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Biology and population dynamics of bullet tuna (*Auxis rochei*) and frigate tuna (*Auxis thazard*) in Babuyan Channel, Philippines

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Abstract

Babuyan Channel is one of the major fishing grounds in the counrtry where major fish species such as bullet and frigate tuna are observed throughout the year. The data was collected from April 2012 to April 2014 in Babuyan Channel to generate information vital for policy formulation for the management of tuna species in the fishing ground. Standardized method of the National Stock Assesment Program was used in the collection of samples. Gonadosomatic index and population parameters were processed using the five point scale of maturity and FAO-ICLARM Fisheries Stock Assessment Tools II, respectively. Sex ratio was 1:1.9 for *Auxis rochei* and 1:1.3 *for A. thazard.* Majority of tuna samples were immature females. *A. rochei* attained complete sexual maturity during March and July to September, while January and March to April for *A. thazard.* Both exhibited bimodal recruitment.

Fishing mortality of *A. rochei* (5.64 yr^{-1}, 2.5 yr^{-2}) is higher than natural mortality (1.11 yr^{-1}, 1.2 yr^{-2}) with an exploitation rate of 0.84 yr^{-1} and 0.66 yr^{-2}. For *A. thazard*, fishing mortality (2.55 yr^{-1}, 1.9 yr^{-2}) is higher than natural mortality (1.22 yr^{-1}, 1.17 yr^{-2}) with an exploitation rate of 0.6 yr^{-1} and 0.6 yr^{-2}. These indicates that the species are experiencing high fishing pressure and already exceeded the optimum sustainable level of exploitation. Hence, appropriate management is required for the sustainable management and conservation of tuna in Babuyan Channel.

Key words: *Auxis thazard*, *Auxis rochei*, mortality, recruitment, reproductive biology

INTRODUCTION

Tuna and tuna-like species are economically important and considered as significant source of protein for humans. In Babuyan Channel, Philippines, these species are observed to be abundant and are considered commercially important species, hence the need to ensure its sustainability. The species are widely distributed throughout the world and generally occur in tropical and temperate waters between 45℃ north and south of the equator and are broadly classified into coastal and neritic species (Pillai and Satheeshkumar 2012).

In Babuyan Channel, the poduction of bullet tuna (*Auxis rochei*) and frigate tuna (*Auxis thazard*) is fluctuating through the years. Fishing gears used to catch these species includes round haul seine, ring net, gillnets, multiple handline, and beach seine.

To date little is known about the reproductive biology of these commercially important species. Hence, a study on the reproductive biology of these marine species is vital as basis in the formulation of management and conservation measures for its sustainable production.

METHODOLOGY

Study Site

The study sites were in four coastal municipalities of Cagayan, Philippines − Claveria (18°36'27" North, 121°5'6" East), Aparri (18°21'22" North, 121°38'27" East), Gonzaga (18°16'0" North, 122°0'0" East), and Sta. Ana (18°28'4" North,

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122° 8' 37" East). These municipalities lie open to the Babuyan Channel. It has a coastline length of around 154 km and has a total area of approximately 477,550 hectares.

There were seven pre-determined sampling sites where majority of tuna species caught along the Babuyan Channel are being landed at Taggat in Claveria, Cagayan, Punta and Centro in Aparri Cagayan, Minanga and Batangan in Gonzaga, Cagayan and San Vicente and Palauig in Sta. Ana, Cagayan (Fig. 1).

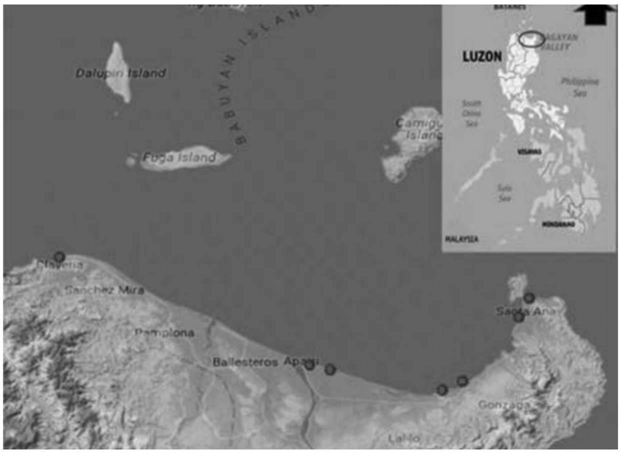

Fig. 1. Map of Babuyan Channel showing the seven tuna observation site.

