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RESEARCH ARTICLE

Reproductive Biology and Population Dynamics of Largehead Hairtail (*Trichiurus lepturus* Linnaeus, 1758) in Babuyan Channel, Philippines

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ABSTRACT

Trichiurus lepturus is a species that is highly valuable in the commercial fishing industry along the Babuyan Channel, a significant fishing ground in the Philippines. Data was collected from April 2018 to March 2020 at the established National Stock Assessment Program (NSAP) fish landing centers along the Babuyan Channel. The population parameters and gonadosomatic index were analyzed using FAO-ICLARM Fisheries Stock Assessment Tools II software and a five-point scale maturity index, respectively. A total of 2,597 fish samples were collected, with a higher number of female individuals. The mean fecundity observed was 48,576 eggs, with spawning occurring mainly in May (1st peak) and October to November (2nd peak). Majority of the observed females were at Stages IV and V, indicating that the Babuyan Channel is a spawning area. The length at first maturity (L_m) was 44.61 cm for males and 55.94 cm for females. The fishing mortality value (F = 1) is slightly higher than the natural mortality value (M = 0.59), indicating a slight increase in fishing pressure. The exploitation rate is E = 0.63, which is higher than the 0.5 sustainable level of exploitation. Thus, to protect and conserve the stock, management options such as banning active gear, using environment friendly fishing gears, strict implementation of fishery laws, and the establishment of additional marine protected areas to support species productivity are recommended.

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1. INTRODUCTION

Biologically, *Trichiurus lepturus* is a benthopelagic and amphidromous species widely distributed in warm and temperate waters around the world. It is found at maximum depth of 350 meters (Nakamura and Parin, 1993) and feeds on a variety of fish, squids, and crustaceans (Randall, 1995; Rohit et al., 2015). The species is locally known as "bulung-unas" in the Province of Cagayan and is considered one of the most important fishery resources in the Philippines. It is a common source of cheap fish protein. This resource is primarily caught along the Babuyan Channel using various fishing gears like bottom set gillnet, multiple handline, drift filter net, beach seine, simple handline, ring net, surface set gillnet, and drift gillnet. The recorded annual average landing for 5 years (2012–2017) is 12.4 metric tons, with the highest recorded landed catch in 2014 at 21.7 metric tons. A total of 10,442 boats are operating (DA-BFARa, 2020), and 48,685 fisherfolk (DA-BFARb, 2020) are engaged in fisheries activities in Region 02, in which the Province of Cagayan has the highest number of registered boats and fisherfolk. The Babuyan Channel is one of the major fishing grounds in the Cagayan Valley Region, with a higher volume of large head hairtail compared to Batanes waters and Isabela waters.

Being one of the top commercially important species in Cagayan Valley Region and belongs to the priority species that needs to be managed in Fisheries Management Area (FMA) 1, Philippines, scientific studies on its reproductive biology particularly on its sex ratio, seasonality, fecundity and gonadosomatic index, length at maturity, length distribution by gear, and population parameters (i.e., mortality, exploitation ratio, and recruitment pattern) are needed to manage the resource. Notably, such studies are still lacking in Babuyan Channel and very limited in the Philippines, in general.

The study's findings can guide policymakers and resource managers in developing sustainable strategies for stock exploitation in the Babuyan Channel area and the Philippines in general. Likewise, the findings of the study will be used to calculate the performance indicator, which is essential in creating Harvest Control Rule (HCR) for the species in FMA 1 Northern Pacific sub-FMA, Philippines. Furthermore, the findings will provide regional input for determining the status of the species in the Philippine International Union for Conservation of Nature (IUCN) Red List of Endangered Species.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted along the Babuyan Channel, covering twelve coastal municipalities in the Province of Cagayan, Philippines (Figure 1). It is approximately located between 18°16' 00" and 11°35' 00" North latitude and 121°02'.00" and 121°14' 30" East longitude. The mainland and island of Cagayan have a combined coastline length of 154 kilometers and an approximate total area of 477,550 square kilometers. The channel in the northern part extends to the islands of Fuga, Camiguin, Dalupiri, Calayan, and Babuyan Group of Islands. It converges with the Pacific Ocean on the east and West Philippine Sea on the west (Villarao et al., 2023).

2.2 Data Collection

Data were collected at the established National Stock Assessment Program (NSAP) landing sites along the Babuyan Channel, Philippines (Figure 1) using bottom set gillnet, multiple handline, drift filter net, beach seine, simple handline, ring net, surface set gillnet, and drift gillnet from April 2018 to March 2020 following the NSAP standard methodology described by Santos et al. (2017). All fishing boats unloading catch of *T. lepturus* were sampled and recorded. A minimum of ten (10) samples per month per gear per observation site were collected, measured, and dissected. Total lengths (in cm) and body weights (in g) were measured and recorded. Individual gonad weights (GW: weight of both lobules) were recorded in grams (g), and parts of the gonads were fixed in a 10% formalin solution and later transferred to a 70% alcohol solution for fecundity and GSI determination. The total lengths were determined to the nearest 0.1 cm, and length data were grouped at 4 cm intervals and subsequently analyzed using the Fisheries Stock Assessment Tool (FiSAT) II Software (Gayanilo et al. 2005). The corresponding body weights of the samples measured to the nearest 0.1 grams were obtained. All information were recorded on the prescribed NSAP forms and eventually transferred to an Excel spreadsheet for processing and analysis.

