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Keynote Lecture

Common dolphinfish fisheries in Babuyan Channel, Philippines

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ABSTRACT

Coryphaena hippurus or commonly known as Common dolphin fish is one of the commercially important species found along Babuyan Channel in Cagayan Valley Region, Philippines. Hence, this study was conducted to determine the status of the common dolphinfish which is vital for policy-makers to devise management actions for sustainable exploitation of the species using the standard methodology for the National Stock Assessment Program (NSAP), Philippines. This study showed that the major gears catching *C. hippurus* are troll lines, long lines and handlines while other gears caught the species through by-catch which is fairly consistent every year with catch peaks from April to May and October to November. The data also showed a decreasing trend from 2015-2017 primarily due to typhoons and bad weather conditions that destroyed boats and fishing paraphernalia in the area. Length infinity of *C. hippurus* in Babuyan Channel was derived at 210 cm fork length with a growth coefficient (k) value of 0.53. Notably, most of the species caught by the major fishing gears has reached the sexual maturity stage and very few are juveniles. However, mortality and exploitation values at 4.29 total mortality (Z), 0.69 natural mortality (M), 3.61 fishing mortality (F) and 0.84 exploitation value (e) indicates that stocks are beyond the sustainable level of exploitation.

Key words: status, mortality, exploitation rates, length infinity, growth coefficient

INTRODUCTION

Babuyan Channel is located along the Kuroshio Current and one of the three (3) major fishing grounds in Cagayan Valley Region, Philippines which caters to a number of fisherfolk where fishing is one of their main sources of income and employment. It likewise houses commercially important fish species wherein one of which is the common dolphinfish, locally known as “dorado” or “pantranko”.

Coryphaena hippurus (Linnaeus 1758) belongs to order Perciformes referring to perch-like fishes and family Coryphaenidae or dolphinfishes. Its body is covered with metallic blue-green coloration on its back and silver with golden sheen color on both sides with a row of dark spots or golden blotches running below dorsal fin and 1, 2 or more on and below lateral line (some scattered irregularly) (Sidthimunka 1970). It is valuable wherever it occurs both as game and commercial fish (Massuti, et. al, 1995).

It is one of the top commodities in Babuyan Channel and is commonly caught by troll line (TL), simple hand line (SHL) and long line (LL). But in spite of the numerous studies conducted to determine the status of Babuyan Channel, there is still no study conducted to determine the status of dolphinfish in the area which is vital for policy makers in devising various management actions for the sustainable exploitation of the said species and the fishery as a whole.

This study generally aims to determine the status of common dolphinfish fishery in Babuyan Channel. It specifically aims to determine the catch trend of *C. hippurus* (Linnaeus 1758) for the past five years (2014 to 2018), seasonality of the species, catch per unit effort (CPUE) of commonly used gears, size and length distribution and population parameters.

MATERIALS AND METHODS

Study area

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The study was carried out in Babuyan Channel covering 29 landing sites namely: San Juan and Macatel in Sta. Praxedes, Taggat Norte, Minanga and Pata East in Claveria, Masisit and Marzan in Sanchez Mira, Centro in Abulug, Ammubuan and Cabaritan East in Ballesteros, Centro, Paddaya, and Punta in Aparri, Paddaya Este and Centro in Buguey, Minanga, Batangan, Tapel, and Baua in Gonzaga, Palawig, Centro, Zinungan, Tangatan and San Vicente in Sta. Ana, and Minabel, Balatubat, Dadao, Centro II, Rakwaksong and Dapulag in Calayan, Cagayan, Philippines (Fig. 1).

