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INDONESIAN FISHERIES RESEARCH JOURNAL

Volume 25 Nomor 2 December 2019

p-ISSN: 0853-8980

e-ISSN: 2502-6569

Accreditation Number RISTEKDIKTI: 21/E/KPT/2018

SOME BIOLOGICAL STOCK INDICATORS OF BULLET TUNA (*Auxis rochei*, Risso 1810) FROM BANDA SEA AND ITS ADJACENT WATERS

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Received; July 27-2019 Received in revised from October 08-2019; Accepted October 11-2019

ABSTRACT

Bullet tuna is considered as one of the important species for tuna purse seine fisheries in Indonesia, especially in archipelagic waters. However, little is known about its biological characteristics which proven to be pivotal in stock assessment. The purpose of this research was to determine some of the biological stock indicators for bullet tuna (*Auxis rochei*) from Banda Sea and its adjacent waters. The study was conducted from February to November 2016. The length of the bullet tuna caught were in between 18.5-32.7 cmFL (mode=24 cmFL). Growth pattern was isometric with b=3.01 and R^2=0.84 Sex ratio was balanced between male and female (1:1). The spawning season allegedly from June to November. The length at 50% mature (L_{50}) was 23.6 cmFL. A good indicator for the fisheries, where at least 75% of the mature fish caught were already spawned. The asymptotic length (L_∞) was 33.63 cmFL, with coefficient of growth (K) around 0.73/year. Natural mortality (M) estimated at 1.87/year, fishing mortality (F) estimated at 2.20/year and total mortality (Z) was 4.07/year. The exploitation level (E) was estimated to be at maximum level (E=0.54/year), for precautionary purpose, the number of efforts should be reduced down to 8% from current effort.

Keywords: Neritic tuna; population dynamics; biological parameters; purse seine tuna fisheries

INTRODUCTION

The management of Banda Sea and its adjacent waters are under Fisheries Management Area of Republic Indonesia (FMA-RI) 714. It is well known for its mega biodiversity and established itself as one of the core fisheries in Indonesia, especially tuna and tuna-like species. Approximately, more than 2,000 fishing vessels, ranged from purse seine, handline, troll line, drifting longline, and pole-and-line are operating in this area, catching more than 17.000 metric ton per year of tuna and tuna-like species (Satrioajie *et al*., 2012). One of which is bullet tuna (*Auxis rochei*) or locally known as *deho* (Amri *et al*., 2016).

Bullet tuna is one of the species from genus Auxis and family Scombridae, known to be the smallest among tuna species in the world (Jasmine *et al*., 2013). Mostly live between epipelagic to mesopelagic waters, widely distributed in the world's oceans from tropical to subtropical waters, and heavily influenced by seasonal variation of coastal temperatures (Uchida, 1981; Collette *et al*., 2001). Although it is considered as highly migratory species but little is known about its distribution (IOTC–WPNT08, 2008).

Research on biological parameters of bullet tuna has been conducted by many scientists worldwide, i.e. western Mediterranean Sea (Macías *et al*., 2005), eastern Mediterranean Sea (Koched *et al*., 2013), and Indian Sea (Jasmine *et al*., 2013). On the other hand, in Indonesia, the study mostly concentrated around western Indonesian waters, such as south Java, Bali, and Nusa Tenggara waters (Febrianty *et al*., 2014); (Setyadji *et al*., 2013); (Widodo *et al*., 2014), western Sumatra (Noegroho & Chodrijah, 2015); (Noegroho *et al*., 2013); (Salmarika & Wisudo., 2019). Nevertheless, study on eastern part of Indonesia is required in order to get a full picture from this fishery.

By far, contrasting with intensive studies on this species in western part of Indonesia, little has been done in the eastern area. Considering bullet tuna plays an important role as a target species for many gears in FMA 714 (e.g. drifting gillnet, hand line, troll line, liftnet and purse seine) (Amri *et al.,* 2016), it is quite problematic in terms of getting a full picture of this species as a whole. Moreover, misidentification and often lumped together with frigate tuna (Amri *et al.,* 2016), with only certain ports managed to distinguish between the two species have become another major

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DOI: http://dx.doi.org/10.15578/ifrj.25.2.2019.103-112

issue. Therefore, this study is expected to have a contributing factor in little tuna management, especially bullet tuna in these waters.

This study specifically aimed for distributing possibly new information related to biological stock indicators of bullet tuna from Banda Sea (FMA 714) and its adjacent waters. The result of the study expected to be a consideration in term of stock assessment or any management measures in the future, especially in the selective area.

MATERIALS AND METHODS

There were two types of data used in this study. The first was catch and effort data, acquired from port authorities, such as: Kendari Oceanic Fishing Port (PPS Kendari) and Sodohoa-Kendari Fishing Port (PPI Sodohoa-Kendari) from 2013-2016 (4 years) (Figure 1). The later was biological data, such as: length, weight, and gonad, were obtained during periodical surveys (January, February, May, June, July, and November 2016) on purse seine fisheries.

