of BSC. A total of five kilos BSC were bought and dissected monthly from each landing site for one year to determine the gonad stages.

Determination of sex and stages of the BSC followed the Five-point Scale (Sumpton et al. 1994) of gonadal maturity of female stages as described in Table 1.

Table 1. Five-point scale of female gonadal maturity used for *Portunus pelagicus* (Sumpton et al. 1994)

Maturity Stages	Classification	Distinguishing Characteristics
Stage 1	Immature/Virgin	Non-ovigerous
Stage II	Developing/Maturing	Ovigerous with pale to dark egg mass. No eyespots visible in eggs
Stage III	Mature/Ripening	Ovigerous with yellow-grey egg mass. Eyespots present
Stage IV	Spawning/Gravid	Ovigerous with grey egg mass. Eye-spots and chromatophores discernible.
Stage V	Spent or resting	Presence of egg remnants.

2.4 Data Analysis

To obtain information on the catch trend, Catch Per Unit Effort was computed for each fishing gear used by the crabbers. The CPUE was standardized to kg per day of operation by dividing the total volume of catch (kg) for the month over the total number of fishing days per month for each gear. The mean CPUE expressed in (kg per day) is presented on a per month basis.

2.5 Relative Abundance

The dominant species caught was determined based on the species' contribution by weight to the total landings monitored within the monitoring period. The dominant species were ranked as to the highest percentage contribution to the catch.

2.6 Length-based method

The length-frequency data were used to estimate population parameters such as asymptotic length ($L\infty$), growth constant (K), Exploitation rate (E), average size, while the reproductive data (i.e., sex, length, and stages) were used to estimate length at maturity (Lm) and Spawning Potential Ratio (SPR). Growth and mortality values were derived using FAO-ICLARM Stock Assessment Tools (FiSAT) II software (Gayanilo et al. 2005), and SPR was determined using the Barefoot Ecologist's Toolbox.

3. RESULTS AND DISCUSSIONS

3.1 Fishing Gears

Crabbers from different localities use a particular type of gear suitable for catching the blue swimming crab. Based on the present survey, crabbers in Danajon Bank used mainly three types of gear: crab nets, crab pots, and bottom set gillnet.

Crab pots, locally called panggal, are common pots used in catching crabs lure and catch crabs for commercial or recreational use. Usually made up of bamboo strips or tie wire and multifilament polyethylene netting. The net is wrapped around a bamboo framework to form a dome-shaped trap (Armada 1996).

Crab net, commonly known as *bintol*, is a type of net intended to catch crabs in shallow waters

Figure 2. Sets of crab pots ready for soaking in Danajon Bank for catching *P. pelagicus.*

Figure 3. Crabbers were fixing their crab net prior to the next operation.

and often baited to lure crabs and sunk to the bottom by line and weights and operated by hauling the net suddenly to the surface, which requires periodic attention.

The bottom set gillnets (BSGN), locally known as *pukot*, consists of several nylon panels, polyamide, or kuralon nettings of different mesh sizes. Generally, it is a long passive gear kept in a vertical position via the opposite forces of the float attached to the head rope and the sinkers attached to the footrope (Armada 1996). Crabs can also be caught by BSGN though its target is finfishes.

Figure 4. Bottom set gillnet catching *P. pelagicus* as by-catch.

Figure 5 shows the profile of BSC geartype used mainly for catching crabs and other gears recorded in the monitoring sites of Danajon Bank from June 2019 to September 2020. In Bonbon, Aguining, the prevalent major BSC gears used were crab pots, about 1200 units operated by 15 fishers, and 35 units crab nets owned by individual fisher. Barehand fishing was also noted to be practiced in the area. Corte Baud had the highest count of crab pot (3000 units) owned by 17 fishers and 14 units individually owned bottom set gill net. The dominance of crab pot in the area can be attributed to the IEC campaign conducted by BFAR and ECOFISH USAID Project back in 2015 where the use of crab pot as a sound gear for BSC was introduced. Fishers in Guindakpan were using crab net (29 units) while in Suba Jao, they used both crab net (34 units) and crab pot (134 units). In Guintaboan, four geartypes were documented of which crab pot and crab net dominated at 450 and 101 units, respectively. Less commonly used gear included in the list were fish pot and fish trap.

A total of 287 fishers were monitored from the five sites. On the fisher's level it generally showed that highest percentage at 71% (204) were using crab net, followed by crab pot 13% (38) and bottom set gill net with 11% (32), while a few were engaged in barehand fishing (3%) (9), fish pot and fish trap at 1% each (Figure 6).

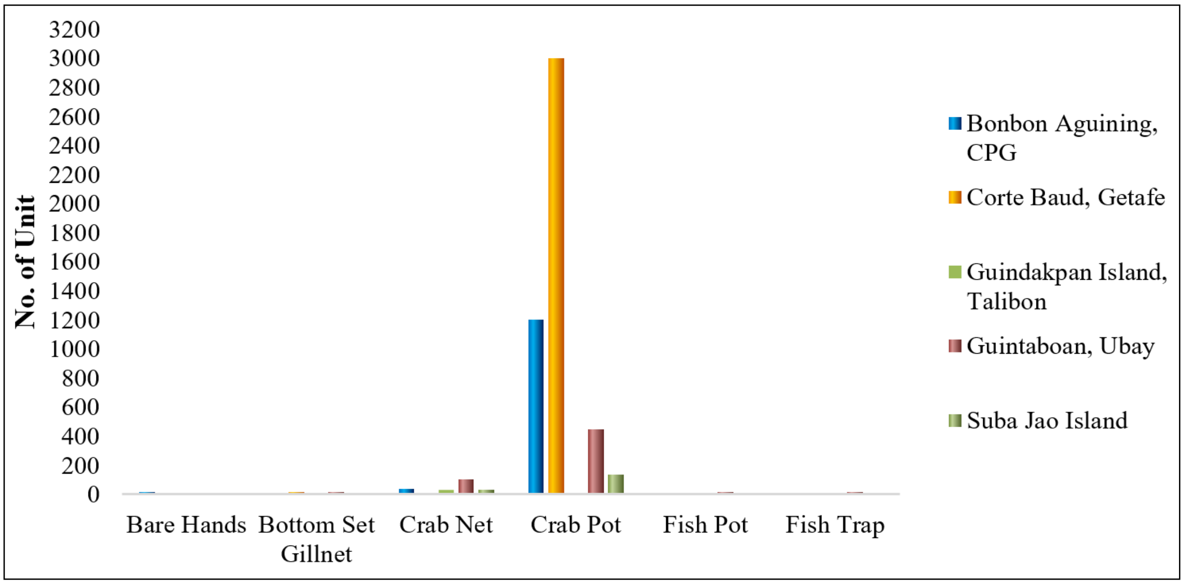

Figure 5. Profile of BSC gears recorded in the five monitoring sites of Danajon Bank June 2019 to September 2020.