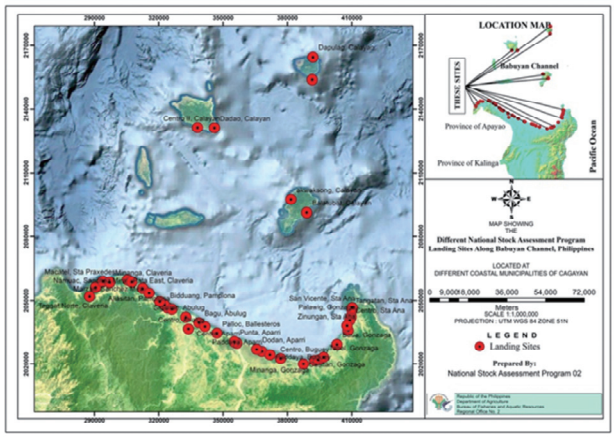

Fig. 1. Location of NSAP landing sites in Babuyan Channel, Philippines where data on *C. hippurus* are reported.

Babuyan Channel is located along the Kuroshio Current and lies approximately between latitude 18° 16'00"and 11° 35'00" North and longitude 121° 02'00" and 121° 14'00" East. It has a total area of approximately 477, 550 hectares which extends to the islands of Fuga, Camuigin, Dalupiri, Calayan and Babuyan Group of Islands to the North, converging with the Pacific Ocean in the East and the West Philippine Sea on the West.

Data collection

Data on *Coryphaena hippurus* (Linnaeus 1758) was collected by trained enumerators assigned in the different landing sites along Babuyan Channel from 2014-2018. Data collection was based on the standard National Stock Assessment Program (NSAP) methodology (DA-BFAR − NSAP Atlas, 2017). Information gathered includes the total number of boats landed per sampling day, total catch and effort per fishing operation, species composition and length and weight measurements of each species.

1. Catch trend

The catch trend of *Coryphaena hippurus* was assessed by reviewing the catch data over the last five (5) years (2014-2018), from the raw data gathered by the NSAP enumerators who were assigned to the different NSAP monitored sites.

2. Seasonality of species

Monthly catch production (in kilograms) of *Coryphaena hippurus* was used to determine its seasonality. The data used in the estimation was based on monitored raw data for 5 years from 2014-2018.

3. Catch, effort and catch per unit effort

The catch was obtained and recorded in kilograms. Annual CPUE was computed and standardized as kilogram/boat. The annual nominal CPUE per gear was obtained by summing up all the monthly harvest (in kilograms) divided by the total number of fishing boats using the same fishing gears per year. Standard effort used was the number of fishing boats.

4. Size composition and length distribution

Catch was sorted per species and length measurements were recorded. All length measurements for *Coryphaena hippurus* caught by various gears were obtained and was recorded in centimeter. Length at first maturity of the species was based from literatures and from fishbase. org to determine the percentage of juveniles and mature samples.

Population parameters

Population parameters were obtained using the FAO-ICLARM Stock Assessment Tools (FISAT) Software (Gayanilo et. al., 1997). The ELEFAN routine in FiSAT II was applied to estimate the growth parameters length infinity ($L\infty$) and growth contant (K), assuming that the body growth followed the von Bertalanffy growth equation (Gayanilo et al., 2005). The growth model has the formula:

$$L(t) = L\infty[- \exp(-K(t- t0))]$$

where L(t) is the length at age t, $L\infty$ is the asymptotic length, k is a growth coefficient, and t0 corresponds to the theoretical age at which the fish length is zero. The ELEFAN routine fits the growth curve that passes through a maximum number of peaks in the length frequency distribution (Pauly, 1984). An index of goodness of fit, (Rn), was determined by automatic computer (Gayanilo et al., 2005). In order to compare the growth rates in this study with those of other authors, the standard growth index (ϕ') was used as a measure of overall growth performance (Pauly and Munro, 1984). The index is defined as:

$$\phi' = \text{Log10 (K)} + 2\text{Log10 (L}\infty\text{)}$$

Longevity was calculated from Pauly's (1984) equation:

$$tmax = 3 / K$$

The theoretical age at length zero (t0) was estimated using Pauly's (1979) empirical equation:

Log10 (-t0) = -0.392 - 0.275 Log10 (L ∞) - 1.038 Log10 (K)

Assessment of the instantaneous mortality coefficients and related parameters. Once the growth parameters of the von Bertalanffy growth (VBGF) equation were obtained, total mortality (Z) was estimated by the length converted catch curve method as implemented in ELEFAN. The linearized length-converted catch curve (Pauly, 1984) was constructed using the formula:

Ln (Ni / Δ ti) = a + b ti

where Ni is the number of individuals in length class i, Δ t is the time needed for the fish to grow through length class i, t is the relative age (computed with t0 = 0) corresponding to the midlength of class i. The slope (b) of the curve with its sign changed gives Z. The regression lines were extrapolated to approximate the probability of capture given natural mortality (M). FiSAT II provides an option to estimate this value using the empirical equation of Pauly (1980) as following:

Log10 (M) = -0.0066 - 0.279 Log10 (L ∞) + 0.6543 Log10 (K) + 0.463 Log10 (T), SD (Log M) = 0.245

where (T) is the annual mean of habitat temperature (in degrees Celsius). The indicated value is equal here to 27° C (Djidohokpin et al., 2017b). This method of estimating M is widely used throughout the tropics where time series of reliable catch and effort data and several years of Z values are not available (Pauly, 1980). Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained using this formula E = F / Z. The exploitation rate indicates whether the stock is slightly (E < 0.5) or strongly (E > 0.5) exploited, based on the assumption that fish stock is optimally exploited when F = M or E = 0.5 (Gulland, 1971). The estimates of length-at-first-capture (L_c or L_{50}) were derived from probabilities of capture generated from the catch curve analysis. The extrapolated points of the length-converted catch curve were used to approximate the probability of capture for each length group using the running average method to estimate the selection parameter L_{50} through linear interpolation.

RESULTS

Catch trend

Notably, the annual catch trend decreased from 2015-2017 and with a slight increase in 2018 as shown in Fig. 2.

Seasonality of species

Monthly seasonal distribution of the species from 2014-2018 is fairly consistent every year which peaks from March to May and September to November (Fig. 3).

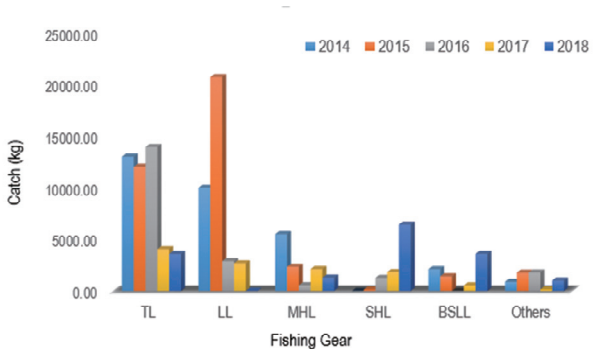

Fig. 2. Gears catching *Coryphaena hippurus* in Babuyan Channel, Philippines from C.Y 2014-2018.

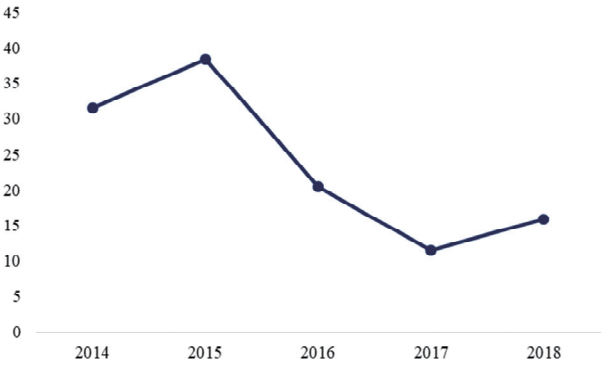

Fig. 3. Catch trend of *Coryphaena hippurus* in Babuyan Channel, Philippines, 2014-2018.

Catch, effort and catch-per-unit effort

In Babuyan Channel, *Coryphaena hippurus* is oftentimes targeted using troll lines, long lines and hand lines. Some of the catches are being caught through by-catch by other gears including ring net, gill nets, round haul seine and trawl. Figure 4 shows that troll line caught most of the reported *Coryphaena hippurus* catch in the area from 2014-2018 followed by long line, multiple hand line, simple hand line and bottom set long line. Other gears that are catching the said species include the drift gill net, ring net, trawl, tuna gill net, beach seine, drift long line, bottom set gill net, round haul seine and surface set gill net.