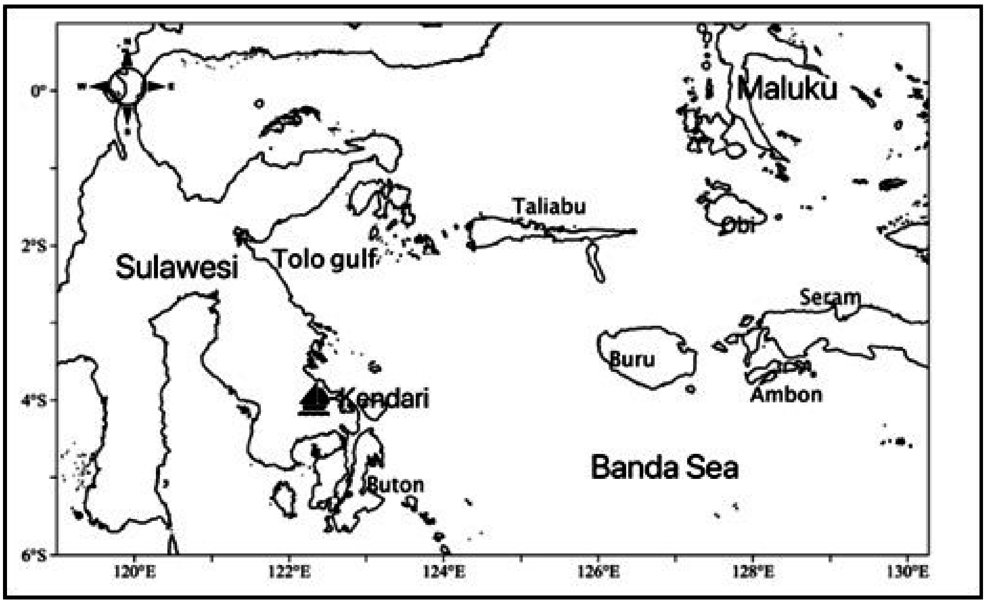

Figure 1. Map of study area, projecting Banda Sea and landing site in Kendari bay.

Sex ratio was determined for all fish pooled and for each area by month. Comparisons if sex ratio departed from the expected 1:1 rate were determined by Chi-square test at 95% confidence level. The length-weight relationship was calculated by the least square method for combined sexes using the equation, as follows:

$$W = aL^b \quad \text{...(1)}$$

To test b=3 or b$\neq$3 we used Student's t-test under the R stats package 2.3.2, testing the hypothesis H_0: β =3 (isometric) dan H_1: $\beta \neq 3$ (alometric). The t-statistic was calculated as $t = (b-3)/S_b$, where S_b =standard error of '*b*'; $S_b = \sqrt{\left(\frac{1}{(n-2)}\right) * \left[\left(\frac{b s_y}{s_x}\right) - b^2\right]}$. S_y and S_x are the standard deviations of *y* and *x* respectively. The significance of t-value was calculated at 5% level of significance with (n-2) degrees of freedom (Sawant *et al*., 2013).

The size at first maturity defined here as the size (using cumulative frequency distribution) at which 50% of the individuals in the sample size are mature (stage III and IV) and was determined using the logistic model, where *p* is proportion of mature females at length (*L*), *a* and *b* are parameters to be estimated. The calculation was performed using sizeMat package inside R version 3.5.3 (Torrejon-Magallanes, 2018).

$$\log it(p) = a + bL \quad \text{..(2)}$$

Length at which 50% of females are mature are defined as

$$Lm_{50} = -a/b \quad \text{..(3)}$$

Population parameters such as: asymptotic length (*L*) and growth coefficient (*K*) were estimated using *Electronic Length Frequency Analysis* (ELEFAN), under FISAT II software (Gayanilo *et al*., 2005). Natural mortality was estimated based on empirical equation from Pauly (1983) as follows:

$$\log M = -0{,}0066 - 0{,}279 \log L_\infty + 0{,}6543 \log K + 0{,}4634 \log T \quad \text{.........(4)}$$

Total mortality (*Z*) was estimated based on length converted catch curve (Pauly, 1983), while fishing mortality was derived from simply subtract Z with M.

F=Z-M ....(5)

Exploitation rate (*E*) was assumed as fishing mortality divided by total mortality, following equation from (Pauly, 1983):

E=F/Z=F/ (F+M) ....(6)

Recruitment pattern was estimated using ELEFAN by inputting L, K, and t_0 if available (Gayanilo *et al*., 2005). Recruitment pattern intended to monitor any new adding stock into the population of a particular species (i.e. bullet tuna) on an annual basis, based on its length frequency distribution.