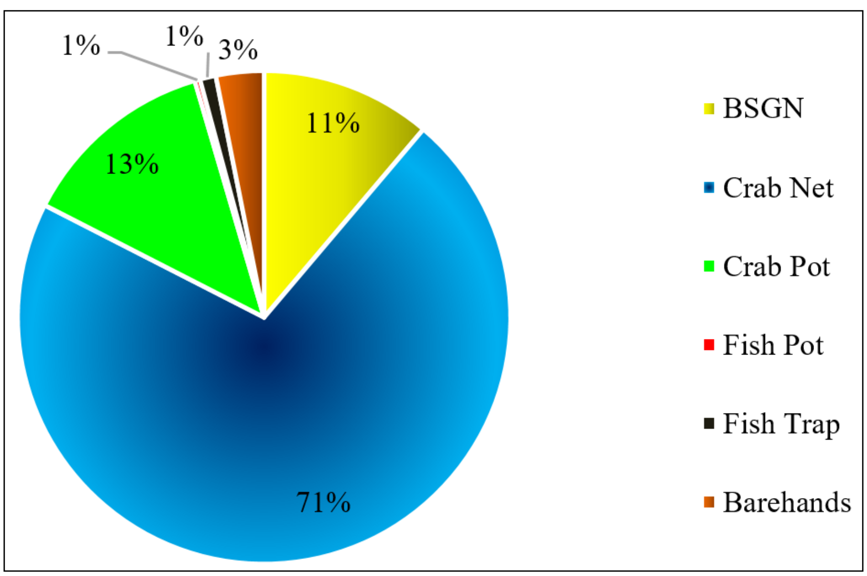

Figure 6. Percentage of fishers by gear type in the five sites monitored in Danajon Bank.

3.2 Species Composition and Relative Abundance

Among the species documented in this survey, the top ten major species were determined and ranked as to the percentage shared from the overall catch (Figure 7). The relative abundance of the top ten species was computed by dividing the total volume of each species caught from all gear types over the combined total volume of all species caught from all gears multiplied by 100. Of the total 70 species listed during the survey in Bohol areas, *Portunus pelagicus* comprised the highest percentage at 66%, being the target of the gears mentioned above. Among the non-target finfish species, *U. sulphureus* obtaining 13% and *L. splendens* at 9.15% dominated. On the other hand, *S. leptolepis* had 4.30%, *C. beauforti* and *S. qenie* contributed 2% each, and *N. hexodon*, *E. adscensionis*, *P. erumie*, and *P. lentjan* had only less than one percent each.

It appears that catch composition seemed to be gear specific. BSC comprised 99.9% of crab pot and 97% from crab net. A scanty share of 1.73% from bottom set gill net and 1.13% from fish trap were also noted (Figure 8).

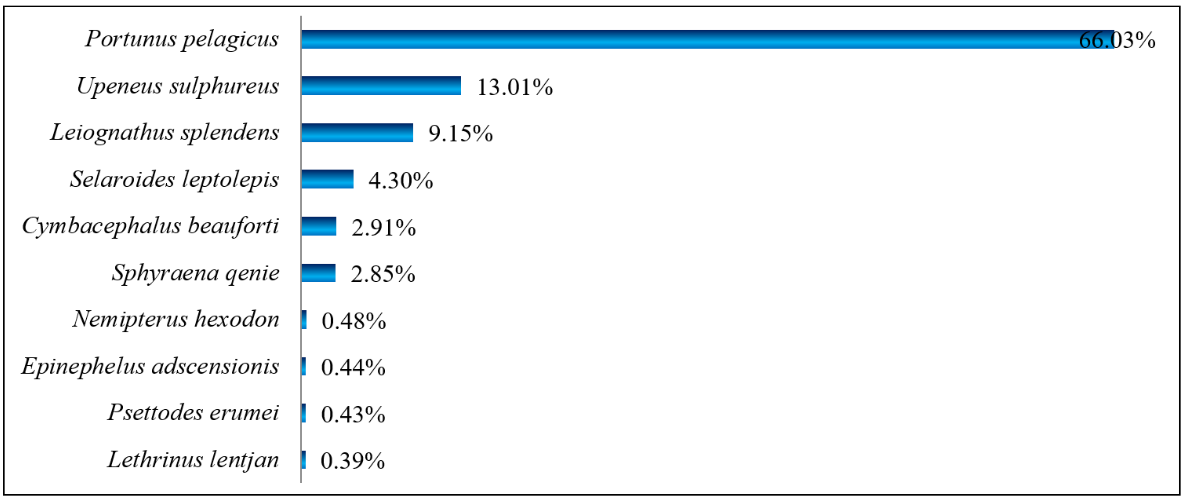

Figure 7. Relative abundance of the ten major species in the crabbing areas of Bohol (Danajon Bank) during the conduct of Blue Swimming Crab monitoring from June 2019 to September 2020 monitored from all gear types.

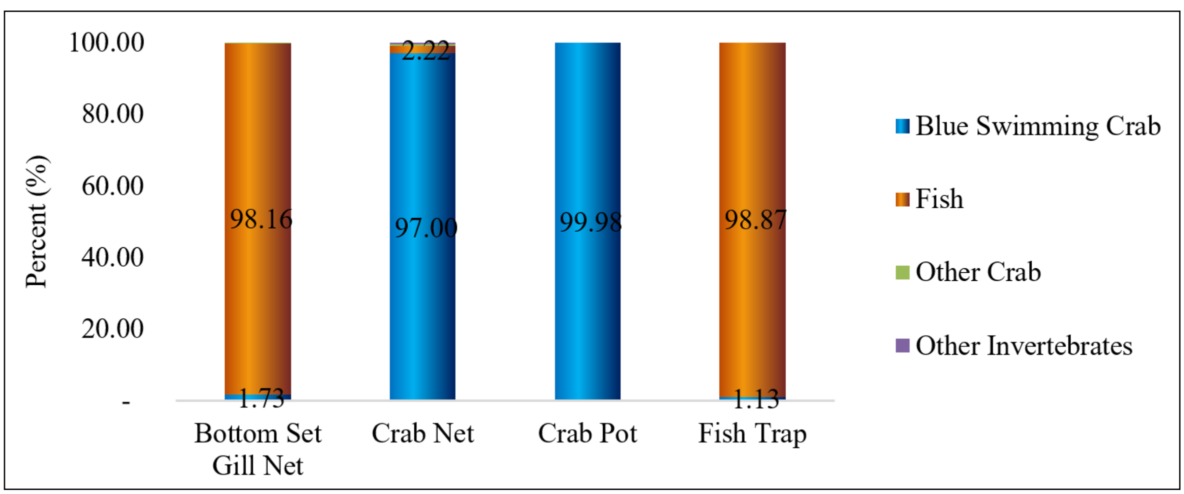

Figure 8. Percentage share (%) of BSC and by-catch from the total monitored landings by fishing gear in Danajon Bank .

Catch Per Unit Effort (CPUE)

The CPUE was computed to obtain information on the catch rate and efficiency of gears observed during the monitoring period. Figures 9A-C show the monthly mean CPUE (kg/day) trend of BSC gears used in the five coastal areas of Bohol, Danajon Bank from June 2019 to September 2020. The CPUE of crab net was quite stable ranging from 1.85 to 2.57 kg/day (Figure 9A). Higher CPUEs were obtained in 2019 particularly in the months of August (2.57 kg/day), September (2.42 kg/day) and December (2.41 kg/day), July (2.37 kg/day) and October (2.30 kg/day). The catch rate observed during these months were mostly indicative of the annual mean for crab net computed at 2.19 (kg/day). The annual mean CPUE obtained in this study was quiet lower than 2.29 (kg/trip) reported by ECOFISH for the same gear in Danajon Bank (ECOFISH 2015).