Troll line was the major fishing gear catching *Coryphaena hippurus* showing a fluctuating trend in its annual Catch-per-Unit-Effort (CPUE) from 2014-2018 (Fig. 5). Highest catch was noted in 2016 with 13,922 kilograms and a CPUE at 26 kilograms/ boat. A decreasing trend was also noticed from 2017-2018, with a decrease in catch and number of boats landed with the lowest CPUE in 2018 at 8.8 kilograms/ boat. Meanwhile, it was also noted that there was a declining trend for the Catch and annual CPUE of long line

with the highest CPUE of 29.92 kilograms/ boat in the year 2015 and the lowest CPUE at 8.18 kilograms/boat in 2018 (Fig. 6). Other than Troll Line and Long Line, Hand Lines are also used in targeting large pelagic species to include dolphin fishes with a decreasing trend in catch and annual CPUE from 2014-2018 with the highest CPUE recorded in 2016 at 26.28 kilograms/ boat and lowest in 2018 at 9.6 kilograms/ boat (Fig. 7).

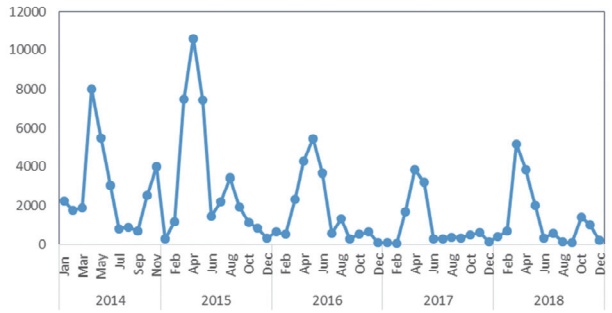

Fig. 4. Seasonality of *Coryphaena hippurus*, in Babuyan Channel, Philippines, 2014-2018.

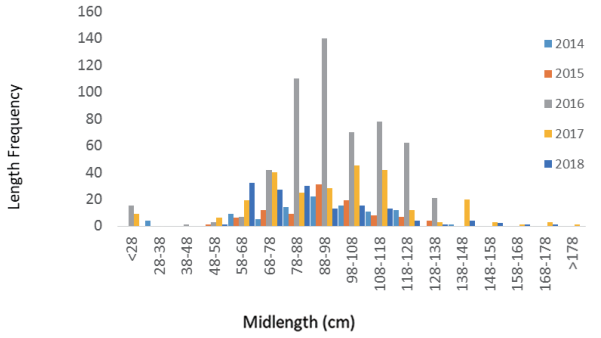

Fig. 5. Length composition of *Coryphaena hippurus* caught by Troll line in Babuyan Channel, Philippines, 2014-2018.

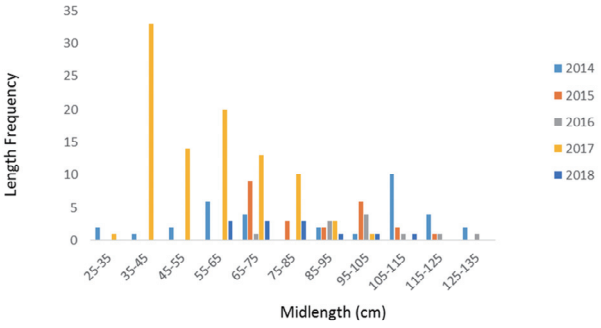

Fig. 6. Length composition of *Coryphaena hippurus* caught by Multiple Handline in Babuyan Channel, Philippines, 2014-2018.

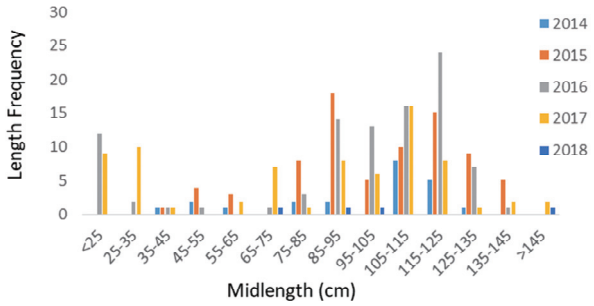

Fig. 7. Length composition of Coryphaena hippurus caught by Long Line in Babuyan Channel, Philippines, 2014-2018.