RESULT AND DISCUSSION
Result

Catch Dynamics

Kendari Ocean Fishing Port (PPS. Kendari), located in the Southeast Sulawesi province is regarded as one of the biggest landing sites in western part of Banda Sea (FMA 714). Latest statistical data from local fishing authority suggested that around 82% of total catch of purse seiners based in south east Sulawesi province are landed there, the rest are in Wameo-Baubau (10%) and Sodohoa (8%), respectively. Neritic tuna caught as by-catch from tuna purse seiners is dominant catch, contributed 44 % from total catch of purse seiners. Catch composition of small tunas is dominated by bullet tuna (50%), followed by frigate tuna (*Auxis thazard*) and kawa kawa (*Euthynnus affinis*) around 30% and 20%, respectively (Figure 2).

The catch of bullet tuna in 2016 rose substantially from approximately 2,100 tons to staggering 5,100 tons in just 4 years, with average catch slightly less than 3,500 tons/year. In addition, the fishing season usually occur during the 4th and the 1st quarter of the season, with catch varied from 200-650 tons, on the other hand, low season (below 200 tons) happens in transition between 2nd and 3rd period of the season, with the exception of 2016, where the recorded catch in July was the 3rd highest (~450 tons) after December and January (both slightly less than 650 tons) (Figure 3).

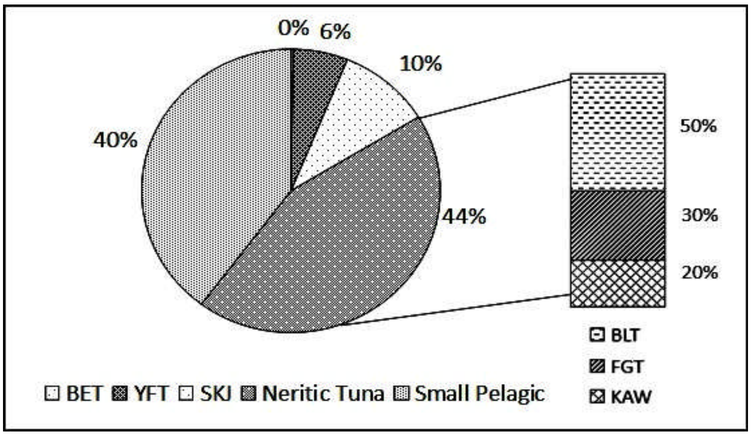

Figure 2. Catch composition of tuna purse seiners landed in PPS. Kendari, South East Sulawesi (note: right panel illustrate the list of neritic tuna species).

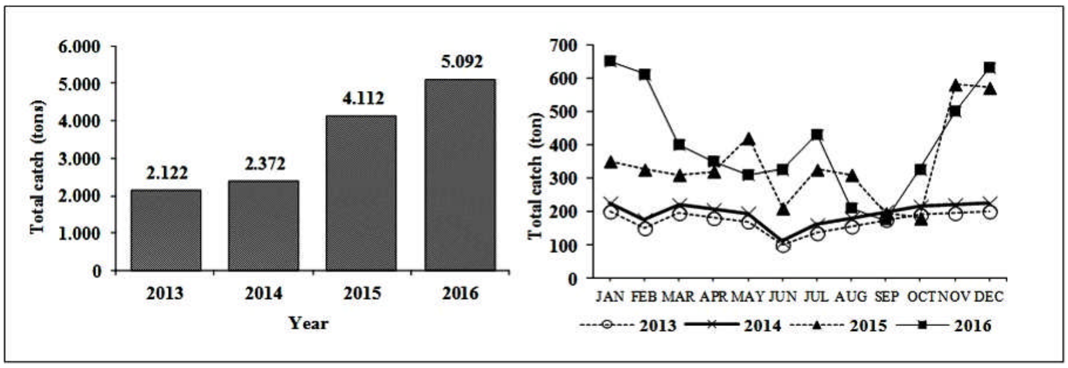

Figure 3. Annual (left) and monthly (right) catch trend of *A. rochei* landed in PPS. Kendari from 2013-2016 (Source: PPS. Kendari official statistical data).

Catch-at-size

A total of 7,716 length samples have been collected during observation between a period of January to November 2016, with exclusion of September and October, due to technical reasons the data were not available for analysis. The sample size varied from 18.5-32.7 cmFL, with average size 24.8±1.04 cmFL. Sample sizes mainly distributed between 24-26 cmFL length class, with mode at 24 cmFL(Figure 4). There was no obvious shifting pattern of monthly length frequency distribution (Figure 5). However, in general, at the start of the year most of the bullet tuna caught in smaller size, and gradually bigger toward the end of the year, as shown by the occurrence size greater than 30 cmFL since May.