CPUE of Crab Pot as shown in (Figure 9B) ranged from 3.13 to 5.12 (kg/day), highest of which was obtained in July 2019 and lowest was noted in March 2020. Comparable CPUEs were observed in 2020 particularly in the months of May (4.60 kg/day), June (4.65 kg/day), July (4.54 kg/day), August (4.5 kg/day) and September 2019 at (4.5 kg/day). The annual mean CPUE obtained for crab pot in the present study was 4.23 (kg/day), higher than 3.03 (kg/trip) reported by ECOFISH in their study from May 2014 to May 2015 in Danajon Bank.

On the other hand, CPUE values obtained from bottom set gill net were very low compared to the other two gears indicating that this gear did not target the blue swimming crab (Figure 9C). The catch rate of BSGN ranged from 0.26 (kg/day) to 3.01 (kg/day) highest rate was obtained only in October while most of the months had less than 1.0 kg/day. There was no record of BSC catch in July and August 2019 and April 2020. The lack of BSGN data in April 2020 was due to COVID 19 pandemic since the enumerator where BSGN is operating had opted to stop monitoring for one month. The low catch rate can be attributed to very low relative abundance of blue swimming crab from BSGN which was only 1.73% of the total catch.

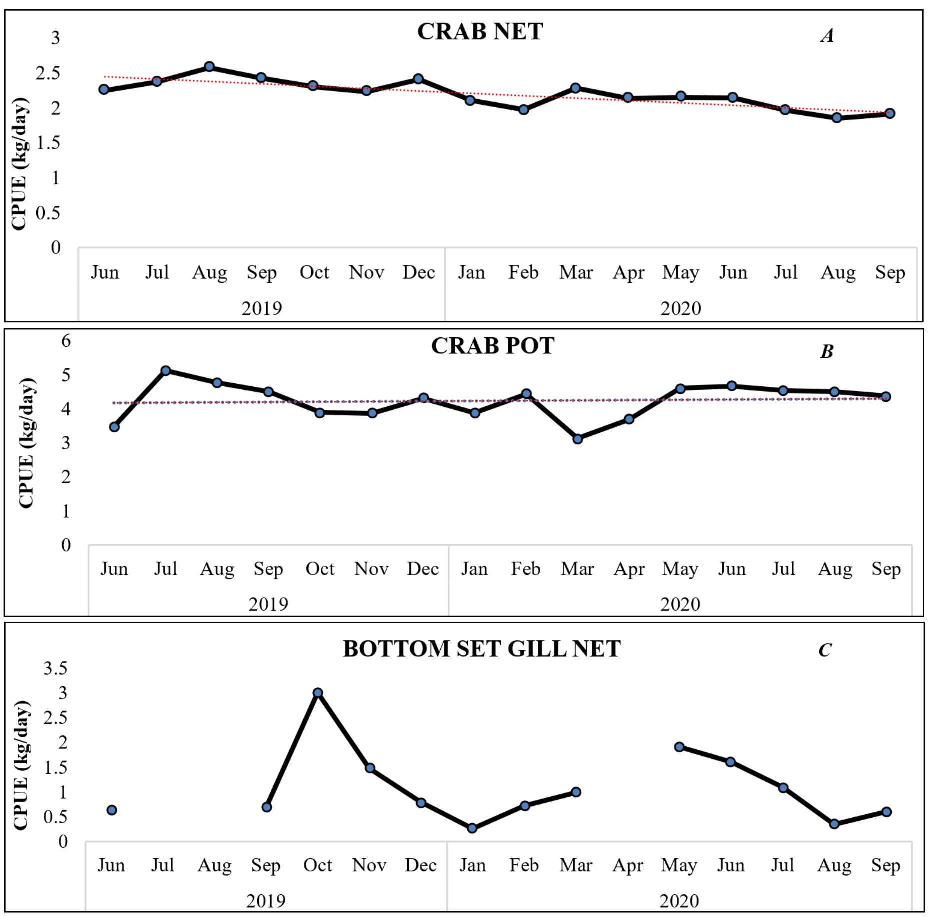

Figure 9A-C. Monthly trend of mean CPUE (kg/day) of BSC gears in Danajon Bank from June 2019 to September 2020.

Distribution of Length Sizes

The size distribution of blue swimming crab by geartype sampled in the five landing sites in Danajon Bank is presented in Figures 10A-C. A total of 49,738 (58%) individual *P. pelagicus* caught from Crab Net (CN) were sampled for length frequency measurement from the five sites (Figure 10A). The mean length (cm) carapace width (CW) derived from CN was 13.96 cm. Crab Pot on the other hand had smaller samples of 35,321 (41.2%) pieces compared to crab net and also recorded a smaller mean length of 12.68 cm CW (Figure 10B). Previous assessment conducted in Danajon Bank recorded mean length of 13 cm CW, 12 cm CW and 10 cm CW for crab gill net, crab pot and crab lift net, respectively (ECOFISH Report 2015). Present average sizes of BSC were bigger than the sizes reported in the past assessment. It is notable that more samples were collected from crab net since based on the fisher's profile, 71% of them were engaged in crab net fishery. The mean size of BSC from bottom set gill net was also big at 13.65 cm CW however sample lengths were very few since this gear targets mainly finfishes and crabs as by-catch only (Figure 10C). The average sizes of *P. pelagicus* from the three aforementioned gears were above the 10.2 cm prescribed size pursuant to the Department of Agriculture (DA) and Department of Interior and Local Government (DILG) Joint Administrative Order No. 1, series of 2014 on the Regulation for the Conservation of Blue Swimming Crab *Portunus pelagicus*. It is stated there that it is illegal to catch BSC having sizes of less than 10.2 cm.