Size and length distribution

Within the five-year study period, it was noted that 96.93% of *Coryphaena hippurus* caught by troll line exceeded the length at first maturity and only 3.07% are juveniles (Fig. 8); 68.75% mature and 31.25% juveniles are caught by long line (Fig. 9); 70.06% mature and 29.94% juveniles are caught by multiple hand line (Fig. 10) 92.31% mature and 7.69% juveniles are caught by simple hand line (Fig. 11).

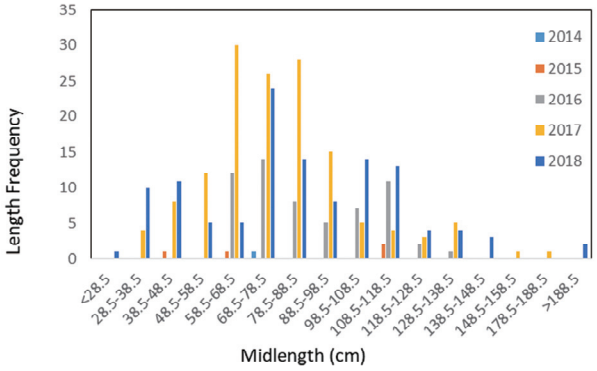

Fig. 8. Length composition of *Coryphaena hippurus* caught by Simple Handline in Babuyan Channel, Philippines, 2014-2018.

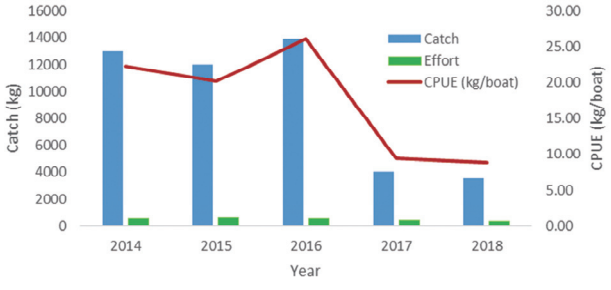

Fig. 9. Annual Catch, Effort and Catch Per Unit Effort (CPUE) of Troll Line in Babuyan Channel, Philippines, 2014-2018.

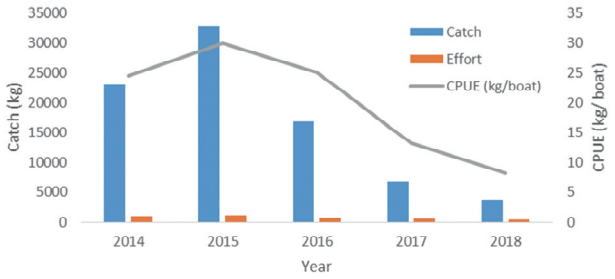

Fig. 10. Annual Catch, Effort and Catch Per Unit Effort (CPUE) of Long Line in Babuyan Channel, Philippines, 2014-2018.

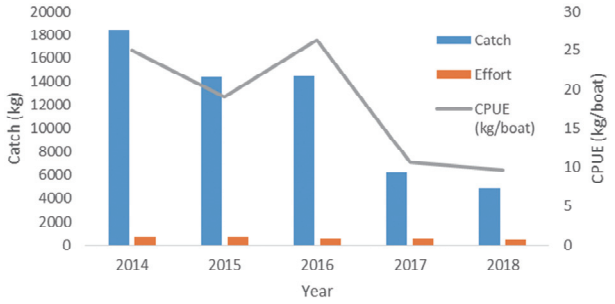

Fig. 11. Annual Catch, Effort and Catch per Unit Effort (CPUE) of Multiple Hand Line in Babuyan Channel, Philippines, 2014-2018.