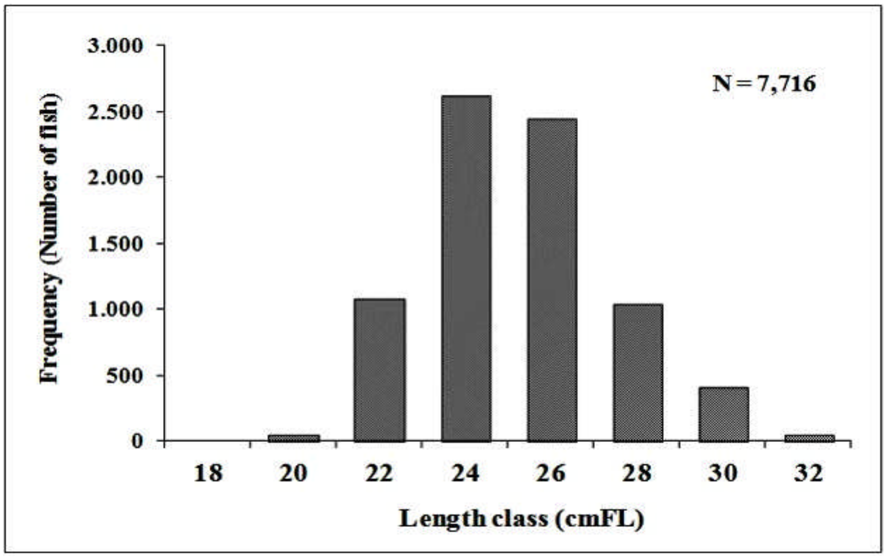

Figure 4. Size distribution of *A. rochei* observed from Banda Sea and its adjacent waters in 2016.

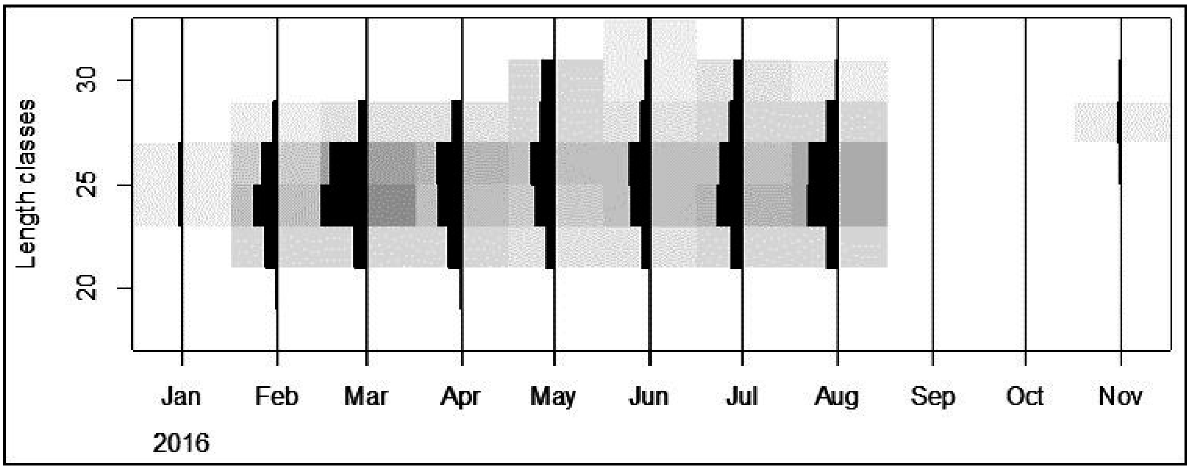

Figure 5. Monthly size distribution of *A. rochei* observed from Banda Sea and its adjacent waters in 2016.

Morphometric Relationship

Data reconstruction was necessary due to high deviation, only 287 pair of length-weight data were used out of 6,723 (4.3%). Most of the reconstructed data came from robust source, i.e. direct measurement by scientist on-site during survey. The rest of the data, which came from the enumerator, contained a lot of uncertainty. Weighing scale malfunction could be the main issue, since the same length could have a lot of weight variations . From Figure 6, it is seen that the model exhibits a quite fit to the reconstructed data (R^2=0.84) with the possible exception of a number of individuals. The equation of the best-fit on the original scale is $RW=0.0143*FL^{3.0167}$. T-test result showed bullet tuna allegedly to perform isometric growth curve ($p>0.05$) with an exponent parameter (*b*) between 2.86 and 3.17, with a 95% confidence.