2.3. Data Processing and Analysis

2.3.1 Sex ratio

The sexual stages were classified using Ismen's (2002) five-point scale (Table 1). All relevant information, such as date and month of collection, fishing gear used and time operated, species, individual length, individual weight, sex, gonadal stage, and weight of gonad were encoded. Monthly sex ratios were expressed as the proportion of females to the total number of juveniles and males (Sheng-Ping et al., 2003):

$$Sex\ ratio = Fn/n$$

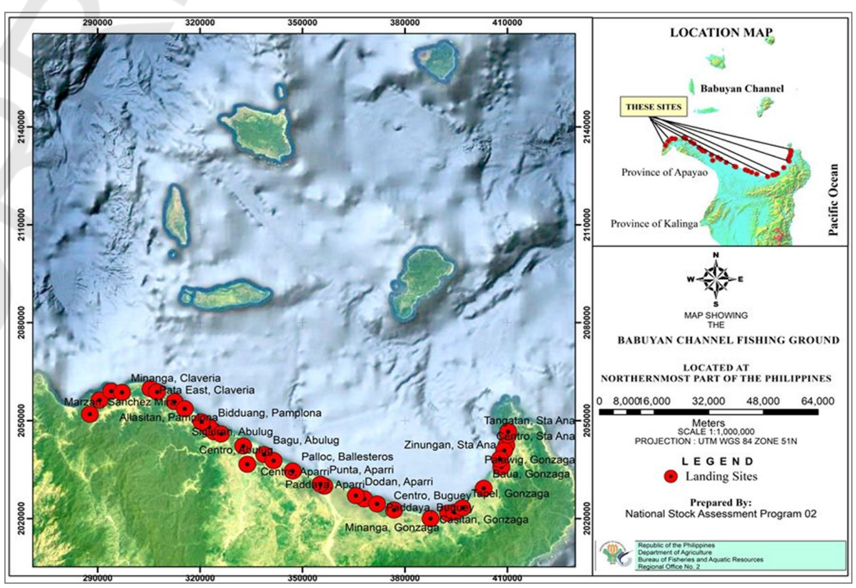

Figure 1. Map of Babuyan Channel, Philippines showing the location of National Stock Assessment Program landing sites.

Table 1. Five point scale of female gonadal maturity (Ismen, 2002).

Maturity Stages	Classification	Distinguishing Characteristics
Juvenile	Juvenile	Fish samples are very small in sizes and have not yet engaged in reproduction;
Stage I	Immature/Virgin	Young individuals have not yet engaged in reproduction; gonads are very small.
Stage II	Developing/Maturing	Sexual products have not yet begun to develop; gonads are very small in size; eggs are not distinguishable to the naked eye.
Stage III	Mature/ Developed	Female- Eggs are distinguishable to the naked eye; very rapid increase in weight of the gonads is in progress. Male- testes change from transparent to pale rose color.
Stage IV	Gravid and Spawning	Sexual products are ripe; gonads have achieved its maximum weight; sexual products are extruded in response to light pressure on the belly; weight of the gonads decreases rapidly from the start of the spawning to its completion.
Stage V	Spent or Resting	The sexual products have been discharged; the genital aperture is inflamed; gonads have the appearance of deflated sacs; the ovaries contain a few leftover eggs and the testes had some residual sperms. And finally on the resting stage, inflammation on the genital aperture has subsided; gonads are very small; and the eggs are not distinguishable to the naked eye.

Where Fn is the monthly count of females, and n is the monthly total number of samples.

2.3.2. Seasonality

Collected data on the volume of samples were used in the determination of the seasonal abundance of the species. The data were pooled to come up with a better presentation of seasonal abundance. The abundance of the species during the summer and cold seasons was also discussed. The seasonality of the species was based on the total sub-sample (in kg) from the total landed catch per month. The monsoon season in relation to seasonality was also analyzed.

2.3.3 Fecundity and GSI estimation

Stage III (Mature/developed) and IV (Gravid/spawning) female gonads, stages where mature gonads are apparent, were considered for fecundity estimation. Gonad portions were sampled from the upper lobe, middle lobe, and lower lobe of each gonad calibrated at 0.05 g. The total number of eggs was estimated from the number of eggs from these portions and the total weight of the gonad.

The equation used by Shimose and Tachihara (2005) was used to calculate the gonadosomatic index (GSI).

$$GSI = GW\ x\ 100/PW$$

where GW is the total wet weight of the gonad and PW is the total wet body weight without the bill, caudal fin, gills, and viscera. The relative gonadal frequency distribution was analyzed on a monthly basis using the count of juveniles and females per stage, which was then converted to percentages.

2.3.4. Length at maturity

Length at maturity (Lm) of *T. lepturus,* both male and female fish caught by all gears from Stage 1 to Stage V samples were used in the analysis. Length frequency data were grouped using the class interval mentioned earlier and fitted in the logistic curve of Sparre and Venema (1992).

$$P = \frac{1}{1 + \exp(S1 + S2\ x\ L)}$$

where P is the proportion of mature individuals within a length class, S_1 is the intercept, S_2 is the slope, and L is midpoint length. Slope a (a) and intercept (b) using the excel spreadsheet were also computed for better estimation or better fit of the logistic curve.

2.3.5. Length distribution per gear

The length-frequency measurement of *T. lepturus* caught by bottom set gillnet, multiple handline, drift filter net, beach seine, simple handline, surface st gillnet, drift gillnet, and ring net was encoded in an Excel spreadsheet. The length frequency distribution was analyzed by gear type to determine which type of fishing gear caught the species before length at maturity (Lm). The generated L_m value in this study was used as a reference in determining the percentage of juvenile and mature *T. lepturus* caught by various fishing gears.