Population parameters

The analysis of the length data using the non-parametric scoring of VBGF fit using ELEFAN I (Fig.12) for *Coryphaena hippurus* resulted to a length infinity value of 210 cm FL and 0.53 as the growth constant. The length converted catch curves are presented in Fig. 13. Instantaneous mortality rates Z, M and F and exploitation rate E are 4. 19, 0. 69 and 3. 50, respectively. The exploitation value (e) is 0.83 which is above the assumed optimum value (0.5) for sustainable exploitation. The exploitation rate E0. 1 (exploitation rate at which the marginal increase of Y'/R is 10% of its entire stock) and E0.5 (exploitation rate under which the entire stock is halved) and were estimated at 0.557 and 0.339, respectively (Fig. 14). For this study, the logistic selection model showed that the estimated length of captured *Coryphaena hippurus* at 25% is at 97.52 cm FL, 114.44 cm FL at 50% and 131.37 cm FL at 75% (Fig. 15). In addition, the recruitment pattern of the species showed to have a bimodal distribution indicating two distinct spawning events (April and August to September) (Fig. 16).

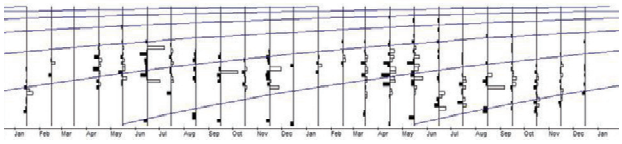

Fig. 12. Von Bertallanfy Growth curve of *Coryphaena hippurus* in Babuyan Channel, Philippines.

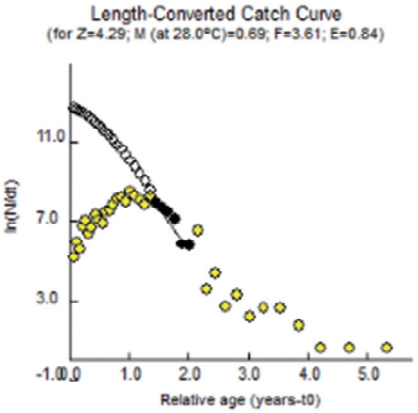

Fig. 13. Length-Converted Catch Curve of *Coryphaena hippurus* in Babuyan Channel, Philippines.

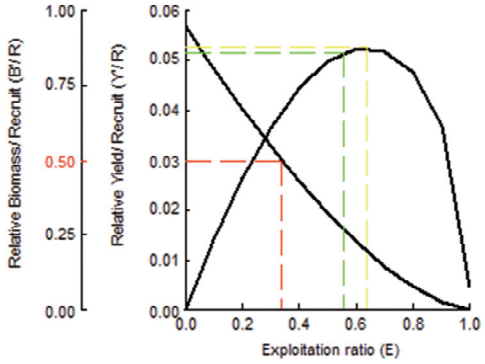

Fig. 14. Relative yield-per-recruit and biomass-per-recruit curve for *Coryphaena hippurus* in Babuyan Channel, Philippines using the Selection o-give option.

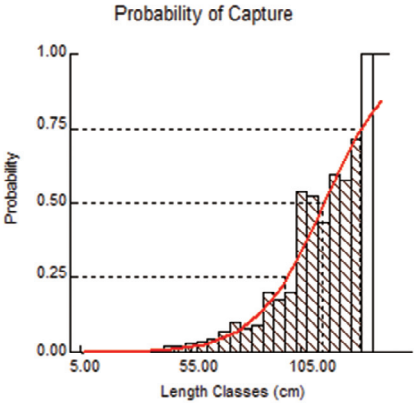

Fig. 15. Probability of capture of *Coryphaena hippurus* in Babuyan Channel, Philippines.