Data collection

National Stock Assessment Program (NSAP) enumerators assigned in the pre-determined observation sites within Babuyan Channel were tapped to collect additional information on reproductive biology of frigate and bullet tuna at a weekly sampling frequency. This was in addition to the catch and effort data collection through interview with fishers conducted every other two days, regardless of Saturdays, Sundays, and Holidays. A minimum of 30 tuna samples per observation site were collected, sorted, measured and dissected for gonads determination. Total length of the species was measured in centimeter using a fish ruler and corresponding total body weight was recorded in grams using an electronic weighing balance of 0.1 grams accuracy. After species identification and length measurement, dissection of the samples was done to identify the sex and gonadal maturity using the five point scale of maturation by Ismen (2002). Juveniles collected were also included and recorded. Individual gonads were extracted and identified according to the five point scale of gonadal maturity (Table 1).

Data processing and analysis

All data collected were encoded on specified forms to include information on observation sites, month and date, fishing gear used and time operated, species, individual length, individual weight, sex, gonadal stage, weight of gonad, and the coputation of individual gonadosomatic index.

Sex ratio

The sex ratios by month was expressed as the proportion of females to the total numbers of juvenile and male (Sheng-Ping et al. 2003):

$$Sex\ ratio = \frac{Fn}{n}$$

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

Gonadal frequency pattern

Gonadal frequency pattern was tabulated using the count of juvenile and female per stages. These counts were converted to percentage for the relative frequency distribution per stages.

Gonado-somatic index (GSI)

Gonadosomatic Index (GSI) was calculated using the equation of Ismen (2002):

$$GSI = \left(\frac{GW}{BW}\right)100$$

where GW is the total wet weight of gonad and BW is the total wet body weight.

Length ranges

Comparison of minimum and maximum length ranges of same species caught by the different fishing gear were made to determine the type of fishing gear which is sustainable and those catching small/juvenile size, size prior to first maturity.

Population paramaters

Population parameters were obtined using the Fisheries Stock Assessment Tool (FiSAT II) Software.

Growth

Growth parameters were determined first by estimating L_∞ (asymptotic length) using Powell-Wetherall method (Gayanilo et.al. 1997) based on the equation of Beverton and Holt (1956):

$$Z = k\,((L_\infty - L) / (L - L'))$$

where Z is the total instantaneous mortality, k is the growth coefficient, L is the mean length, L_∞ is the asymptotic length, and L' is the initial length of sample. The estimated value of L_∞ was further processed in ELEFAN I (ELectronic LEngth Frequency ANalysis) (Gayanilo and Pauly 1997) for the verification of the value for L_{oo} and k. Analysis of the estimation of growth parameters and mortality used the von Bertalanffy (1934) growth equation of:

$$L_t = L_\infty\,(1 - e^{-k(t-to)})$$

where Lt is the length of fish at age t, e is base of the Naperian logarithm, to is the hypothetical age the fish would attain at length zero.

Mortality and exploitation rate

Natural mortality was calculated using Pauly' s empirical equation.

$$Z = M + F$$

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. Total mortality was obtained from slope (b) of the descending limb of the catch curved with the sign changed.

Instantaneous natural mortality (M) was estimated using Pauly's (1984) empirical formula of:

$$Log(M)= 0.654*(Log(k)) - 0.28*(Log(L_\infty))+ 0.463*(Log\,(T))$$

where L_∞ and k are the Von Bertalanffy Growth Function (VBGF) growth parameters and T is the annual mean habitat temperature (28°C) taken as the average temperature of the area where samples are taken.
Values obtained for mortality were used in the computation of exploitation rate.

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

where E is the exploitation rate.

Recruitment pattern

Using the equation on growth parameters and mortalities, prediction of recruitment patterns and virtual population analysis could be estimated using the routines found in FISAT programs (Gayanilo et. al. 1997).

Recruitment patterns were obtained by backward projection onto the length axis of a set of length frequency data. The following steps were followed:

a. projection onto the time axis of the frequencies after they have been divided by Δ t, the time needed to grow through the length class, this leads to recruitment patterns with peaks much narrower than when untransformed length frequency data were used,
b. summation for each month (and irrespective of year) of the

adjusted frequencies projected onto each month,

c. subtraction (from each monthly sum) of the lowest monthly sum to obtain zero value where apparent recruitment is lowest, and
d. output of monthly relative recruitment, in percent of annual recruitment.

Probabilities of capture and VPA

Probabilities of capture involves the method of extrapolating the right descending left side of a catch curve such that fish that "ought" to have been caught are added to the curve with the ratio of those "expected" numbers to those that are actually caught being used to estimate the probabilities of capture. This can be computed as the ratio of the numbers observed over the numbers available (Ni), using the equation:

$$P_i = \ln(N_i / \Delta t) / \ln(N_{ai} / \Delta t)$$

where P_i refers to the points for probabilities of capture, N_i is the numbers of observed catch or the population size, and N_{ai} is the numbers of available catch, and Δ t is the change in time.