2.3.6. Population parameters

The Von Bertalanffy Growth Function (VBGF) (Von Bertalanffy, 1934) was estimated using the ELEFAN I (Electronic Length Frequency Analysis) (Pauly and David, 1981) of the FiSAT Software. Pooling all the length data for all fishing gears in this study, a total of 2,071 unraised length-frequency data for *T. lepturus* were collected from April 2018 to March 2020. Initially, the collected length data were validated to double-check for any outliers in measuring and encoding. Before the length data were processed, these were cleaned, and extreme lengths exceeding 165 cm were not included in the analysis based on established length at the maximum of species (FishBase.org). Lengths below 6 cm were eliminated and no longer included in the processing of population parameters. In the estimation of population parameters, all length frequencies were combined to find the best asymptotic length (L_∞) and growth coefficient (K) to give a better stock assessment result for the stock. The population parameters were computed using the formula:

$$Lt = L\infty\,(1 - e^{-k\,(t - \mathrm{to})})$$

where L_t is the length of fish at age t, e is the base of the Naperian logarithm, t_o is the hypothetical age the fish would attain at length zero. The estimated (L_∞) and K values were used in the estimation of the growth performance index for the species using the equation of Pauly and Munro (1984).

$$\Phi' = 2\log 10\ L\infty + \mathrm{Log}\ 10K$$

Where Phi (Φ') = growth performance index,
L_∞ = Asymptotic length
K= Growth coefficient of the VBGF
The natural mortality (M) of the species was computed using the empirical formula of Pauly (1984).
Log M = 0.654 Log k – 0.28 Log L∞ + 0.463 LogT

The T which is equivalent to 28 °C is the mean annual habitat sea temperature in the fishing ground. The total mortality (Z) was of *T. lepturus* calculated from the length converted catch curve using FiSAT software where fishing mortality (F) was estimated (Pauly, 1984) as:

F = Z-M

where Z is the instantaneous total mortality, M is the instantaneous natural mortality due to predation, aging, and other environmental causes, and F is the instantaneous fishing mortality caused by fishing.

Further, the exploitation rate was computed using the equation:

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

where E is the exploitation ratio.

Using the equation on growth parameters and mortalities, the prediction of recruitment pattern was estimated using the routines found in FiSAT program (Gayanilo and Pauly, 1997).

3. RESULTS

3.1 Sex ratio

A total of 2,597 samples were collected and dissected during the study of which 747 were males (30.1%), 1,069 were females (41.16%), and 781 were juveniles (30.1%). Table 2 shows the sex ratio (female to male) of the monthly population of *T. lepturus.* The males were outnumbered by females during the study period except in the months of May, August, and October to November wherein the female ratio is quite low compared to males. The overall female to male sex ratio is 1.4:1.

Table 2. Sex ratio of female and male *Trichiurus lepturus* in different months during the study.

Months	**Female (N)**	**Male (N)**	**Sex Ratio (F:M)**
April	93	65	1.43:1
May	21	1	0.9
June	32	11	2.9:1
July	85	20	4.25:1
August	109	113	0.96:1
September	56	47	1.2:1
October	144	154	0.96:1
November	52	95	0.55:1
December	61	36	1.7:1
January	193	74	2.7:1
February	149	85	1.8:1
March	74	46	1.7:1
Overall ratio			**1.4:1**

3.2. Seasonality

Figure 2 shows the seasonality of *T. lepturus* based on the volume of samples collected during the study period. A total of 508.304 kilograms were collected, sampled, and dissected from the landed catch of bottom set gillnet, multiple handline, drift filter net, beach seine, simple handline, surface set gillnet, drift gillnet, and ring net.

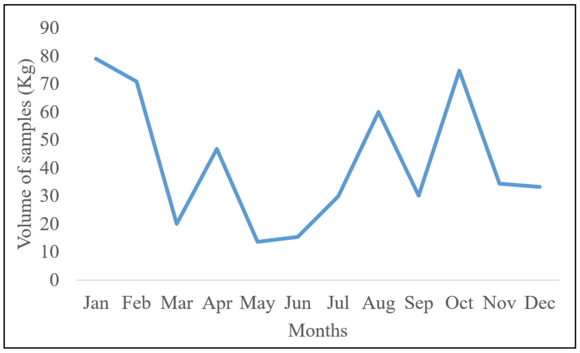

Figure 2. Seasonality of *Trichiurus lepturus* in Babuyan Channel, Philippines.

Notably, a fluctuating trend of *T. lepturus* landings was observed, with the largest volume of samples recorded during the southwest monsoon, particularly from October to February until the onset of the northeast monsoon. However, low samples and landings of *T. lepturus* were observed during the summer, with the lowest volume from May to June.

3.3 Fecundity

A total of 450 individuals in Stages III and IV were studied for fecundity. The smallest length weighs 155 grams, and the biggest length weighs 1,889 grams. The absolute fecundity observed ranges from 4,429 eggs to 453,711 eggs for every ovary weighing 0.129 grams and 36.76 grams, respectively. The computed mean fecundity was 48,576 eggs. Monthly mean GSI values for female *T. lepturus* have a continuous spawning season, with the highest peak in May and the second peak in September–November, and a decline from December until January (Figure 3).