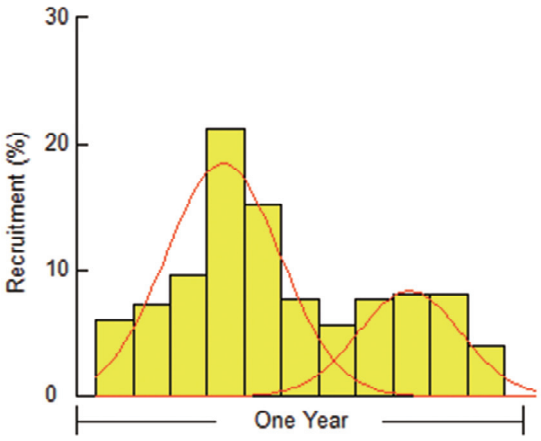

Fig. 16. Recruitment pattern of *Coryphaena hippurus* in Babuyan Channel, Philippines.

DISCUSSION

There are various factors being considered that could have attributed in the fluctuating catch trend of *C. hippurus* in Babuyan Channel to include environmental and socio-economic factors that affected fishing during the study period. Particularly in 2016, typhoons have devastated the area which resulted to the destruction of a number of fishing boats and fishing paraphernalia used by fishermen in the area. Notably, some of the fisherfolk shifted from fishing to farming or to being construction laborers who are paid daily to sustain their livelihood. In addition to why fish caught decreased, fishers would rather not go fishing due to the high-cost of fuel but with less catch resulting to high fishing operation cost but with less income according to interviews conducted with some local fishers.

Seasonality is a critically important aspect of environmental variability, and strongly shapes all aspects of life organisms loving in highly seasonal environments (Williams, et. al, 2017). In the Pacific Ocean, the dolphin fish is found year round from early summer to autumn where the species performs seasonal migrations into the adjacent seas of Japan, where it is a target of important fisheries (Sakamoto, et. al, 1999). Generally, the abundance or biological production of the top commercially important species in Babuyan Channel to include *C. hippurus* is highly seasonal (Calicdan et. al, 2018). This might be due to the prevailing conditions of the area where typhoons and bad weather conditions due to monsoon winds occurring after summer season which results to natural close season in the area. Moreover, factors such as food availability, rainfall, sunshine duration and salinity, wind movement and other meteorological parameters might have played in the seasonality, distribution and annual catch of the species (Calicdan et. al, 2018).

Aside from determining the size composition of species to assess their status, CPUE can also be used and often, these standardizations are used to reflect fish abundance. CPUE implies that catch is directly proportional to effort (Aljafary et. al, 2019). Though the catch per unit effort will rarely be exactly proportional to the stock density, it is often essential to have some measure of the stock, and the catch per unit will nearly always be the best available - better than for example, total catch (http://www.fao.org/3/x5685e/x5685e04.htm). In Babuyan Channel, annual CPUE of the major fishing gears was noted. It is also important to consider that catch and effort are not always directly proportional hence, CPUE of the major fishing gears does not always depend on these two variables. Factors that might have affected the CPUE could be environmental factors such as the occurrence of bad weather conditions due to typhoons and seasonal conditions prevailing in the area that might have affected the frequency of fishing trips and duration of fishing spent by fishers in catching the species. Moreover, socio-economic factors such as increase in fishing operation cost due to increase in the price of fuel and the shifting of livelihood by fishers in the area might have also affected the CPUE.

C. hippurus is distributed widely in the tropical and subtropical regions of the Atlantic, Pacific and Indian Oceans. Considered as a highly migratory species, they are exploited by coastal nations within their ranges (Mahon and Oxenford, 1999; Rivera and Appeldoorn, 2000). They exhibit early maturity, a short life span and high growth rates (Oxenford, 1999). Knowing this, it is important to assess fishery stock status in order to set catch limits and reduce the risk of stock collapse and associated adverse social and economic impacts (www.fishe.edf.org) and size compositions are easy to collect and are one of the bases in assessing fish stocks. However, estimates of the size at 50% maturity vary among studies (regions) and by sex (Alejo-Plata et al., 2011; Massutí and Morales-Nin, 1997; Schwenke and Buckel, 2008; Wu et al., 2001) and are in the range of 45.7 − 54.5 cm (fork length) for female and 47.6 − 61.8 cm for male.