Virtual Population Analysis was used to estimate the catch, to draw inference or a quantity that cannot be readily estimated: the population that produces such catches which follow the equation:

$$C_i = N_{i+1} * (F_i/Z_i) * (e^{Zi-1})$$

where C_i is the catch from a population during a unit time period (i), Ni is the population size at the beginning of the time period, F_i/Z_i is the fraction of death caused by fishing, and e Z^{i-1} is the fraction of total deaths.

Beverton and Holt's (1957) relative yield per recruit and biomass per recruit models was used in the prediction of yield and standing biomass. Relative yield per recruit model is suitable for assessing the effect of mesh size regulations and it belongs to a length-based model as parameters. Biomass per recruit on the other hand expresses the annual average biomass of survivors as a function of fishing mortality, and that average biomass is related to the catch per unit of effort. The said prediction models use the equations:

$$(Y/R)' = E*U^{M/k} (1\text{-}3U/1 + m + 3U^2/1 + 2m - U^3/1 + 3m)$$
$$(B/R) = \exp^{(-M*(Tc-Tr))} *W_\infty * (1/Z - 3S/Z + k + 3S^2/Z + 2k - S^3/Z + 3k)$$

where m = k/Z, U = 1- L_c/L_∞, E = F/Z, T_c = age at first catch, T_r = age at first recruit, and W = weight at infinity.

RESULTS AND DISCUSSION

A total of 1, 636 tuna samples (553 frigate and 1083 bullet) was collected from April 2012 to April, 2014.

Sex ratio

Sex ratio revealed that there were more females (58%) than males (30%) in the collected bulltet tuna samples obtainining a sex ratio of 1:1.9 (F/M). One hundred twenty-six samples which constitute 12% of the total population were indentified to be juveniles. Different sex ratios of bullet tunas were obtained from different studies from various locations like in the Indo Pacific Region which is 1:1.2 (Yesaki and Arce 1991), and 1:1.2 in Mangalore waters (Muthiah 1986).

Conversely, from the 553 frigate tuna samples caught during the study, 42% of these were males, 41% were females, and 17% were juveniles showing a sex ratio of 1:1.03 (F/M). Juveniles (18 cm TL) were also indentified in all the sampling sites. Muthiah (1986) obtained sex ratio of 1: 1. 6 for *A. thazard*, 1.14:1 for Bachok (2004) in East Coast of Peninsular Malaysia.

In the study of Shao et al. (2016), size related variations in sex ratio of southern bluefin (*Thunnus maccoyii*) tuna were observed with female bias of less than 170 cm FL and male bias for greater than 170 cm FL. The authors furthered that the trend of increasing proportion of males with size above 170 cm FL is likely to be related to sexual dimorphisms in growth rates as male length at age is greater than that for females after age of 10 years. The male dominances of *T. maccoyii* maybe due to the observed sexual dimorphism Farley et al. (2014) in growth as suggested for albacore tuna in the Pacific Ocean (Farley et al. 2013). Similarly, Chen et al. (2006) proved that male Kawakawa (*Euthynnus affinis*) greatly outnumbered females in large adult fish measuring > 100 cm FL. According to Farley et al. (2014) the reason for the predominance of females in length classes < 170 cm is less clear but may reflect sexual differences in vulnerability or availability on the spawning ground. Females may be more catchable than males if they are more likely to be feeding or actively spawning (i.e., spending a greater proportion of time near the surface targeted by the shallow-setting gears). However, Chen et al. (2006) reported that female and male ratio was estimated at 1:1 for *Thunnus orientalis*. This only indicates that the sex ratio of tuna species stock varied largely in different areas.

Gonado-somatic index

Gonadosomatic index is the calculation of the gonad mass as a proportion of the total body mass. The mean gonado-somatic index of male and female *A. rochei* was calculated from the months of April 2012 to April 2014.

Mean GSI values of both males and females reached a peak during the month of March in both years of observation (Fig. 2) and values increased remarkably during the third quarter (July, August, September) on both phases. This could only mean that the specimens collected perhaps reached its complete sexual maturity starting the months of March and July to September. The highest mean GSI value observed for males was 2.8 yr^{-1} and 3.7 for yr^{-2} while the highest GSI mean for female was 3.23 yr^{-1} and 3.52 yr^{-2}.