3.4. Gonadosomatic index

Figure 4 shows the gonadal frequency of *T. lepturus* during different months of the study period. The study observed that all five gonadal maturities of the species were present throughout the year, including during the period when juveniles were also present. Most Stage I juveniles were observed from the beginning of the northeast monsoon until the onset of the southwest monsoon. Stage I and II samples were also observed throughout the year, with high numbers occurring from January to April. The monthly mean GSI for *T. lepturus* indicated that ovaries were ripe and ready for spawning from April to November and possibly until January, with peak spawning occurring in May and September to November. About 70.17% of *T. lepturus* caught in May had ripe gonads (Stage IV), and 35.57% and 34.23% in October and November, respectively. Mature samples (Stage III) occurred throughout the period, with the highest proportion represented in September (63.6%). Most of the Stage V samples laid their eggs throughout the year.

3.5. Length at maturit\y

The observed total length of female and male *T. lepturus* ranges from 14.39 cm to 146 cm and 16.2 cm to 152 cm., respectively. The length at first maturity obtained for male *T. lepturus* was 44.61 cm TL and

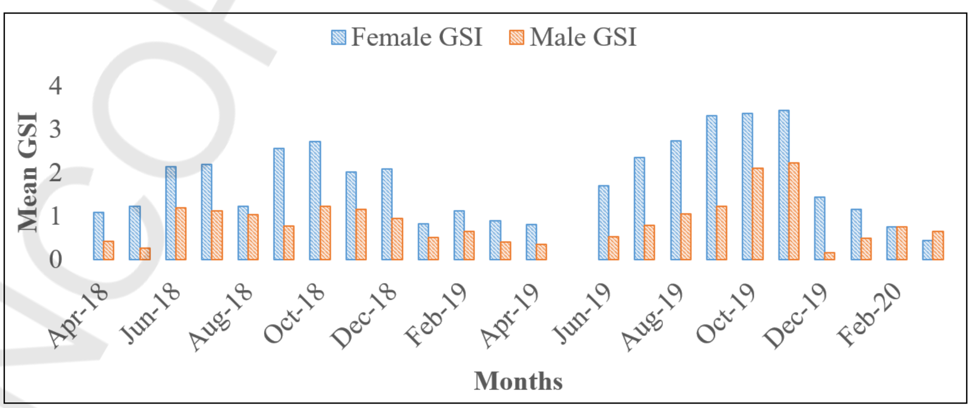

Figure 3. Monthly changes in the mean gonadosomatic index of female and male *Trichiurus lepturus* in Babuyan Channel, Philippines.

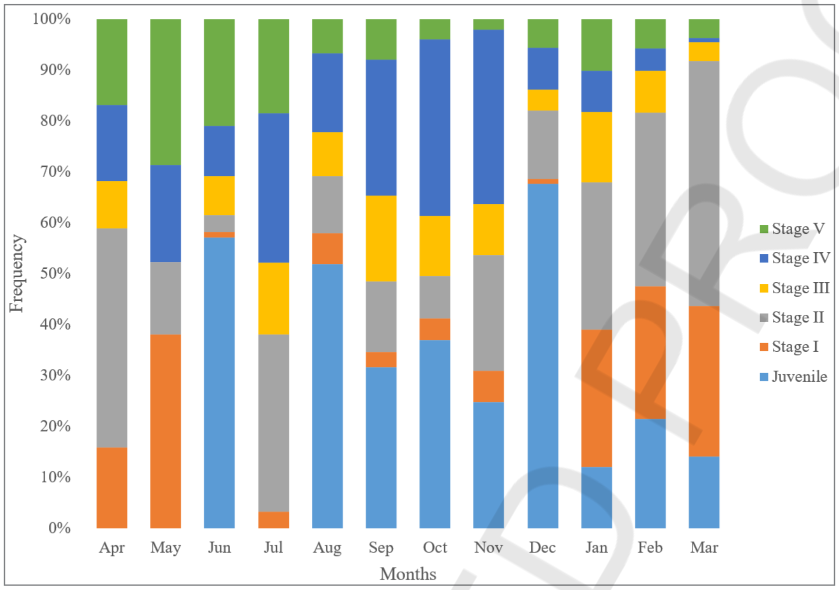

Figure 4. Frequency of occurrence of gonadal stage of maturity of *Trichiurus lepturus* in different months in Babuyan Channel, Philippines.

55.94 cm TL for females. It can be noted that male *T. lepturus* mature first before the female *T. lepturus* (Figure 5).

3.6 Length frequency distribution by gear

Figure 6 shows the length-frequency distribution of *T. lepturus* caught by bottom set gillnet, multiple handline, drift filter net, beach seine, simple handline, surface set gillnet, simple handline, drift gillnet, and ring net during the study period. Pooling the length-frequency from Phase I and Phase II, the observed length for bottom set gillnet ranges from 18.2 cm to 89.8 cm, multiple handline 8.1 cm to 146 cm, drift filter net ranges from 17 cm to 58.5 cm, beach seine ranges from 13.6 cm to 98 cm, simple handline ranges from 66.1 cm to 152 cm, ring net ranges from 16.2 cm to 21.9 cm, surface set gillnet ranges from 53 cm to 80.2 cm, and drift gillnet ranges from 54.6 cm to 119.5 cm. The observed minimum length for all the fishing gears catching *T. lepturus* for the two-year study period was 8.1 cm and the maximum length was 152 cm. The length at maturity (L_m) generated for *T. lepturus* which are 44.61 cm (male) and 55.94 cm (female), were used in determining the percentage of juvenile and matures in the landed catch. Pooling the length frequencies, multiple handlines caught 98.72% mature fish, drift gillnets caught 100% mature fish, surface set gillnets caught 100% mature fish, simple handlines caught 100% mature fish, drift filter nets