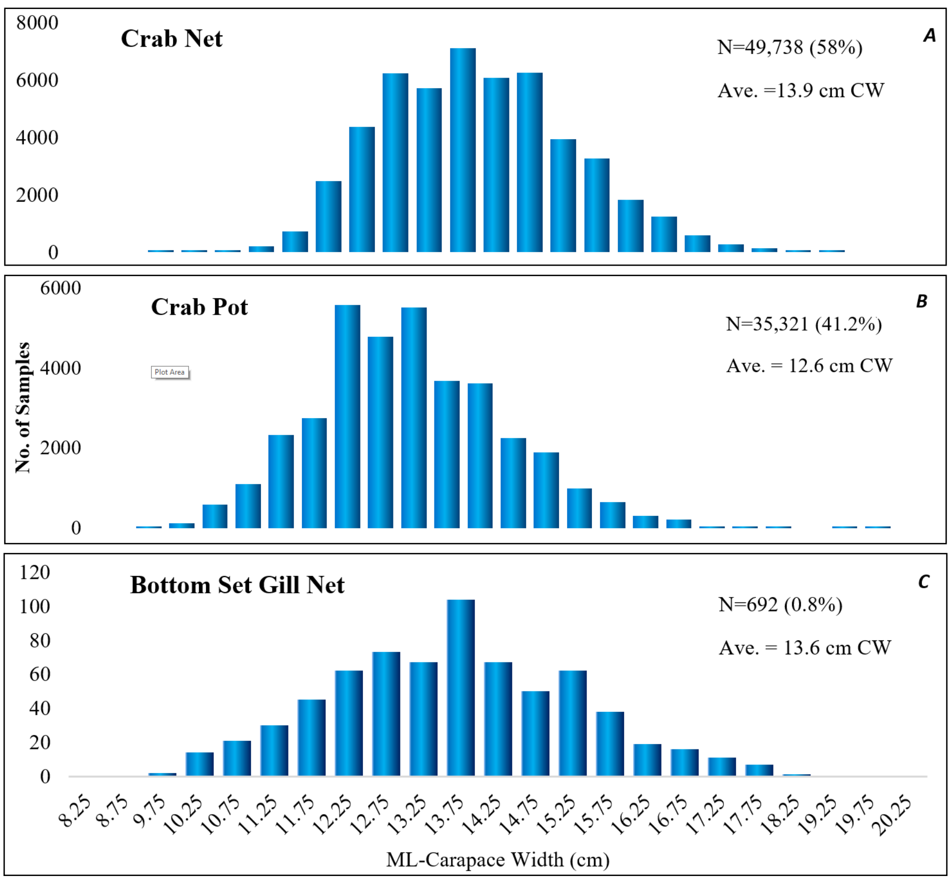

Figure 10 A-C. Length frequency (carapace width-CW) distribution and average size of *P. pelagicus* by geartype monitored from five sites in Danajon Bank from June 2019 to September 2020.

The size distribution of female and male BSC was segregated to assess whether there is difference in their dominance as well as in their average sizes. Any difference may have something to do with their population characteristic and life history and may aid in future management initiative of the species. The total sampled lengths were dominated by female crabs comprising 56.15% or 48,226 pieces while the male shared 43.85% or 37,661 individuals (Figure 11A). The mean length of female was calculated at 13.5 cm (CW) slightly bigger than 13.3 cm (CW) of male BSC (Figure 11B). Both sizes were observed to be bigger than the previous study which reported mean size of 12 cm (CW) for female and 11.8 cm (CW) for male (ECOFISH Report 2015). The computed sex ratio of male to female BSC was 1:1.28, indicating that female crabs were captured more than the male crabs.

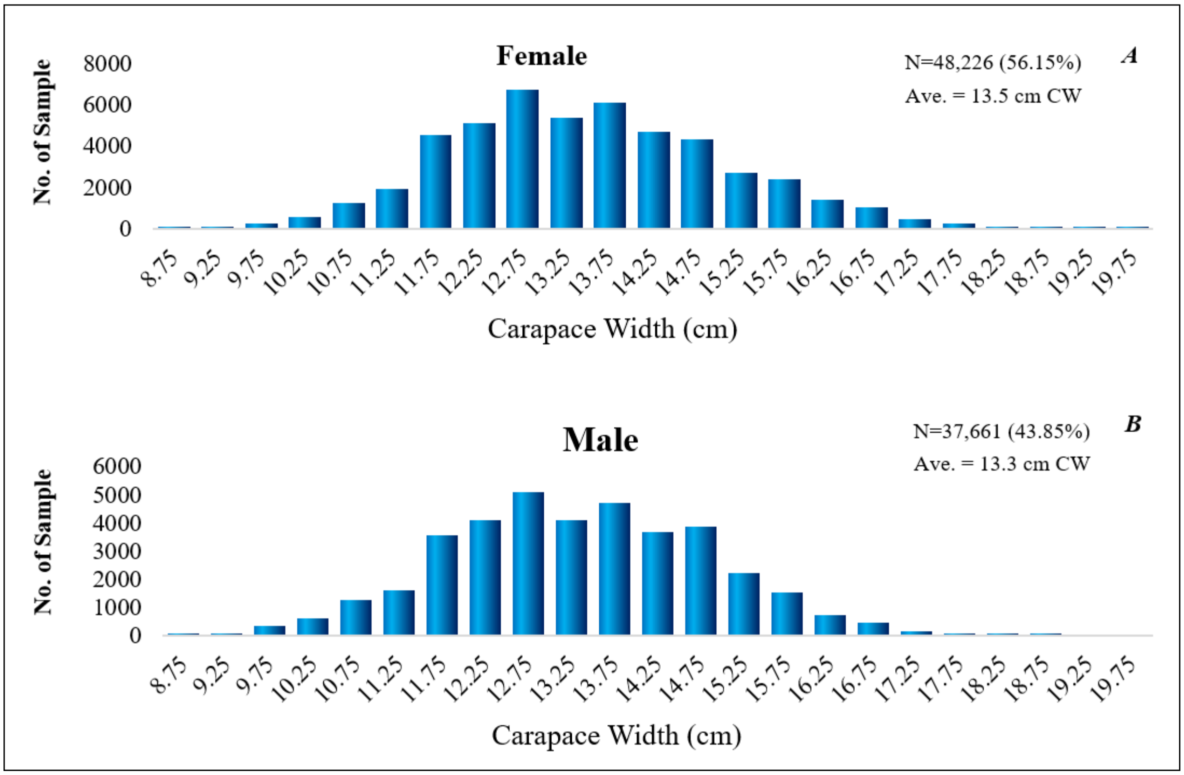

Figure 11A-B. Length size distribution, average length and percentage of female and male BSC sampled in five monitoring sites of Danajon Bank (June 2019 - September 2020)

Population Parameters

A. Growth, Mortalities, Exploitation Rate, Relative Biomass/Yield per Recruit, Probability of Capture and Recruitment Pattern

Marine environment consists of many factors that can affect the survival of individual species. Overfishing is one of the leading reasons that collapsed the extinction of other species; also include adverse conditions, lack of food, competition and predation (King 1995).

The population parameters such as asymptotic length ($L\infty$), growth constant (K), Fishing Mortality (F), Natural Mortality (M), Total Mortality (Z) Exploitation rate (E), probability of capture, yield per recruit and recruitment pattern were estimated separately for female and male blue swimming crab using FiSAT II software. Female BSC can grow to as big as 21.4 cm ($L\infty$-carapace width CW) at 1.28^{yr-1} growth rate (K) while male blue crab can reach to as big as 21.65 cm and corresponding K of 1.3^{yr-1} (Figure 12). It seemed that in Danajon Bank, the male crab grows slightly faster than female as reflected in its higher growth rate and size at length infinity.