The result of independent samples t-test indicated that there were no significant differences ($p > 0.05$) in mean GSI between males and females. The spawning season of *A. rochei* varies from region to region, and indirect evidence suggested that the season extends at least from June through July off Taiwan Island and from May through August off southern Japan as indicated by gonad indexes and larval counts (FAO 2017). According to Muthiah (1985), the reproductive period of *A. rochei* in Mangalore occurs in September while spawning season of bullet tuna in the Batangas Bay, occur during March, June and July, and extends from November to December (Arce 1987).

On the contrary, mean GSI values for males and females *A. thazard* showed a difference in GSI pattern (Fig. 3). It is however notable that both sexes have the highest GSI values in the month of January having a mean GSI value of 44.4 yr^{-1} and 4.9 yr^{-2} in female species and 4.4 yr^{-1} and 4.5 yr^{-2} in male species. Another peak was observed in the the month of March to April. No GSI values was obtained during the month of the December since there were no collected *A. thazard* during that period. Studies on maturity-stage and GSI of frigate tuna have not been conclusive due to varied results. The spawning period of this species in the southern Indian Ocean, has been reported to occur from August to April, and from January to April in north of the equator at sea surface temperatures of 24°C or higher (Klawe 1963). Based from the data generated, it has been observed that frigate tuna attained sexual maturity from January for both sexes, and extends from March to April for females. The results of independent samples t-test indicated there were no significant differences ($p > 0.05$) in mean GSI between males and females.

Generally, the GSI values obtained in this study showed that females had higher mean GSI values than male. This perhaps could be associated with heavier weight of ovaries which are conained in the eggs of the females.

Gonadal frequency pattern

Using the stages of gonad maturation, gonadal frequency

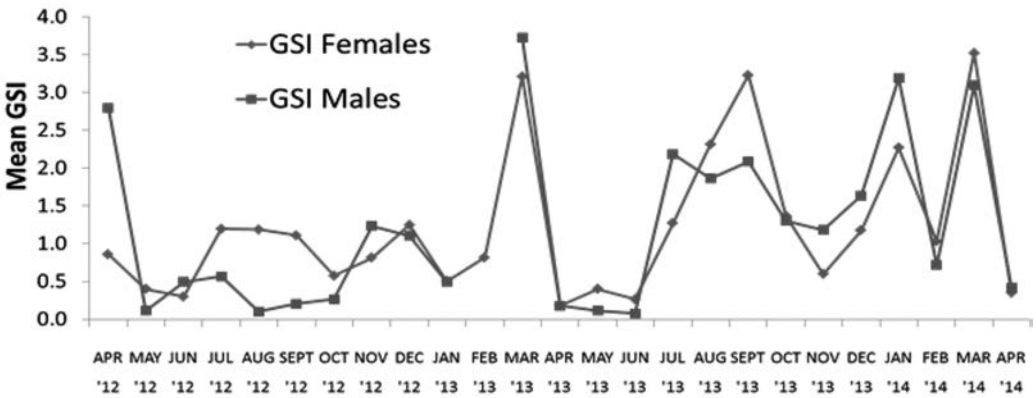

Fig. 2. Mean Gonadosomatic index of *Auxis rochei*, April 2012-April 2014.

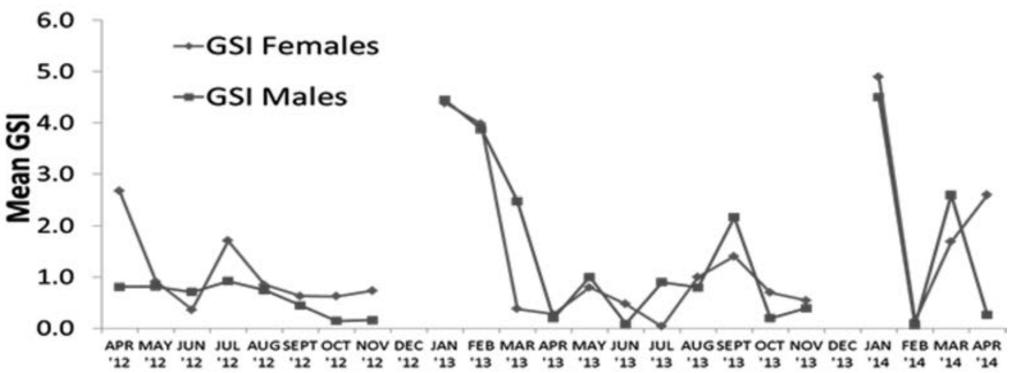

Fig. 3. Mean Gonadosomatic index of *Auxis thazard*, April 2012-April 2014.