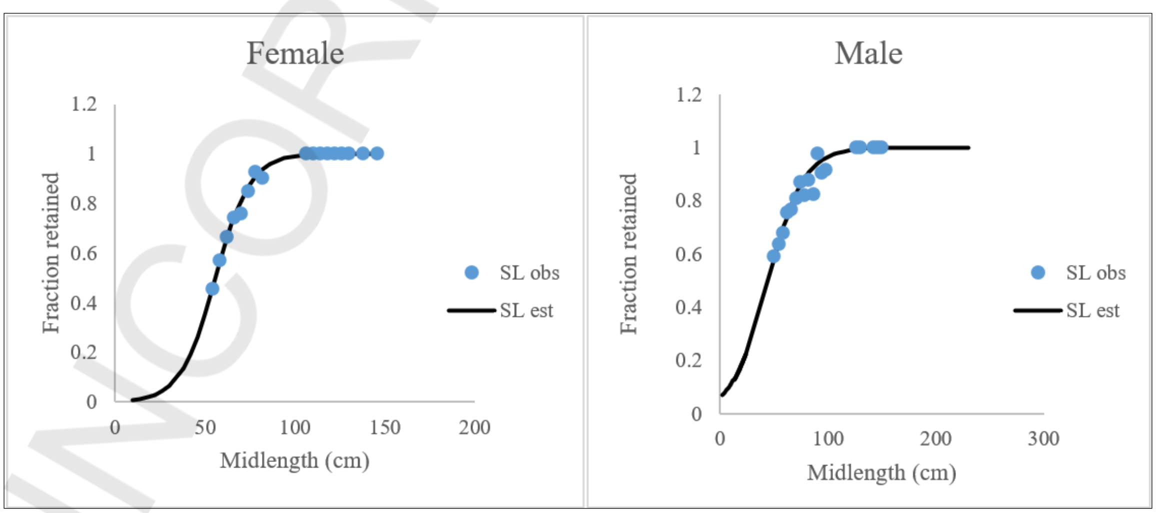

Figure 5. Observed length at first maturity (Lm) for female (a) and male (b) *Trichiurus lepturus* in Babuyan Channel, Philippines.