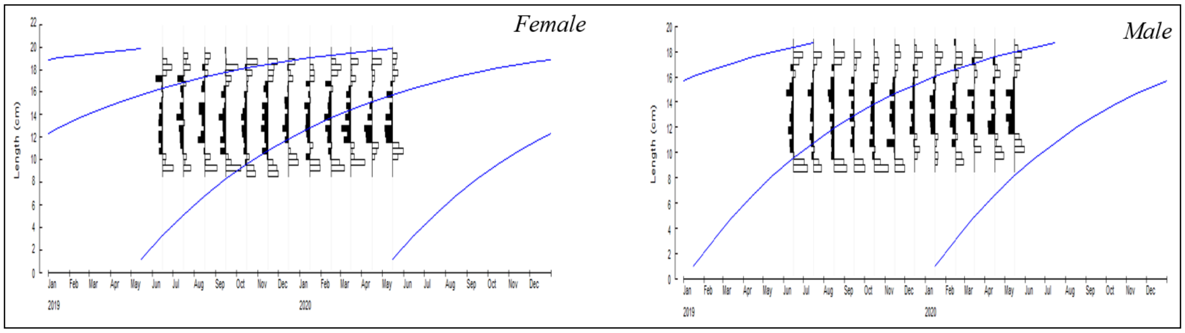

Figure 12. Length frequency and fitted growth curves of female and male blue swimming crab restructured by ELEFAN 1 in Danajon Bank. Note: Female (L_∞=21.4 cm CW, K=1.28 $^{yr-1}$); Male (L_∞=21.65 cm CW, K= 1.3^{yr-1})

Using the length frequency data, total mortalities and exploitation rate of *P. pelagicus* were estimated by the length-converted catch curve routine of FiSAT II software. The results are presented in Figure 13. Specifically, the exploitation rate (E) was computed by dividing the fishing mortality over total mortality. If fishing mortality is high it would also generate high E value. It is accepted that the optimum fishing mortality in an exploited stock should be approximately equal to natural mortality or $E_{opt\approx}$0.5 (Pauly and Ingles (1984)). In this study, the computed exploitation rate of female BSC was 0.66^{year-1} while male had 0.72^{year-1}

The high exploitation rate (E) was further confirmed by the result of the relative yield-per-recruit exploitation rate which yielded (E_{max}) of 0.76 for female; 0.79 for male and present exploitation rate (E_{10}) at 0.65 for female and 0.66 for male which is relatively higher than the optimum exploitation level (E_{50}) at 0.36 female and 0.38 for male (Figure 14).

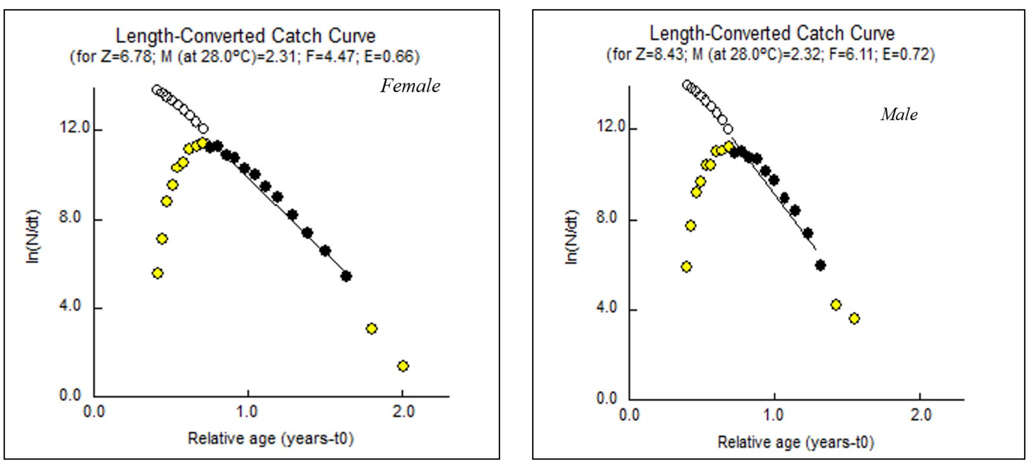

Figure 13. Length-converted catch curve analysis of female and male blue swimming crab in Danajon Bank.
Note: Z= Total Mortality, M=Natural Mortality, F=Fishing Mortality, E= Exploitation Rate

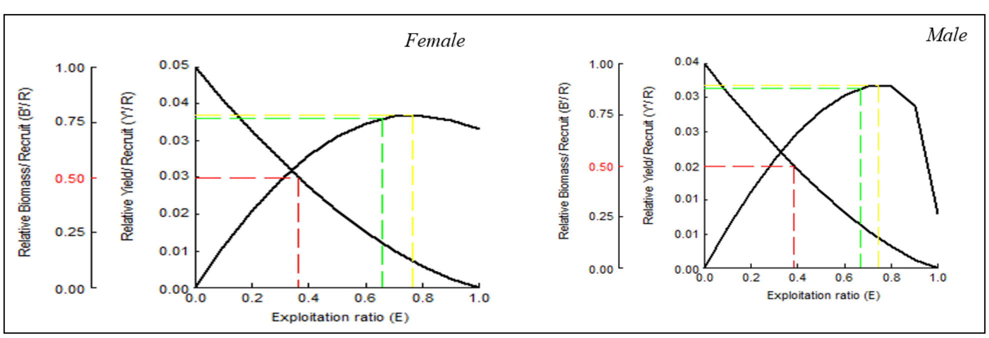

Figure 14. Relative yield per recruit exploitation rate (E) of female and male blue swimming crab in Danajon Bank.

However, probability of capture for BSC showed bigger sizes with L25 or 25%, L50 or 50%, L75 or 75% falling at 11.88 cm, 12.43 cm, 12.98 cm for female and 12.01 cm, 12.62 cm, 13.23 cm for male, respectively (Figure 15). All sizes were above the 10.2 cm (carapace width) recommended size indicated in the JAO DA-DILG no.1 s. 2014.

Recruitment pattern have commonly consist of two pulses because Philippines lies in a tropical region which means two pulses of stock-recruit is equivalent also with two different cohorts in a year. Every recruitment identified as a weak and strong pulse or equal pulse of recruit (Mesa et. al 2018). As observed on Figure 16, a bimodal pattern was created for female BSC. The major recruitment has peaked in April at 16.12% and May at 11.46% while the secondary pulse was observed in August at 12% and September at 11.98%.

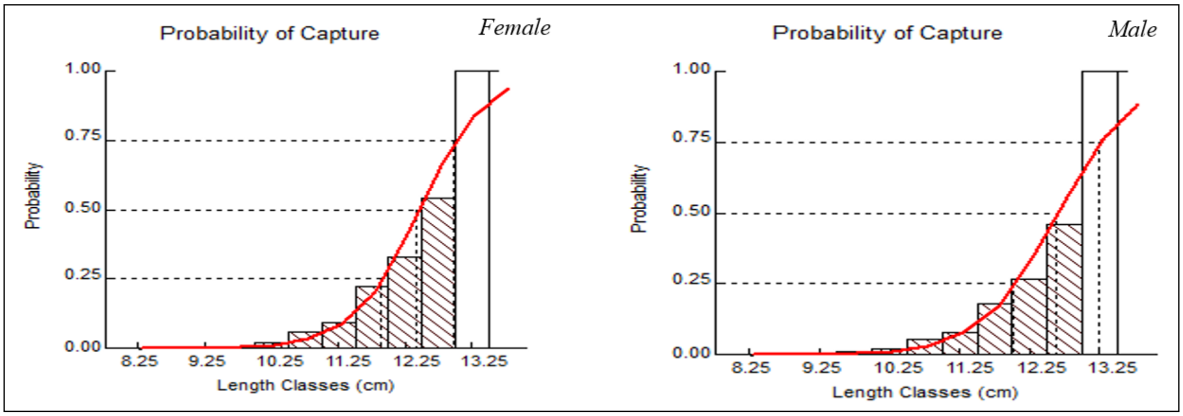

Figure 15. Probability of capture of female and male blue swimming crab in Danajon Bank.