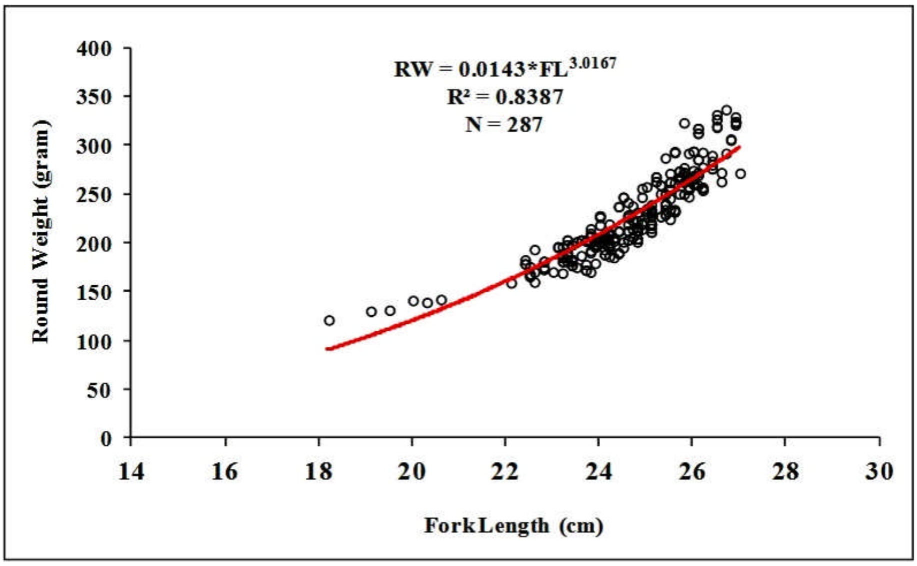

Figure 6. Length-weight relationship of *A. rochei* observed from Banda Sea and its adjacent waters in 2016.

Sex Ratio

Gonad inspection was thoroughly checked on 407 bullet tuna samples. As many as 214 samples (53%) were male, and the rest, 193 samples (47%) were female. Sex ratio of male compared to female was 1.16:1 or considered as equal (Chi-square test, $p>0.05$). More females were found during January, February, and June, by contrast, males were more likely found during May, July, and November (Figure 7).

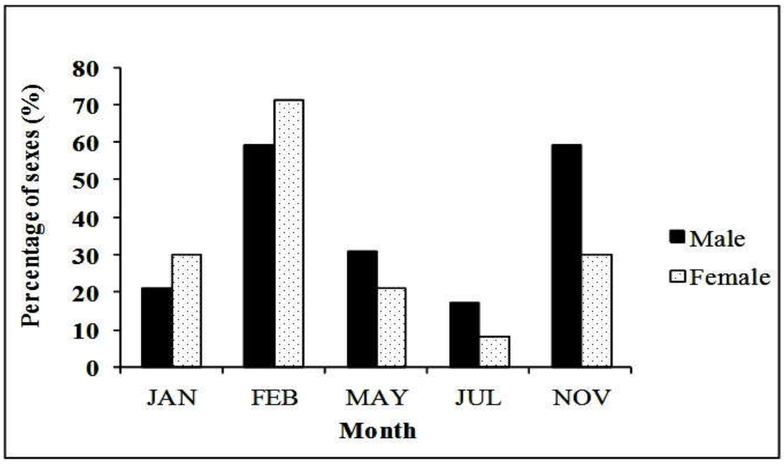

Figure 7. Temporal distribution of *A. rochei* by sex from Banda Sea and its adjacent waters in 2016.

Maturity

The analysis was conducted on 123 females of *A. rochei*, 32 was identified as immature and 91 as mature individuals. The fitted values for the curve logistic regression was ranged from 23.6711-23.6738 cmFL with 95% confidence intervals. The length at 50% of mature for *A. rochei* was 23.6 cmFL with R^2=0.53 (Figure 8).

Population Parameters

Population parameters were produced from length frequency analysis on a monthly basis (January-November). The asymtotic length (L_∞) was estimated 33.63 cmFL, growth coefficient (K) was 0.73 $year^{-1,}$ and theoretical age when length is zero (t_0) was -0.213 year. Thus, the von bertalanffy equation was L_t=33,6[1-$e^{0,73(t+-0,213)}$] (Figure 9). *Auxis rochei* is considered as fast-growing species, reaching 15 cmFL just in a year and expected to reach maximum length at 8-9 years old.

From the length-converted catch curve,the natural mortality (M) was 1.87 $year^{-1}$, fishing mortality (F) was 2.20 $year^{-1,}$ and total mortality was estimated 4.07 $year^{-1}$ (Figure 10). Exploitation rate was estimated around 0.54 $year^{-1}$ (~0.55 $year^{-1}$), means the resource has been utilized e up to its maximum capacity.