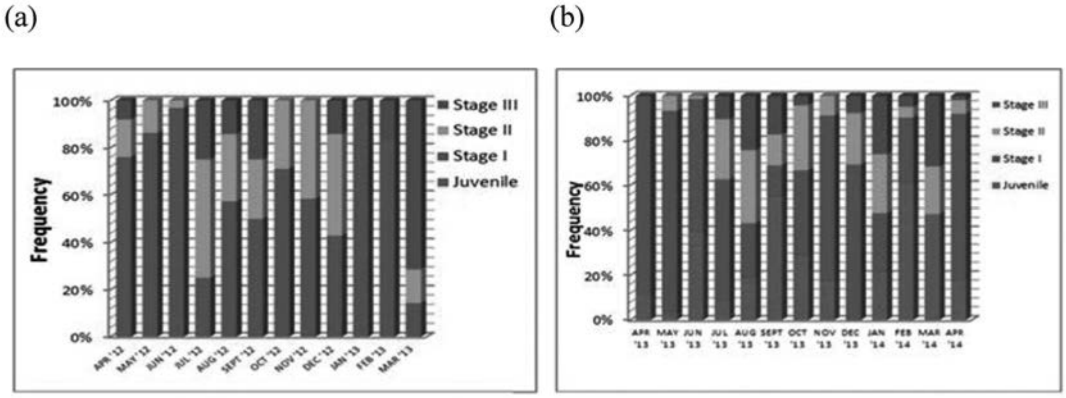

Fig. 4. Percentage occurrence of different maturity stages of *Auxis rochei*. (a) April 2012-March 2013, (b) April 2013-April 2014.

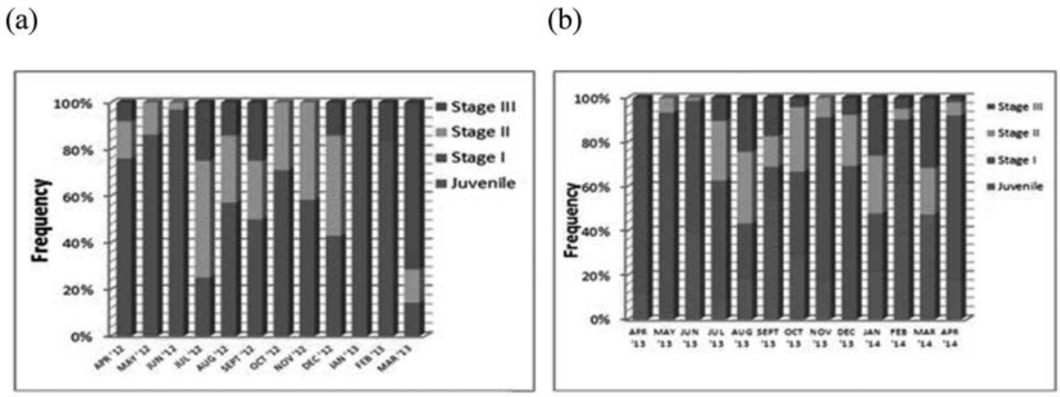

Fig. 5. Percentage occurrence of different maturity stages of *Auxis thazard*. (a) April 2012-March 2013, (b) April 2013-April 2014.

pattern was determined. Different stages of gonadal maturity for female *A. rochei* were recorded in all months (Fig. 4).

Occurrence of highest number of matured females were observed during March and in July to September for both years of observation. Juveniles accounted (16.6%), immature/virgin (Stage I) accounted 60. 4% of the population, developing females (Stage II) 14.7% and mature (Stage III) only has 8.3%.

On the other hand, *A. thazard* showed a different pattern for gonadal frequency (Fig.5). Matured females were observed to occur during the months of January for both sexes and extends from March to April for females in both years of observation. As observed, there were 29.1% juveniles, 40.6% immature (Stage I), 15.6% developing (Stage II), and 14.7% mature (Stage III). No samples were collected on the months of December on both years of the study and it was noted that in January most of the collected samples were already mature. The high frequency of maturity in December under phase I could be the result of high frequency of developing females in October and November while it is notable that juvenile and immature samples were recorded in Novemeber under phase II of the study but a high frequency of mature individuals in January. The high number of mature individuals in January under phase I and II of the study could come from other populations of *A. thazard* that migrated inshore and offshore.

Generally, the high number of juveniles and mature individuals in the study could be an indication that the spawning area for tuna species appears to be in other area and not in Babuyan Channel. It can also be inferred that both species already attain their complete sexual maturity as the species migrated in the Babuyan Channel area.

Population parameters

Length frequency data of *Auxis rochei* and *Auxis thazard* collected from April 2012 to April 2014 were subjected to FAO-ICLARM Stock Assessmet Tool Software for the analysis of natural mortality, fishing mortlity, exploitation rate, and probability of capture.