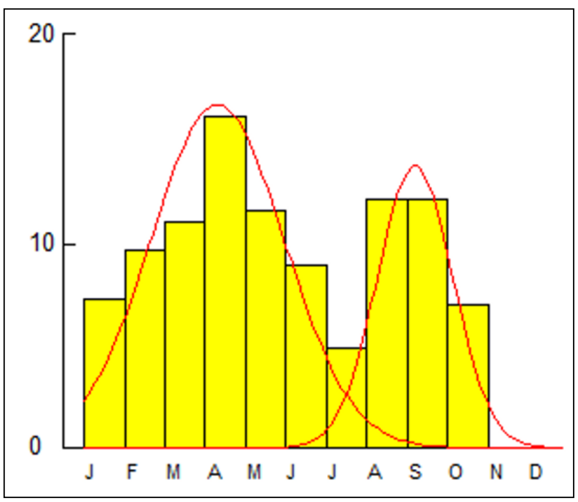

Figure 16. Recruitment pattern observed for female blue swimming crab in Danajon Bank.

B. Gonadal Stages, Length at First Maturity (Lm) and Spawning Potential Ratio (SPR)

Combining all the reproductive data collected for one year in Danajon Bank, as shown in Figure 17, stages I and II were predominantly caught by the crabbers. Stage 1 described as immature or non-ovigerous had the highest percentage of the overall samples in almost all sampling months. It reached to 70% during the month of March 2020 and its lowest percentage was 36% noted in October 2019. As observed from October 2019 to January and August 2020, there was no record of stage V or spent/resting stage and minimal share in the remaining months. Stages II (developing and maturing) and III (mature) were highest in November and October 2019 at 38% and 14%, respectively. Apparently blue swimming crabs spawned whole-year round as gravid crabs were noted in all sampling months of which highest spawning was obtained in May 2020 (11.6%). Higher spawning frequencies were also recorded in December 2019 (10.5%), April 2020 (10%) and October 2019 (9.4%). Zairion and Fahrudin (2015) described the spawning of *P. pelagicus* in Lampung Coastal Waters of Indonesia as seasonal-continuous in a year with peak spawning and breeding in April to June and October to November. While Ernawati et al. (2017) observed fast growth and peak season of BSC between February to April and in August to October in Java Sea, Indonesia. BSC is highly fecund with female crabs release up to two million eggs per batch. De Lestang et al. 2003 reported that fecundity for small-sized, about 8 cm CW was at 78,000 and 1,000,000 for large-sized (18 cm CW) in the West coast of Australia.

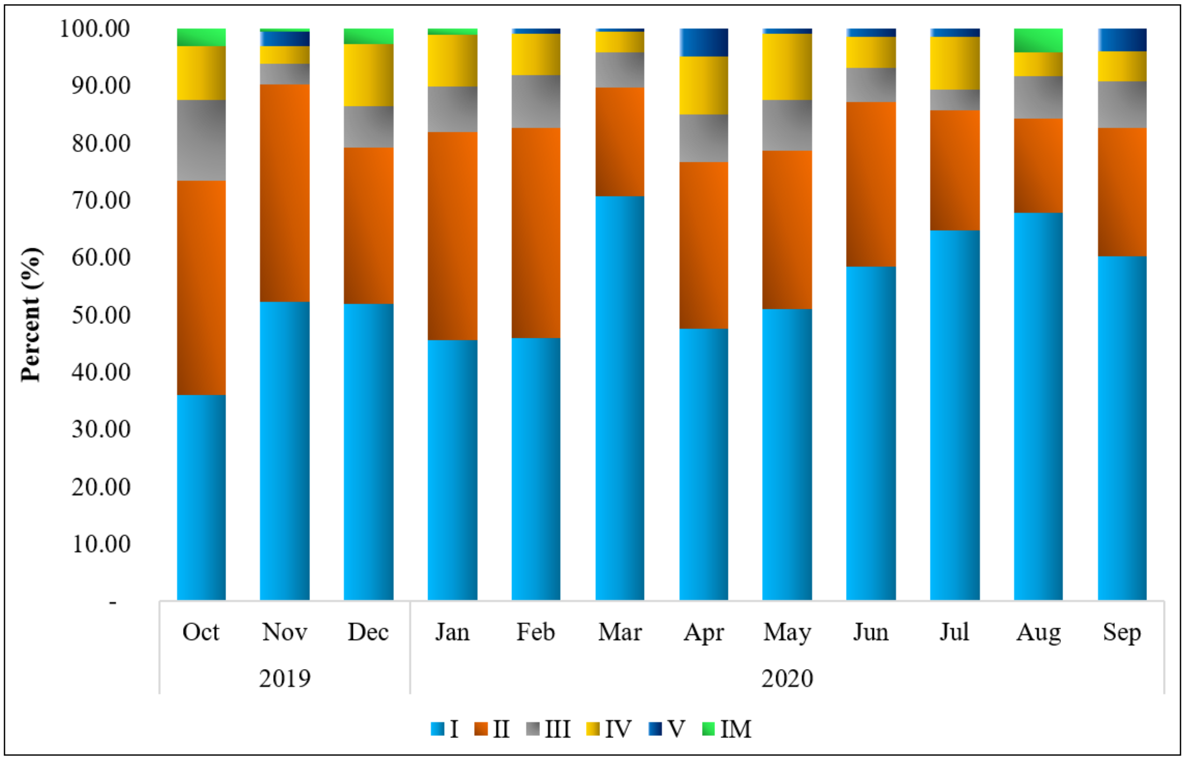

Figure 17. Monthly gonadal frequency (%) distribution obtained for *P. pelagicus* caught in Danajon Bank from October 2019 to September 2020.

Size at first maturity is important in the context of stock reproductive strategy and production. Large size at maturation is beneficial for a high reproductive potential and generally related to fecundity. It has been suggested that high fishing pressure may reduce the size at maturity (Stearns 1976; Pollock 1995).

For this assessment, the length at first maturity (L_m) or the size at which 50% of the crabs have reached sexual maturity occurred at 10.54 cm (Figure 18A-B). The minimum and maximum observed lengths were at 8.5 cm and 20.25 cm, respectively. The Lm obtained for *P. pelagicus* in this study was smaller than 12 cm and 11.2 cm reported in Danajon Bank (Armada et al. 2009; ECOFISH Report 2015), slightly smaller than 10.6 cm in Visayan Sea and Guimaras Strait (Ingles 1996). However, comparable to the average size of maturity for female crab at 10.56 cm in Ragay Gulf (Ingles and Braum 1989). Nevertheless, the present Lm of BSC in Danajon Bank is slightly bigger than 10.2 cm (CW) prescribed as legal size under the DA-DILG JAO No. 1, series of 2014 on the Regulation for the conservation of blue swimming crab *Portunus pelagicus* suggesting that bigger-sized crabs are still abound in Danajon Bank.