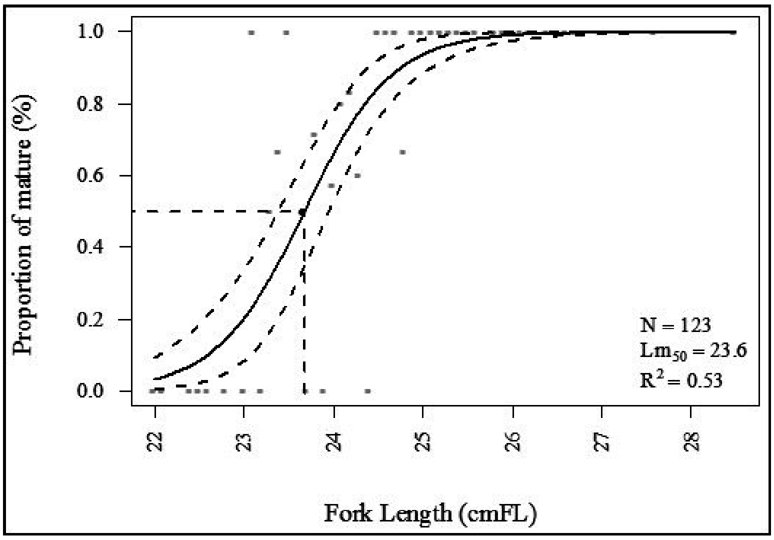

Figure 8. Length at 50% of mature of *A. rochei* by sex from Banda Sea and its adjacent waters in 2016.

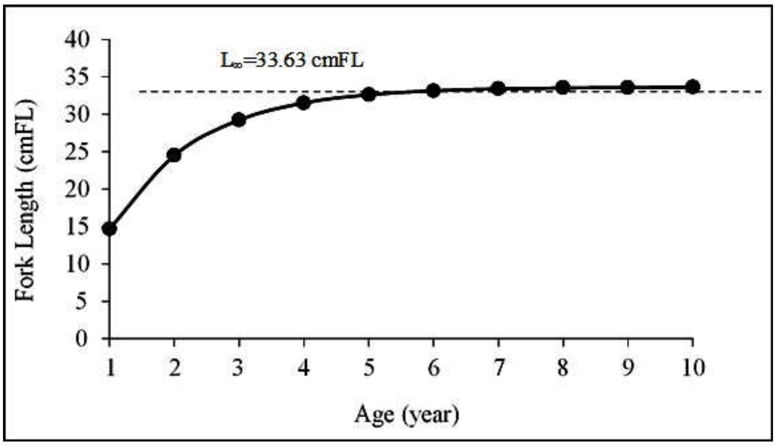

Figure 9. Theoritical growth curve of *A. rochei*, derived from length frequency analysis.

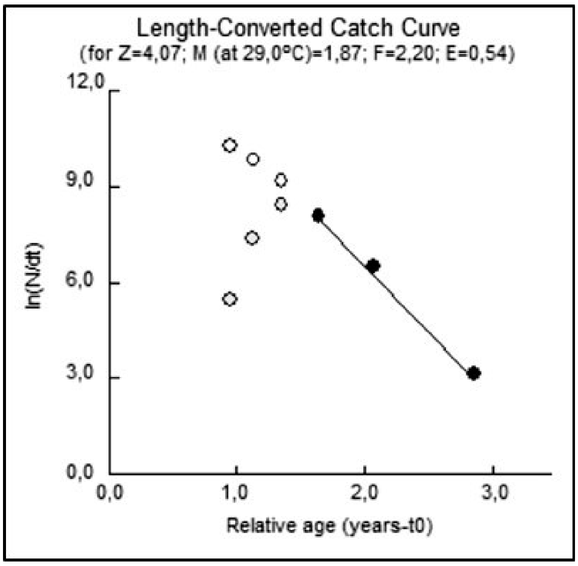

Figure 10. Length-converted catch curve of bullet tuna (*A. rochei*) from Banda Sea and its adjacent waters in 2016.

Recruitment Pattern

There is a strong seasonal recruitment pattern detected and predicted occurred at least twice a year, in April and July. April produced the higher recruitment compared to July, with proportion around 17.58% and 14.89%, respectively (Figure 11).

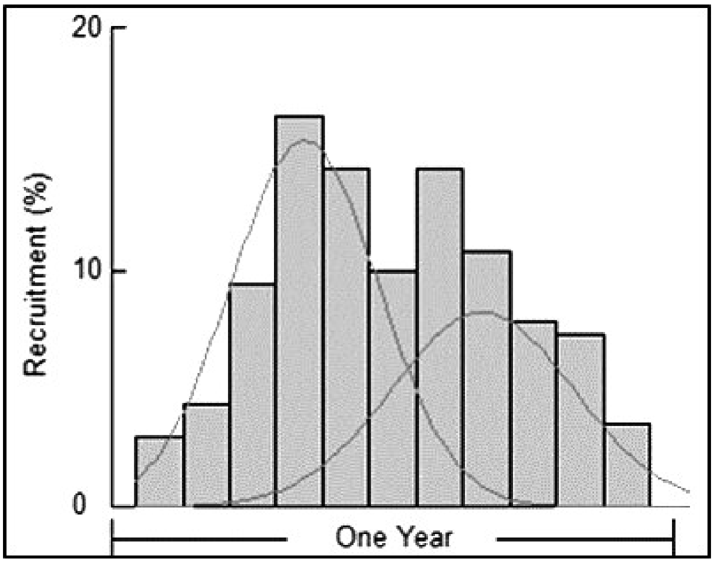

Figure 11. Recruitment pattern of bullet tuna (*A. rochei*) from Banda Sea and its adjacent waters in 2016.