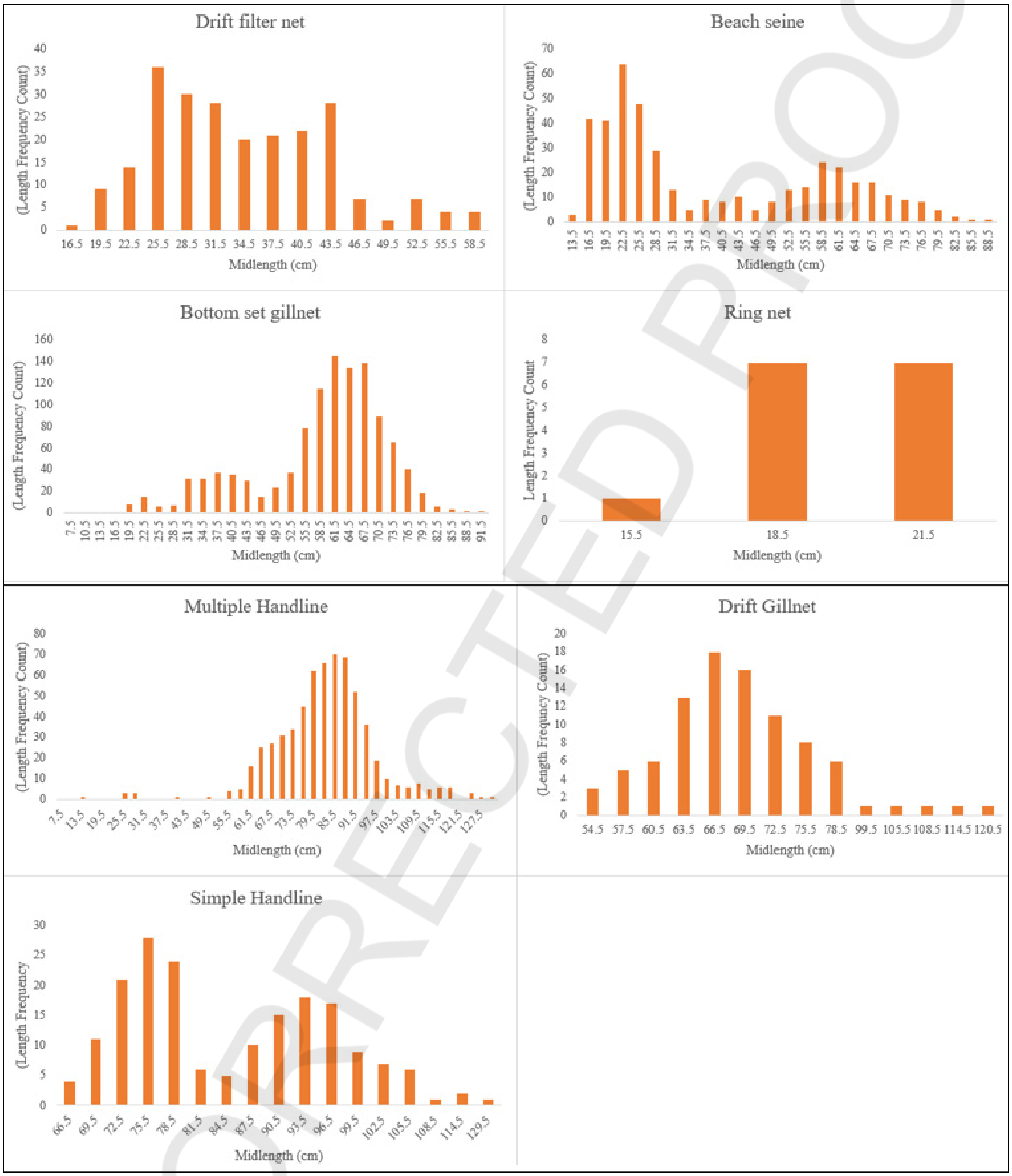

Figure 6. Length frequency distribution of *Trichiurus lepturus* caught by drift filter net, beach seine, bottom set gillnet, ring net, multiple handline, drift gillnet, and simple handline in Babyan Channel Philippines.

caught 10.30% mature fish, beach seines caught 36.30% mature fish, and ring nets caught 100% immature fish.

3.7. Population parameters

Using the FiSAT software in running the length-frequency data, Table 3 presents the parameters used in the estimation of mortality and exploitation ratio. To get the best combination of asymptotic length (L_∞) and growth coefficient (K) value, and a good fit for the modal progression, the data was re-run several times. The 115.50 cm L_∞ and K of 0.33 were obtained using the starting sample length of 30 cm and starting sample of 8. The obtained values were eventually used in the computation of the growth performance index (Φ') which was computed at 3.57.

Table 3. Growth population Parameters for *Trichiurus lepturus* in Babuyan Channel, Philippines.

Parameters	Values obtained
Asymptotic length (L∞)	115.50 cm
Growth coefficient (K)	0.33
Growth performance Index (Φ')	3.57
Starting Length	30
Starting Sample	8

3.7.1 Mortality and Exploitation ratio

Combining all the datasets, Figure 7 shows the analysis of the converted catch curve, which generated a total mortality (Z) estimate of 1.59. The estimated fishing mortality (F) in this study, which is 1, is slightly higher than the estimated natural mortality (M), which is 0.59, and the current exploitation (E) rate of 0.68. Based on the result of the relative yield per recruit (Y'/R) analysis using the selection Ogive, the exploitation status for *T. lepturus* in the fishing ground, which is E=0.68 to the exploitation maximum (E_{max}) of 0.67, implies that *T. lepturus* in Babuyan Channel has already gone beyond the sustainable level of exploitation.

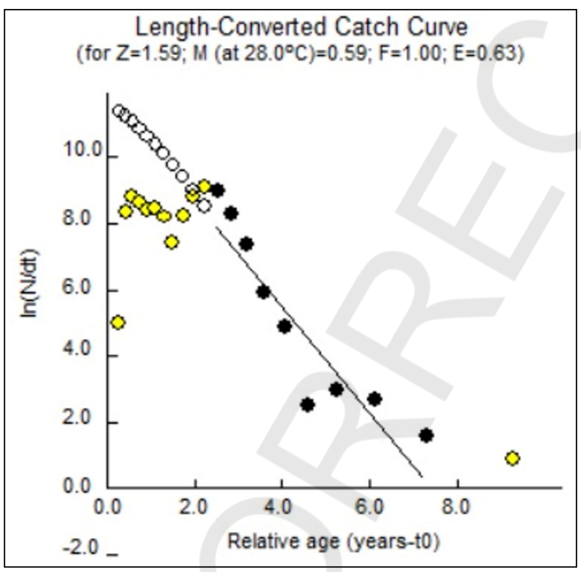

Figure 7. Estimated mortality and exploitation ratio of *Trichiurus lepturus* in Babuyan Channel, Philippines.

3.7.2 Recruitment pattern

T. lepturus has a year-round recruitment pattern, with two peaks of differing strengths. The species major peak of recruitment is observed during the southwest monsoon, specifically from March to June, while the lowest peak occurs during the northeast monsoon, particularly from July to November (Figure 8).

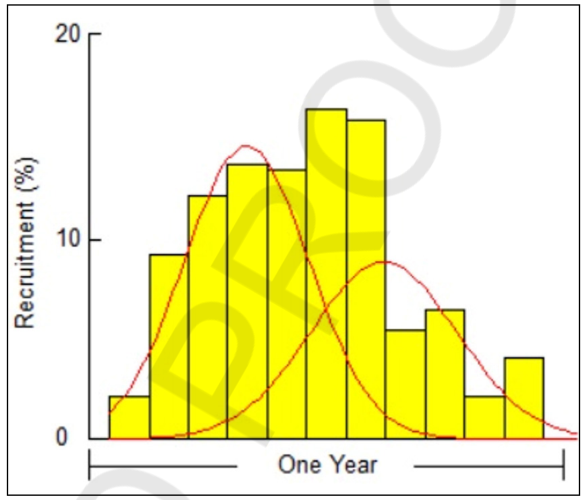

Figure 8. Recruitment pattern of *Trichiurus lepturus* using various gears in Babuyan Channel, Philippines.