The Spawning Potential Ratio refers to the measure of current egg production of the fished stock relative to the maximum possible egg production at the unfished stock level (Hordyk et al., 2015 a and b). It is the proportion of the unfished reproductive potential left at any given level of fishing pressure. SPR is a widely accepted approach in fisheries management for addressing recruitment overfishing in exploited fish stocks based on the concept that a sufficient number of fish should be left in the sea (under prevailing exploitation rates) to survive, reproduce, perpetuate, and replenish the stock at a sustainable level (Sivestre et al. 2020). SPR is commonly used to set target and limit reference points for fisheries (FISHE 2015).

The result from Spawning Potential Ratio analysis is given in Figure 19. The SPR of *P. pelagicus* was computed at 26%, which is 6% higher than the 20% limit, however slightly lower than 27% reported in the study of ECOFISH in Danajon Bank (ECOFISH Report 2015). A parallel assessment of BSC conducted in Visayan Sea Region 7 from October 2019 to September 2020 as part of PACPI funded project recorded much lower SPR of 21% (unpublished Report). The SPR reported in other tropical country particularly from Java Sea, Indonesia was at 11% to 24% only (Ernawati et al. 2017). The higher SPR obtained in Danajon Bank compared to Visayan Sea where there is no stock enhancement intervention can be attributed to the BSC stock

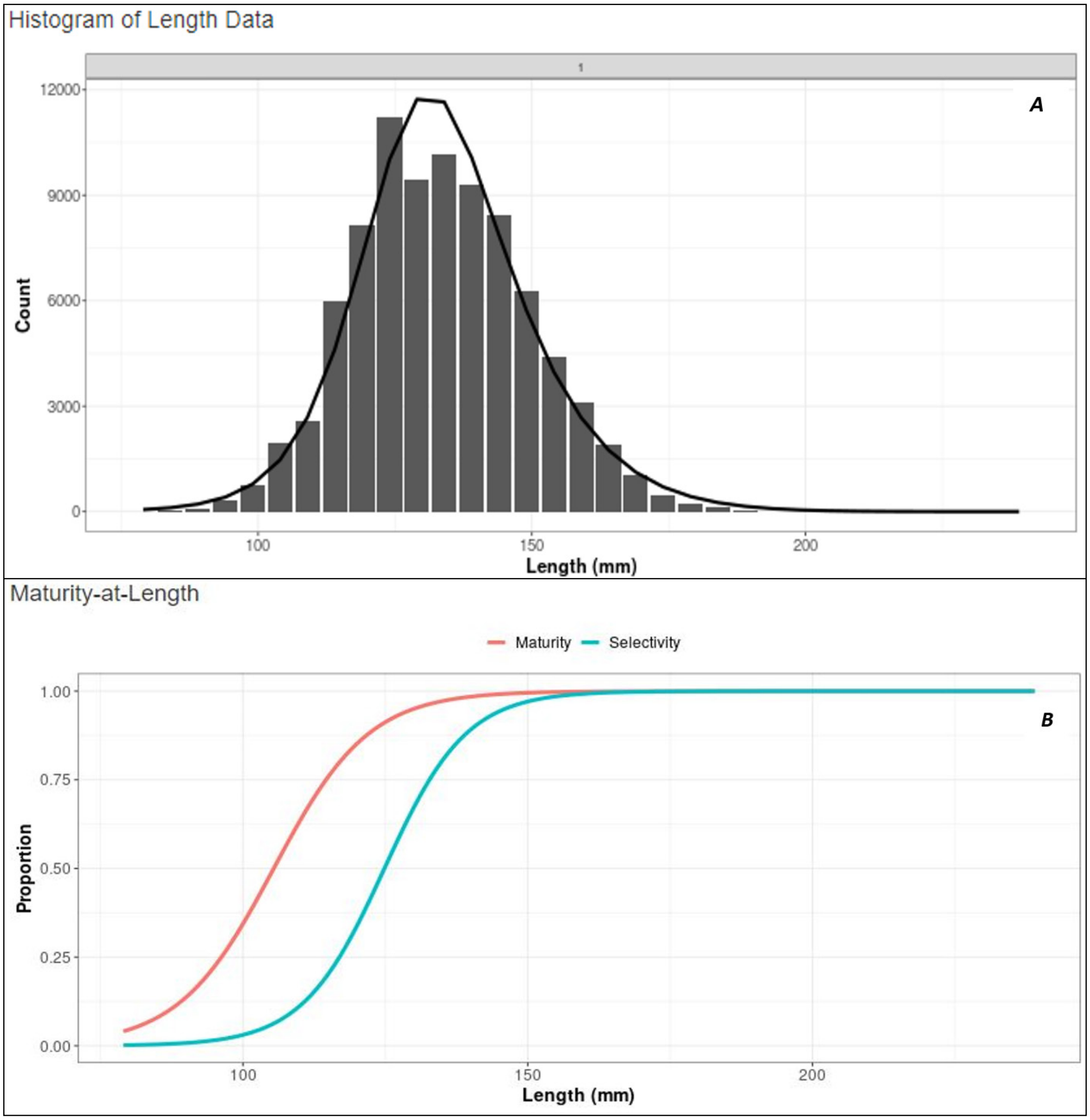

Figure 18A-B. Histogram of pooled length frequencies of *P. pelagicus* from the five landing sites in Danajon Bank from June 2019 to September 2020. B) Graphical representation of Length at First maturity (Lm).

enhancement activity of PACPI and BFAR 7, though it is not yet conclusive to declare at this time. The present SPR of blue swimming crab though above the limit reference point but it is already below the 30% precautionary threshold for most of the stocks to remain sustainable. The SPR generated for BSC was also reflective of the result from the reproductive sampling where percentage of gravid crabs sampled/ dissected was lower compared to non-ovigerous crabs.

CONCLUSION AND RECOMMENDATIONS

Results from 16 months assessment (June 2019 to September 2020) revealed that *P. pelagicus* dominated the species composition in Danajon Bank accounting for 66% of the overall catch. A few species of finfishes were also caught in minimal volume. The two major gears frequently used by majority of the fishers were crab net and crab pot. Patchy information obtained from bottom set gill net was also recorded. Estimation of growth parameters showed that male BSC grows slightly faster having higher asymptotic length ($L\infty$) and higher growth constant (K) compared to female crab. The sex ratio of male and