Discussion

Purse seine is the main gear for catching bullet tuna in Kendari, no other gears reported catching this species. Although, some bullet tuna were reported to be caught by troll line in Sodohoa fishing port. The fishing ground are mostly around Banda archipelagic waters, i.e. Wowoni Island, Umbele, Taliabo, and southern part of Buru Island. Fishing activities were conducted mainly in surrounding fishing aggregating device (FAD), owned by personal and/or group. During peak fishing season (west monsoon), some fish were discarded at sea due to abundant catch and poor preservation. In most cases, bullet tuna was lumped together with frigate tuna and kawakawa because of their physical similarities, especially in Kendari. While in Sodohoa, since 2016, the catch between bullet tuna and kawakawa were separated, but not with frigate tuna (Amri *et al*., 2016). In order to get species-level composition, sampling and interview was conducted in-situ. Among neritic tuna group, 50-70% of the catch was dominated by bullet tuna, with the rests belong to frigate tuna and mackerel tuna (kawakawa), with proportion around 20-30% and 10-20%, respectively.

There was no noticeable trend on monthly catch-at-size distribution across the year. Most of the sample size were gathered at 22-32 cmFL. Similar condition were found in south of Java (Setyadji *et al*., 2013) and west of Sumatera waters (Noegroho & Chodrijah, 2015). However, the maximum size found in west of Sumatra was larger (42 cmFL) (Table 1). Bullet tuna typically form a schooling to avoid predation. Most of the schooling usually consist of a single cohort,dominated by a particular size range and came from the same recruitment year. Similar catch-at-size pattern was also found in western part of Sumatra (Noegroho & Chodrijah, 2015).

Table 1. Summary of catch-at-size distribution of *A. rochei* from various area and gear across Indonesian waters

Sites	Gear	Range	Mode (cmFL)	Reference
South Java, Bali and	GN	20-45	40	(Widodo *et al*., 2011)
Nusa Tenggara	PSSS	23-32	30	(Setyadji *et al*., 2013)
	TL	25-27	na	(Febrianty *et al*., 2014)
Western part of	PS	11-42	na	(Noegroho *et al*., 2013)
Sumatra	Mixed (PS, TR, LN, TL)	11-42	25-26	(Noegroho & Chodrijah, 2015)
Banda sea	Mixed (PS/PSSS, TL)	22-32	24-26	Recent study

Remarks: GN=Gillnet; PS= Purse seine; PSSS= Small scale purse seine; TR=Trawl; LN=Lift net; TL=Troll line.

Gear selectivity will limit the size range of fish caught (Fauconnet & Rochet, 2016). For example, gillnet has different selectivity compared to purse seine or liftnet, even though all aforementioned gears consisted of net. In term of selectivity, gillnet is likely caught larger fish compared to small scale purse seine in southern part of Java, Bali, and Nusa Tenggara waters. In addition, industrial purse seine in Banda Sea and western part of Sumatra have similar mode (24-26 cmFL), but the later caught more juvenile fish because it usually has smaller mesh size (2-3 cm) (Sartika *et al.*, 2017). Size range of bullet tuna caught in Banda Sea relatively similar with what reportedly caught in Indian waters (15-32 cmFL) (Pillai & Pillai, 2000), but smaller compared to eastern Mediterranean (Kahraman *et al.,* 2011), Turkish waters (Bök & Oray, 2001), and Liguaria Sea, Italy (Palandri *et al*., 2006), which around size range 34-48 cmFL, 28.5-44.5 cmFL, and 27-46,5 cmFL, respectively.

Based on length-weight relationship, the growth pattern of bullet tuna resides in Banda Sea is isometric (b=3.01; R^2 = 0.8387; n = 287), which means the increment of length is proportional to its weight. This finding similar with the study from Febrianty *et al*. (2014) in Palabuhanratu and its surrounding waters. By contrast, some study from south western Spanish Mediterranean (Macías *et al*., 2005), Turkish Waters (Bök & Oray, 2001) and Indian Waters (Jasmine *et al*., 2013) all shown allometric growth with *b* value 3.32, 3.24, and 3.25, respectively.

Overall, the proportion of female compared to total sex combined was on par at 50% (or 1:1). However, in monthly scale the proportion mostly unequal (x^2, p>0.01). Sex ratio in other tuna are reportedly 1:1, with male more dominant at larger length classes (Schaefer, 2001). The monthly differences are less clear but reproductive behavior, environmental conditions, and level of exploitation could be one of the determining factors (Bal & Rao, 1984).