4. DISCUSSION

The dominance of females over males, or vice versa, varies depending on the environment. According to Rueben et al. (1997), the reason for the dominance of females over males in this study could be due to differential fishing. This could be the result of changes in the multiple migration patterns of sexes to and from the fishing grounds. It is also possible that spent males may have left the spawning grounds before the females, or it could be because only a few males can fertilize numerous eggs considering that the species are multiple spawners (Amador and Aggrey-Fynn, 2020). According to Bryan et al. (2007), the larger proportion of females in the samples could be related to the fishing gear used in catching *T. lepturus.* The authors revealed that *T. lepturus* caught by trawl and measuring under 25 cm are predominantly male, while species caught with lures presented in larger sizes (80 cm) are mainly females. Therefore, it could be inferred that there are more female samples in this study because most of the length frequencies obtained are larger and were caught by fishing gear using bait or lures like handlines, while only a few samples were obtained from net gear. Furthermore, the dominance of female *T. lepturus* in this study is consistent with that reported by Bryan et al. (2007), Torres (2014), Al-Nahdi et al. (2009), Kwk and Ni (1999), and Ros and Perez (1978) in the localities of Southeastern Florida, Bora del Rico, Mexico, the Sea Coast of Oman, the South China Sea, and the Coast of Cuba, respectively. As mentioned earlier from various studies, including James et al. (1986), Gosh et al. (2014), Al-Nahdi et al. (2009), Kwok and Ni (1999), and Rajesh et al. (2015), the dominance of female over males was also consistently observed throughout the study. Other studies have also reported a significant dominance of female *T. lepturus* over males in most months (James et al., 1983; Guillena 2017). For this species, females often have an advantage, particularly in larger size classes, as observed by Martins and Haimovici (2000).

The fecundity of the species observed in the study varies across different stages and years. This variation could be attributed to the availability of food in the fishing grounds. It is worth noting that Babuyan Channel is a nutrient-rich fishing ground that aids in the spawning and growth of the species owing to the presence of the Kuroshio Current. It can be observed that *T. lepturus* are highly fertile due to their biological characteristics as multiple spawners.

It is worth noting that the seasonality of fishing in the area is strongly influenced by the northeast and southwest monsoon seasons, as well as transition winds that frequently occur in the fishing grounds. Additionally, sudden changes in weather conditions also play a role. Despite the peak of fishing activity in the area occurring during the dry season, peak landings happen during the wet season, while low landings occur during the dry season. This is due to the type of fishing gear used and the seasonal abundance of the species. During the wet season, hand lines are mostly used, while net gear is used during the summer season. However, some *T. lepturus* is caught with net gear during the summer season, but it is mainly composed of other species. It is important to note that *T. lepturus* is only a bycatch of the gears, except for simple handlines and multiple handlines, which are mainly used to catch the species.

It has been observed that T. lepturus has two spawning seasons throughout the year, as indicated by the gonadosomatic index. This finding is consistent with a study conducted by Guillena (2017) which reported that T. lepturus in the Zamboanga del Norte Coast spawns during the months of November and December, as well as in February. However, other studies in different countries have shown that the peak of spawning occurs at different times. For instance, in the South China Sea, the peak of spawning occurs from March to June (Kwok and Ni, 1999), while a long spawning period from April to October was noted by Li (1982) and Lou et al. (1982) in the East China Sea, and November to March in the East Coast of India (Abdussamad et al., 2006). These differences in spawning patterns may be due to the location of the species and the various environmental conditions that affect their spawning period. The prolonged spawning observed in Babuyan Channel may be associated with the availability of planktonic prey. Babuyan Channel is one of the pathways of Kuroshio Current, which carries rich nutrients such as phytoplankton and zooplankton that serve as food for T. lepturus. This may possibly influence the multiple spawning behavior of the species in the fishing ground. In addition, the presence of monsoon season (southwest and northeast) could also contribute to the behavior of the species.

Notably the average GSI values indicate that the highest peak of spawning for Stage IV samples occurs in May, while the second peak occurs between September to November, and gradually decreases until January. Therefore, it can be inferred that the species' major breeding activities in the fishing grounds happen during the southwest monsoon (May) and another spawning occurs during the northeast monsoon (September to November). Amador and Aggrey-Fynn (2020) reported that *T. lepturus* primary breeding, which coincides with the rainy season, could be attributed to a strategy for ensuring the maximum survival of offspring, as the wet season is characterized by high water volume and food availability. The fluctuating GSI pattern of *T. lepturus* in different months could be the result of multiple spawning periods for the species. The findings also agreed with the observations of Amador and Aggrey-Fynn (2020) in Ghanaian waters, who reported that spawning takes place all year round, with the peak in March. Similar observations were also recorded by Kwok and Ni (1999) in the South China Sea, Al-Nahdi et al. (2009) on the Arabian Sea Coast, and Patadiya et al. (2017) in India.

It is interesting to note that the presence of a five-point scale of gonadal maturity for T. lepturus throughout the year is due to the species' flexible reproductive strategy, as revealed in several studies (Thiagrajan et al., 1992; Kwok and Ni, 1999; Martins and Haimovici, 2000). Similar results were also observed by Narasimhan (1994).