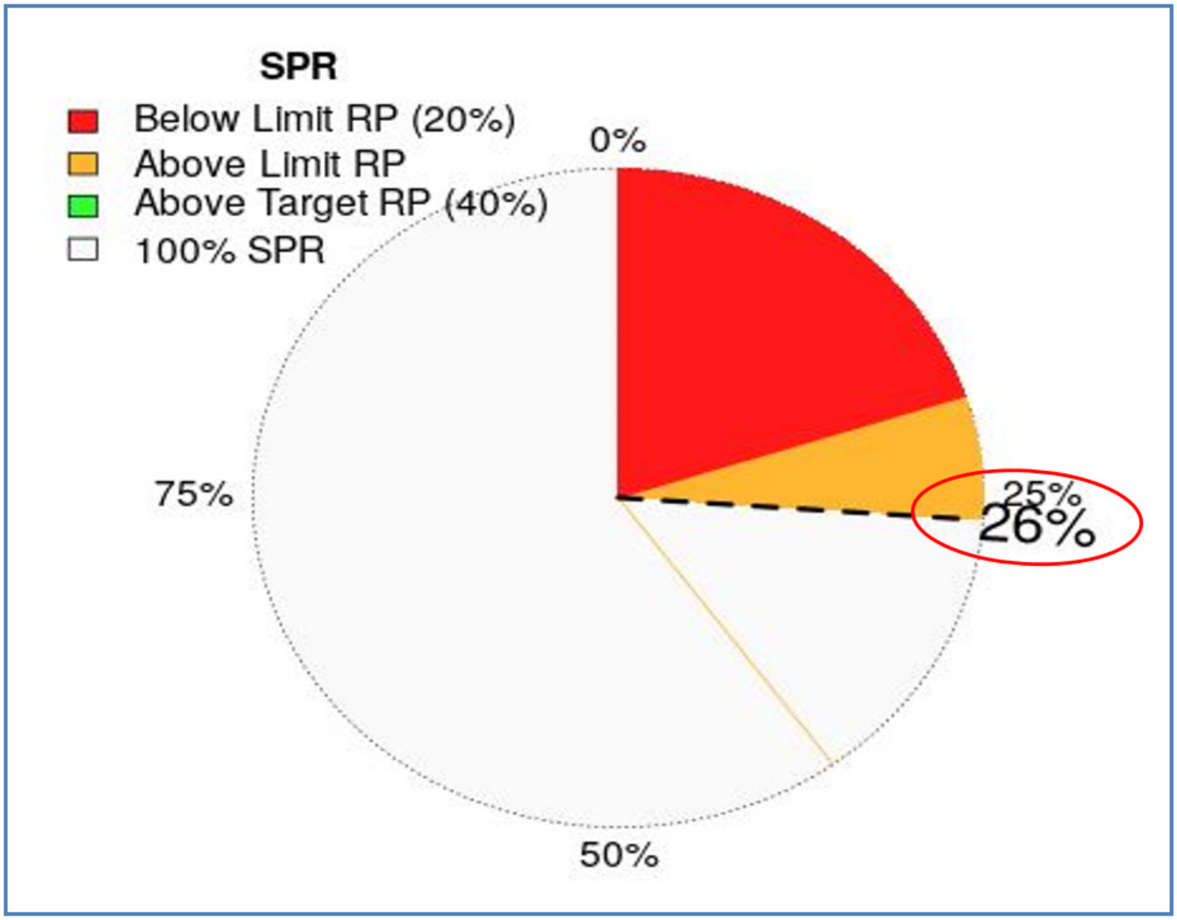

Figure 19. Spawning Potential Ratio (SPR) of *P. pelagicus* obtained in Danajon Bank from June 2019 to September 2020.

female crab was computed at 1:1.28 indicating that more females were captured than males. When it comes to reproduction, two recruitment pulses were observed during the study. The first peak was noted in April and May and the second pulse was in August and September. Reproductive biological sampling indicated that BSC were gravid in April, May, December and October. This observation can be linked to the information published in literature which reported that highest spawning activity of BSC in the tropics happened in the months of May and October.

In conclusion, the biological performance indicators evaluated in this study showed both favorable and unfavorable implications. The positive indicator was reflected in the slightly improved CPUE of major BSC gear used in the area. The catch rate of crab pot was higher than the CPUE reported in the previous study of ECOFISH while the CPUE of crab net was comparable. Other good indicators are the mean length and probability of capture sizes of both male and female crab, observed to be above the 10.2 cm CW limit set by DA-DILG JAO No. 1, series of 2014 on the Regulation for the conservation of blue swimming crab *Portunus pelagicus*. Though it appears that the length at first maturity of BSC calculated at 10.54 cm was lower than the previous studies (11.2 cm and 12 cm) but it is still above the 10.2 cm threshold. Similarly, the 26% SPR generated was slightly lower than the value obtained in the past work of ECOFISH (27%) but it did not yet breach the 20% limit reference point.

On the other hand, unfavorable indicators are exhibited in the results of mortality estimates. The values obtained for exploitation rate (E), yield per recruit exploitation ratio for both female and male crabs were high and already breached the limit. The scenario showed that excessive crabbing was on going in Danajon Bank. In spite of the stock enhancement efforts done by PACPI and BFAR, it seemed the BSC fishery was undergoing exploitation. However, higher SPR obtained in Danajon Bank (26%) compared to Visayan Sea Region 7 (21%) where there is no stock enhancement activity can be attributed to the BSC stock enhancement initiative of PACPI and BFAR 7.

The following recommendations are proposed:

- Jointly PACPI and BFAR to present the results of assessment to the concerned LGUs;
- To continue the BSC stock enhancement activity taking consideration some strategies for improvement of the project as follows:
  - o Characterization of BSC dispersal sites/areas should be conducted prior to stock enhancement and/or dispersal activity.
  - o Determine the survival rate of BSC prior to dispersal. It can be done by holding first the hatchery-produced juveniles BSC in the hapa nets for 3 to 7 days to monitor survival prior to release.
  - o Tagging of hatchery-bred BSC.
- To continue thorough reproductive biological study by technically trained and experienced personnel;
- To conduct total boat and gear inventory (BGI) of BSC geartype and other gears in the coastal areas around Danajon Bank, in order to estimate the Maximum Sustainable Yield (MSY) for blue swimming crab;
- LGUs that have existing policy on the prohibition of catching gravid/berried crabs must strictly impose the policy;
- LGUs that do not have yet the policy must also implement the same to protect the gravid/berried crabs;
- To continue stock assessment of BSC in the dispersal sites to monitor catch trend and biological indicators.
- To utilize the present results as baseline or benchmark information for monitoring the blue swimming crab stock enhancement program of PACPI.
- To conduct Information Education Campaign (IEC) on the importance of seagrass beds and coral reefs and other ecosystem as significant habitats of blue swimming crab and other aquatic organisms;
- To propose to PACPI to provide BSC fishers holding pens for gravid crabs for spawning prior to market disposal.

ACKNOWLEDGMENT

The study was made possible through the funding support from PACPI and able supervision of the Program Director, Ms. Marinelle Espino. The support from DA-NFRDI through Acting Executive Director Dr. Lilian C. Garcia; BFAR 7 management through RD Allan L. Poquita; Conrado P. Toston – former Chief of Multi-Species Hatchery, Sinandigan, Ubay, Bohol and his team; PACPI hatchery technicians; field enumerators; Data Encoder; crab pickers; consolidators; DA-LGUs of President Carlos P. Garcia, Getafe, Talibon and Ubay; Barangay Captains of the five BSC stock enhancement sites and most especially the crab fishers is gratefully acknowledged. Special thank also goes to the reviewers and editors of the manuscript. Praise be to God for the continued guidance, protection, strength and insights.

AUTHOR CONTRIBUTIONS

Abrenica BT: Conceptualization, Formal analysis, Writing–Original Draft, Writing–Review & Editing. **Fajardo MJM:** Visualization. **Paran JS:** Formal analysis, Visualization. **Ruinata MN:** Writing–Review & Editing. **Espino MS:** Review & Editing. **Allan PL**: Supervision.

CONFLICTS OF INTEREST

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

ETHICS STATEMENT

The researchers followed all institutional and national guidelines for the care and use of laboratory animals. No animal or human studies were carried out by the authors.

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