The estimation of length at 50% mature (Lm_{50}) for bullet tuna from Banda Sea and its adjacent waters was 23.6 cmFL, relatively similar compared to previous study from *Febrianty et al*. (2014) in Palabuhanratu and western part of Sumatra (Noegroho & Chodrijah, 2015), in which the Lm_{50} was 23.2 cmFL and 24.6 cmFL, respectively. At least 75% of bullet tuna caught from January to November 2016 in the Banda Sea was allegedly mature and/or spawned, a good indicator for the fisheries. In addition, the theoretical asymptotic length (L_{∞}) of bullet tuna was 33.6 cmFL, similar to a study from Rohit *et al*. (2014) in Indian coast but lower compared to western part of Sumatra (Noegroho & Chodrijah, 2015) in which around 34.0 cmFL and 43.5 cmFL, respectively. Bullet tuna considered as fast growth species, in which could grow up to 15 cmFL in their first year, and reaching maturity at the second year. In this study, the growth coefficient was estimated around 0.73 year^{-1}, relatively higher compared to several studies from western part of Sumatra (Noegroho & Chodrijah, 2015) and Indian waters (Jasmine *et al*., 2013), in which each value was 0.54 year^{-1} and 0.61 year^{-1}, respectively. Most of the bullet tuna observed dominated by at least 1.5 year-old fish at size range 24-25 cmFL (Table 2).

Table 2. Estimation growth parameters of bullet tuna (*A. rochei*) from various references.

Sites	L_{∞} (cmFL)	*K* (year)	t_0 (year)	Reference
India Sea (EEZ)	34,00	1,10	N/A	(Rohit *et al*., 2014)
India Sea (territorial waters)	42,30	0,61	0,030	(Jasmine *et al*., 2013)
Western part of Sumatera	43,50	0,54	0,070	(Noegroho & Chodrijah, 2015)
Banda Sea	33,63	0,73	0,213	Recent study

Natural mortality rate (*M*) of bullet tuna was estimated around 2.2 year^{-1}, while fishing mortality rate (*F*) was a bit higher, around 1.87 year^{-1}. So that, total mortality rate was 4.07 year^{-1}. There is a concern about overestimation, especially when the data is incomplete and only cover a short period (less than a year). Even though high mortality rate usually appears on fishes in tropical that was characterized as grow faster, mature earlier and shorter life-span (Juan-Jordá *et al*., 2015). It seems unrealistic to have natural mortality higher than what is caused by fishing, unless the fishing activity on the particular area is rare or still in pristine condition, but it wasn't the case. Since there is a linear relationship between body size, growth coefficient, and temperature in determining *M*, thus there is a probability of *K* has been overestimated. In order to get a more robust result, using simulated annealing and genetic algorithm could be an option (Mildenberger *et al*., 2017). Exploitation level (*E*) was estimated to be at maximum level around 0.54 year^{-1}, in which relatively similar compared to western part of Sumatra (Noegroho & Chodrijah, 2015). In addition, the result was in between compared to Indian territorial waters (Jasmine *et al*., 2013) and Indian EEZ (Rohit *et al*., 2014) (Table 3).

Table 3. Estimation of several population parameters (*Z, M, F,* and *E*) of bullet tuna from various locations.

Sites	*Z*	*M*	*F*	*E*	Reference
India Sea (EEZ)	1,87	1,21	0,66	0,35	(Rohit *et al*., 2014)
India Sea (territorial waters)	5,90	1,18	4,72	0,80	(Jasmine *et al*., 2013)
Western part of Sumatra	1,96	0,89	1,07	0,49	(Noegroho *et al*., 2015)
Banda Sea	4,07	1,87	2,20	0,54	Recent study

Recruitment was expected to happen in April and July, a month slower compared to one in western part of Sumatra, which according to Noegroho & Chodrijah (2015) occurred in March and July. The first recruitment was aligned with the end of first inter-monsoon season, resulted in higher abundance compared to the second recruitment that appeared at the peak of east monsoon. Finally, in order to keep the exploitation level at the optimum level and balanced trade-off between ecological and economical benefit, reducing the effort at least 8% from the current level is advised. Controlling the present of FADs and temporary closure on spawning areas could also be introduced in order to keep the resource sustainable.

CONCLUSION

The bullet tuna (*A. rochei*) stock in Banda Sea and its adjacent waters is currently at optimum level. A good indicator for the fisheries was shown where two-thirds of the population are mature and spawn. However, as a precautionary approach, the effort should be reduced at least 8% from current level to maintain its sustainability.

ACKNOWLEDGEMENTS

This paper is a contribution of Research on Biological Fisheries Characteristic, Habitat, and Potential Fish Resource Production in Fisheries Management Area (FMA) 714 (Tolo Bay and Banda Sea), 2016. The authors would like to thank Enjah Rahmat and Munawar as contributors in processing data and providing daily landing information.

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