Furthermore, the high number of matured or developed gonads in females indicates the dominance of female samples. According to Kwok and Ni (1999), females often spawn more than once in a reproductive season and have synchronous spawning behavior. This could be the reason why mature spawners were observed in all months in varying degrees. Based on the temporal distribution of mature spawners in the fishing grounds, it was presumed that Babuyan Channel is the spawning area of *T. lepturus.*

It has been observed that the length at maturity of *T. lepturus* varies in different environments. The values obtained by Rajesh et al. (2015) in the South

China Sea (55.4) and Narasinham (1994) (51 cm and 52.5 cm) were close to the observed length at maturity. However, lower values were obtained by Reuben et al. (1997) in Visakhapatnam waters where L_m=42.5 cm (50% of the fish attains maturity) and 48 cm (100% are mature). James et al. (1986) found the length to be 43.1 cm, which was close to the values obtained for the male *T. lepturus.* The mean length observed was 64.01 cm, which is quite close to the mean length observed by Menekiyo and Kuwahara (1988) in Japan but far from the mean length values observed by Bellini (1980) in Brazil. The variation in mean length observed could be due to various factors such as availability of food, fishing pressure, and healthy habitat, which may affect the growth of the species. Most of the immature *T. lepturus* are caught by drift filter net, beach seine, bottom set gillnet, and ring net gears. This implies that these net gears contribute to recruitment overfishing as the species is caught before attaining maturity. The wide range of length at maturity of *T. lepturus* in different environments only demonstrates that the species could adapt to different environments and environmental conditions where the species thrives.

The observed values were close to those obtained by Calicdan et al. (2018) in Babuyan Channel and Ingles and Pauly (1984) in Manila Bay. However, the estimated L_∞ in this study is lower than the mean L∞, which is 98 cm (FishBase.org), which could be due to the smaller length frequencies observed.

Based on the available data from earlier studies, the mortality parameters for *T. lepturus* resulted in Z estimates lower than those obtained by various authors, as shown in Table 4. According to Gayanilo and Pauly (1997), the rule of thumb for a stock to be growth dominated is when Z/K = 1, whereas if it is higher than two (2), it is considered fishing mortality dominated. Therefore, the high mortality estimates in this study indicate that the stock is highly fishing mortality dominated.

It was found that fishing morality values were higher than the natural mortality values for the species, indicating that there is a high fishing pressure on the stocks. Due to high fishing pressure, the exploitation ratio of the species is now beyond the sustainable level of 0.5 implying that there is heavy exploitation of the stock in the fishing grounds. Various authors have observed similar values in different fishing grounds, and it can be noted that high fishing mortality and exploitation rate values have been observed for the species in Babuyan Channel, Philippines since 2010 (Table 4).

The recruitment pattern observed in this study was similar to the pattern observed in previous studies in Babuyan Channel and Karnataka, south-west coast of India, where recruitment is influenced by environmental conditions. The differences in exploitation rates across the globe could account for variations in the length at which fish mature, as fish may mature early when the fishing pressure is high or when they are over-exploited. The adaptability of the species is demonstrated by the wide range of sizes at maturity in different environments. Most of the Philippine stocks have two pulses of recruitment generated each year, according to Ingles and Pauly (1984), as cited by Ramos et al. (2018).

5. CONCLUSION AND RECOMMENDATION

The seasonality of *T. lepturus* in fishing grounds is largely influenced by three factors: monsoon seasons (northeast and southwest), the species' seasonal

Table 4. Summary of population parameters of *Trichiurus lepturus* in different environments by various authors.

Authors	Location	Exploitation rate (E)	Natural mortality (M)	Fishing mortality (F)	Total mortality (Z)
Rajesh et al. (2015)	Southwest Coast of India	0.73	0.91	2.41	3.32
Reuben et al. (1997)	Visakhapatnam waters	0.5741	0.8934	1.5236	2.4170
Khan (2006)	Northwest Coast of India	0.775	0.93	1.56 (1993); 3.17 (2001)	2.44 (1993) -4.1 (2000)
Abdussamad et al. (2006)	East Coast of India	0.77	0.98	3.34	4.32
Ghosh et al. (2014)	Northern Arabian Sea	0.7	0.91	2.41	3.32
Calicdan et al. (2018)	Babuyan Channel Philippines	0.74 (2010) 0.8 (2012) 0.9 (2013)	0.62 (2010) 0.79 (2012) 0.45 (2013)	1.81 (2010) 3.23 (2012) 4.22 (2013)	2.43 (2010) 4.02 (2012) 4.67 (2013)
Villarao et al. (in this study)	Babuyan Channel, Philippines	0.63	0.59	1	1.59

abundance, and the type of gear used. It is possible that the Kuroshio Current, which carries nutrients and other planktonic prey, contributes to the growth and spawning of the species. The presence of large numbers of mature spawners throughout the year in the Babuyan Channel fishing ground indicates that it is the spawning area of *T. lepturus*.

Majority of the catch from drift filter, beach seine, and ring net is immature, caught before maturity. Only drift gillnet, simple handline, and multiple handline caught the species after attaining maturity. The lower L_∞ values obtained could be due to the smaller sizes recorded than the observed length at maximum length ranges in FishBase.org. The estimated fishing mortality value is higher than the natural mortality values, indicating that the species is already experiencing high fishing pressure with an exploitation rate higher than 0.5. This means that the level of exploitation is beyond the sustainable level.

For management purposes, environmentally friendly fishing gear such as line gears should be introduced, and destructive and active gear should be banned. Strict implementation of fishery laws in the area and establishment of additional marine protected areas to support species productivity are also recommended.

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AUTHOR CONTRIBUTIONS

Melanie C. Villarao: Conceptualization; Methodology, Analysis, Writing-draft preparation; Leon Antonio Jr: Data encoding and processing Angel B. Encarnacion: Conceptualization, Analysis, Reviewing, Editing, and Supervision.

CONFLICTS OF INTEREST

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

ETHICS STATEMENT

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

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