Growth

K scan for *A. rochei* showed a nearly similar growth (K) for both years of the study which is 0.58 yr^{-1} and 0.60 yr^{-2} with a minimum total length of 15 cm and 43 cm, respectively. Lenght infinity (L_{00}) obtained for the species in Babuyan Channel was 37.28 cm yr^{-1} and 45.68 cm yr^{-2}. The K value obtained by Pillai and Ganga (1985) in the West Coast of India was 1 per year and James et al. (1992) obtained a growth of 0.64 per year in Indian waters.

On the contrary, *A. thazard* obtained a growth (K) of 0.60 yr^{-1} and 0.72 yr^{-2} with a recorded minimum total length of 16 cm and a maximum total length of 55 cm. The computed L_{00} *A. thazard* in the fishing ground was 40.95 cm yr^{-1} − 46.20 cm yr^{-2}. The size ranges obtained was nearly similar to the observation of Aragon et al. (2010) in Babuyan Channel in 1999-2010. In the study of Ingles and Pauly (1985) in Bohol Sea, the K value of *A. thazard* was 0.73 which is nearly similar to the values obtained. However, in the study of Ghosh et al. (2012) in Indian waters, they obtained a higher K value which is 1.2 per year. The differences of K values obtained in different environements could be attributed to geographical isolations of the species. Growth of species could varies from region to region. The high value of K obtained in this study only indicates that the two species are fast growing species. According to Juan-Jordai et al., (2013), *A. thazard* is one of the three pelagic tuna species that is fast growing (K = > 0.7 yr^{-1}) given the maximum body size.

Mortality and exploitation rate

Converted catch curve from the Von Bertalanffy Growth Function, *A. rochei* has a natural mortality (M) value of 1.11 yr^{-1} and 1.2 yr^{-2} and a fishing mortality (F) value of 5.64 yr^{-1} and 2.5 yr^{-2} (Table 2). As observed, the fishing mortality values were higher than the natural mortality values for both years. This only indicates that *A. rochei* is experiencing high fishing pressure. The exploitation rate (E) which is 0.84 yr^{-1} and 0.66 yr^{-2} only means that it has already exceeded the 0.3 to 0.5 sustainable level of exploitation set by Gulland (1969). Aragon et al. (2010) obtained an exploitation value of 0.46 - 0.59 in Babuyan Channel in 1999-2010. It was noted that the E value of *A. rochei* in Babuyan Channel is increasing.

On the other hand, natural mortality values (M) for *A. thazard* was 1.22 yr^{-1} and 1.17 yr^{-2} and a fishing mortality values (F) of 2.55 yr^{-1} and 1.9 yr^{-2}. It was noted that fishing mortality values was higher than natural mortality values which is an indication that the species is also experiencing a high fishing pressure. The observed exploitation rate (E) was 0.6 both for yr^{-1} and yr^{-2} which only means that the 0.3 to 0.5 sustainabe level of exploitation for the species is already exceeded.

As perceived, the values of mortality and exploitation rate was reduced from yr^{-1} to yr^{-2} for both species. Though there was a decrease in fishing mortality and exploitation value, the sustainable optimum level of exploitation is still beyond 0.3 to 0.5. The slight decrease of mortality value could be attributed to environmental factors like predation while the decrease in the firshing mortality value could be attributed from lesser to no fishing trips due to environmental (typhoons) and economic (high cost of fuel) factors.

Generally, both the species (*A. rochei* and *A. thazard*) were already experiencing high fishing pressure and already beyond the sustainable level of exploitation. It was noted that both species occurs in the artisanal fishery with frequent fishing due to their cheap source of animal protein for the rural poor along Babuyan Channel and one of the top most commercially important species in the fishing ground. This is also one of target species of some municipal fishermen. These activities contribute to higher fishing pressure.

Table 2. Estimated mortality and exploitation rate of *Auxis rochei* and *Auxis thazard* in Babuyan Channel, Philippines.

Population parameters	*Auxis rochei*		*Auxis thazard*	
	y^{r-1}	yr^{-2}	y^{r-1}	yr^{-2}
Natural Mortality (M)	1.11	1.2	1.22	1.17
Fishing Mortality (F)	5.64	2.5	2.55	1.9
Exploitation rate (E)	0.84	0.66	0.6	0.6

Recruitment pattern

Recruitment is the process by which young fish enter the exploited area and become liable to contact with fishing gear. In the population of *A. rochei*, there were two recruitment peaks in a year (bimodal recruitment) and the peaks overlapped in time to give a continuous year-round pattern (Fig. 6). The highest peak recruitment occured during the of rainy season (October to December) and the lowest peak occured during rainy summer season (February to April) on both years of observation. Two recruitment peaks were also observed in Danao, Philippines by Yesaki and Arce (1993) which particulaly occur during first and third quarters.