Minimum body size at sexual maturity was estimated to be 51 cm for both sexes of *C. hippurus* in the east coast of Taiwan (Wu et.al, 2001). Also, according to Beardsley (1967), in the Straits of Florida female common dolphin begin to mature at about 350 mm FL and at 55 cm FL 100% are mature. He found that the smallest male common dolphin with milt present in the testes was 42.7 cm FL and felt that female dolphin began to mature at a slightly smaller size than males. Both sexes reach sexual maturity in the first year of life (Beardsley 1967; Shcherbachev 1973). Williams and Newell (1957) stated that common dolphin reached maturity at < 53.5 cm SL in East African waters. Based from Figs. 5, 6, 7 and 8, most of the catch of *C. hippurus* in Babuyan Channel are mature and only a small percentage are juveniles. This

suggests therefore, that the gears used do not impose so much threat to the species.

Additionally, *C. hippurus* exhibit early maturity, a short life span and high growth rates (Oxenford, 1999). The largest fish recorded was 197 cm fork length, or 238 cm total length (Lasso and Zapata, 1999), with a maximum age of three to four years (Schwenke and Buckel, 2008). Likewise, the maximum length recorded in Babuyan Channel within the study period was 197 cm fork length (FL). Values for the population parameters were generated using FiSAT where all length frequencies were pooled from different gears catching the species. The computed length infinity of the species at 210 cm fork length with k value of 0.54 is smaller than that of Lasso and Zapata, 1999 however, it is larger than the length infinity in India at 194.25 cm and k of 0.40 year^{1} (Benjamin et.al, 2012). Further, estimated fishing mortality (F) value of 3.61 is much higher than the natural mortality (M) value at 0.69 at 28^{0}C mean sea temperature resulting to an exploitation value (e) of 0.83 indicating a very high fishing pressure or overfishing of the species at present.

It is seen that common dolphinfish, *Coryphaena hippurus* spawns in surface waters and their reproductive season is extensive with frequent multiple spawning (Johnson, 1978; Massutí et. al., 1998). Earlier studies in *Coryphaena hippurus* inhabiting Indian Ocean waters of east Africa revealed that the spawning season may last from March to early June (Enric and Morales, 1997). Dolphinfishes are also capable of spawning during their first year of growth and may reproduce several times during a single spawning season as manifested by the results of the present study. In Florida spawning season of *Coryphaena hippurus* shows a peak in March, which extends from November through July (FWRI, 2008). In earlier studies on growth and reproduction of the dolphin fish in Canary Islands of East Atlantic, the high correspondence between modal length classes and the half year classes suggests that the population of pompano dolphin is made up of two cohorts in each year, as a consequence of two separate and well-defined recruitment periods. On the other hand, the modal progression analysis of the size distribution of common dolphin fish caught in 1995 shows four size classes (Castro et al, 1999). Also, this study showed two recruitment peaks with unequal strength at around April (highest peak) and August to September indicating a continuous recruitment annually for the species which is somewhat similar to that of the result of a study in the Southwest coast of India (Benjamin D. et. al, 2012) with recruitment peaks at around April and November.

CONCLUSION

Most of the fishing gears catching *C. hippurus* are Troll line, Long Lines and Hand lines. Other gears catch the species through by-catch. The five (5) - year data showed that there was a slight increase in fish catch in 2015 and a sudden decrease from 2016-2017. Assessing the length distribution and population of the species caught per gear, it was noted that though most of the fish caught are mature, high fishing pressure was indicated with a very high value of fishing mortality as opposed to the natural mortality value. This can also be supported by the decreasing trend of Catch per Unit Effort (CPUE) of *C. hippurus* considering the major fishing gears catching the species. However, catch and effort do not solely affect the CPUE but other factors such as environmental and socio-economic factors might have affected the CPUE.

Notably, food availability, rainfall, sunshine duration and salinity, wind movement and other meteorological parameters are some of the reasons that could have affected the decrease in fish catch and the seasonal distribution of the species. Also, socio-economic factors to include high cost of fuel and livelihood shifting from fishing to farming or as daily construction workers could have attributed to the decrease in catch during the study period.

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