Same is through with the *A. thazard*, it exhibited a bimodal pattern of recruitment with 2 major peaks throughout the year (Fig. 7). On yr^{-1} of the study, the peak recruitment occured during rainy season (October to December) and the lowest peak was noted to occur during the onset of rainy season just after the summer season. However, on yr^{-2} of the study there is a sudden change of recruitment peak for the species. As noted, major peak occured during summer season

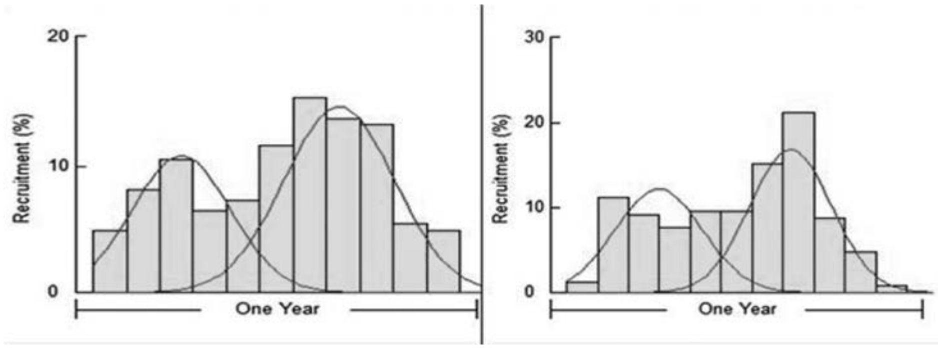

Fig. 6. Recruitment pattern of *Auxis rochei* in Babuyan Channel, Phase 1 (April 2012-March 2013) and Phase II (April 2013-March 2014).

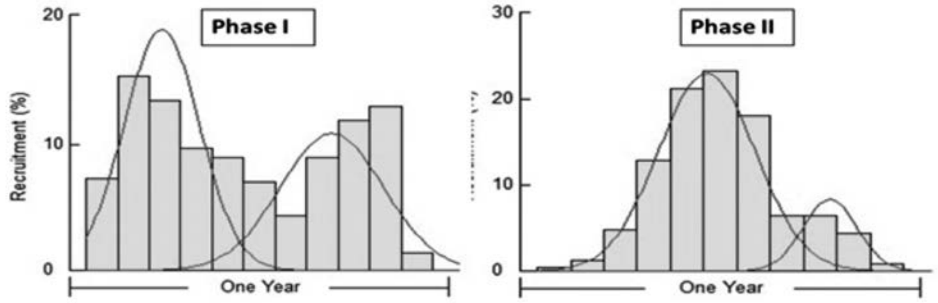

Fig. 7. Recruitment pattern of *Auxis thazard* in Babuyan Channel, Phase I (April 2012-March 2013) and Phase II (April 2013-March 2014).

(May to July) and the minor peak occured during the rainy season (October to December). The observed sudden shift in the recruitment of *A. thazard* from yr^{-1} to yr^{-2} could likely the influence of several environmental factors (i. e. ocean currents, changes in H_2O temperature, moonsoon winds and food availability) that affect the recruitment of the species. High peak of recruitment was observed for *A. rochei* and *A. thazard* during rainy season which could be further attributed to northeast moonsoon that brings lot of precipitation in Babuyan Channel which eventually cools the temperature of the area. There is also a possibility that high recruitment during rainy season is due to availability of nutrients during this period.

The study of Mamauag et al. (2001) in the Philippines presented that most of the regions observed to demonstrate peak occurences of juveniles during northeast moonsoon are generally found along the eastern coast of the archipelago are located on the windward side of the landmass while regions with peak occurences of juveniles during southwest moonsoon are located on the windward side of the prevailing winds. It was further reported by Pauly and Navaluna (1983), Ingles and Pauly (1984), and Corpuz et al. (1985) that there is twin recruitment patterns for Philippine marine fishes. The spawning and recruitment processes were related to the two monsoon seasons of the Philippines (Pauly and Navaluna 1983). The result of the study conforms to the study of Mamauag et al. (2001) where peak in abundance of fish occured generally on northeast monsoon (October to March) in areas like Babuyan Channel (Cagayan Valley Region) Lamon Bay (Quezon: Region IV), south of Sibuyan Sea Northern Panay: Region VI), and Iligan Bay (Lanao del Norte: Region X). During the southwest monsoon (April to September) the abundance of juveniles peaked in ares such as Lingayen Gulf, (Pangasinan: Region I), off the western coast of Luzon including Manila Bay (Region III) Ragay Gulf (Camarines Provices: Region V) and off thewestern coast of summer (Region 08).

Probability of capture and VPA

Probability of capture analysis using the average running technique, the estimated L_{25} (length at which 25% of the fish entering the gear are retained) of *Auxis rochei* was 25.02-26.12 cm. The estimated L_{50} (length at which 50% of the fish entering the gear are retained) ranged from 26.34-27.17 cm and estimted L_{75} (length at which 75% of the fish entering the gear are retained) was 27.39-28.07 cm.

On the other hand, the computed estimated length at first capture L_{25} for *Auxis thazard* was 25.25-29.84 cm, L_{50} of 26.56-30.69 cm and L_{75} of 27.51-31.56 cm.

Based on the lenght at maturity (L_m) of the species (Froose and Pauly 2000) in the Philippines which is 21.70-

38.6 cm for *A. rochei* and 21.50-38.60 cm for *A. thazard*, the values in study only indicates that the species were already matured.

The Virtual Population Analysis indicated that main loss in the stock due to natural causes up to 18.5 cm and 16.5 cm for *Auxis rochei* and *Auxis thazard*, respectively. After this size the species became more vulnerable to gear and the fishing mortality increased and eventually outnumbered the natural losess from size 23 cm onwards for *Auxis rochei* and 24.5 cm onwards for *Auxis thazard*. The maximum fishing mortality for *A. rochei* was recorded at size of 28.5 cm for both yr^{-1} and yr^{2} while 38 cm yr^{-1} and 31 cm yr^{-2} for *A. thazard*.

SUMMARY AND CONCLUSION

A total of 1,636 samples of frigate (553) and bullet (1083) tunas have been collected in seven established tuna sites in Babuyan Channel from April 2012 to April 2014 to determine the reproductive biology needed for resource management. Sex ratio was 1:1.9 (F/M) and 1:1.03 (F/M) for *Auxis rochei* and *Auxis thazard*, resectively. Gonadal frequency shows that 8.3% of *A. rochei* were matured, and based from the GSI pattern, male and female bullet tuna attain their complete sexual maturity during March and July to September. A different GSI pattern was also observed in frigate tuna in which matured male and female (accounted 14.7 %) occured during January and extends from March to April for females. Majority of the sampleswere immature which indicates that the spawning area for tuna species appears to be in another area and not in Babuyan Channel.

The growth parameters, length infinity (L_∞) and growth (K) were 37.28-45.68 and 0.58-0.60 (*A. rochei*); 40.95-46.20 and 0.60-0.72 (*A. thazard*), respectively. Natural mortality values obtained for *A. rochei* was 1.11 yr^{-1} and 1.2 yr^{-2} and a fishing mortality values of 5.64 yr^{-1} and 2.5 yr^{-2} with an estimated exploitation rate of 0.84 yr^{-1} and 0.66 yr^{-2}. Similarly, *A. thazard* has a natural mortality of 1.22 yr^{-1} and 1.17 yr^{-2} and a fishing mortality of 2.55 yr^{-1} and 1.9 yr^{-2} with an estimated exploitation rate of 0.6 both for yr^{-1} and yr^{-2} of the study. The fishing mortality values obtained for both species is higher than that of natural mortality. It can be inferred that the species is experiencing high fishing pressure and already beyond the sustainable level of exploitation of 0.3 to 0.5 as reflected by the exploitation rate values obtained.

Recruitment pattern for both species is a coninous process exhibiting a bimodal pattern of recruitment which only means that the species spawns twice a year.

Probability of capture shows that at size 26.34-27.17 cm (*A. rochei*) and 26.56-30.69 cm (*A. thazard*), 50% of the fish of that sizes entering the gear are retained.

The VPA indicated that main loss in the stock up to 18.5 cm for bullet tuna and 16.5 cm for frigate tuna was due to natural causes. Fishes became more vulnerable to gear after these sizes and mortality due to fishing increased and eventually out numbered the natural losses from 23 cm onwards for bullet tuna and 24.5 cm in frigate tuna.

RECOMMENDATIONS

The obtained exploitation rate suggested that the two species of tuna were experiencing intensive fishing pressure, hence, fishing effort applied should be regulated to uphold its sustainability.

Additionally, catch regulation on fishing of bullet tuna and frigate tuna in the Babuyan Channel will provide and ensure these species attainment of complete maturity. This could be done through formulation of municipal fishery ordinance minimizing the incidence of fishing operation particularly on these species during peak seasons.

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