

Biological aspects of bullet tuna (*Auxis rochei* Risso, 1810) landed in Towo'e Market Tahuna Indonesia

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Abstract. The bullet tuna (*Auxis rochei* Risso 1810) is one of the species of neritic tuna that lives in tropical and subtropical coastal waters. Research on the biological aspects of the bullet tuna in Indonesian waters is very important considering the limited information on this species. The purpose of this study is to analyze size structure, length-weight relationship, sex ratio, length at first maturity and length at first capture. A total of 1353 bullet tuna was randomly collected during February-November 2017 at Towo'e Market Tahuna North Sulawesi. The study was conducted by observation and enumeration. The results showed that the bullet tuna landed in Towo'e Market had a length ranging from 19-29 cmFL with an average size of 23.34 cmFL. The LW relationship indicates a positive allometric condition. The sex ratio of male and female bullet tuna showed an unbalanced condition with the ratio of females and males being 1: 0.97. Lm was 22.82 cmFL and Lc was 23.32 cmFL. This condition indicates that most of the bullet tuna caught are already spawning, so caution is needed in their utilization because it can prevent the recruitment pattern of the bullet tuna.

1 Introduction

The bullet tuna is one of smallest tuna in the world [1] and belongs to the neritic tuna species that lives in tropical and subtropical coastal waters [2], such as in Atlantic, Indian Ocean and Western Pacific Ocean including the Mediterranean Sea [3]. An epipelagic, neritic, oceanic species [4], and highly migratory species [5]. Adults are mainly captured in coastal seas and near islands [6] and form schooling [7].

The bullet tuna is a fish resource that is epipelagic, neritic, and oceanic in warm waters such as Indonesia [8]. In Indonesia, the bullet tuna is distributed in the Indian Ocean waters west of Sumatra [9], Makassar Strait [10-12], Indian Ocean south of Java, Bali, and Nusa Tenggara [13-16], Bone Bay [17] and Banda Sea [18]. The bullet tuna is usually caught with fishing gear such as gillnet, hand line, troll line, lift net, purse seine and seine net [9], [19].

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The Sulawesi Sea has long been utilized for fishing businesses based in Towo'e Market Tahuna. The fishing business is still on a traditional scale or small-scale fisheries. One of the exploited fishery resources is bullet tuna caught using mini purse seine. Fishing ground of mini purse seine based on Towo'e Market in Sangihe waters, Sulawesi Sea [20].

The utilization rate of bullet tuna is thought to have reached full exploitation [11], [17], [21-22]. This phenomenon is very worrying, because fish resources need time to recover after experiencing fishing pressure [13]. This is made worse by fishermen who tend to catch without being balanced with knowledge on how to conserve them [23]. Therefore, there needs to be an effort to manage bullet tuna so that its existence remains sustainable through research on biological aspects.

The biological aspects research of bullet tuna is very important considering the limited information on this fish species, especially in Sulawesi Sea waters. The biological aspects research of bullet tuna has been widely conducted in Indonesian waters, such as in Indian Ocean south of Java, Bali, and Nusa Tenggara [24-27], Indian Ocean west of Sumatra [9], [28-29], Banda Sea [18], Bone Bay [17], Majene waters [10], Makassar Strait [12], and Donggala waters [11]. But it has never been done in Sulawesi Sea waters. This research is needed to get a complete picture of this fishery. Analyze the size structure, length-weight relationship, sex ratio, length at first maturity (L_m), and length at first capture (L_c) are all reproductive biology topics that will be covered in this study. Reproductive biology information is needed in resource management for fishing-intensive waters and for fisheries development for areas with low catch rates [30]. The results of the study are expected to be a consideration for policy makers in the management of bullet tuna in Indonesia, especially in Sulawesi Sea waters.

2 Materials and methods

2.1 Data Collecting

Data was collected during February-November 2017 from Towo'e Market, Tahuna, Sangihe Regency, North Sulawesi (Figure 1). Direct field observation and enumeration were used to conduct the study. A total of 1353 bullet tuna were collected during February-November 2017. Data on length, weight, sex, and gonad maturity were collected during the survey period. Fish length and weight were measured randomly.

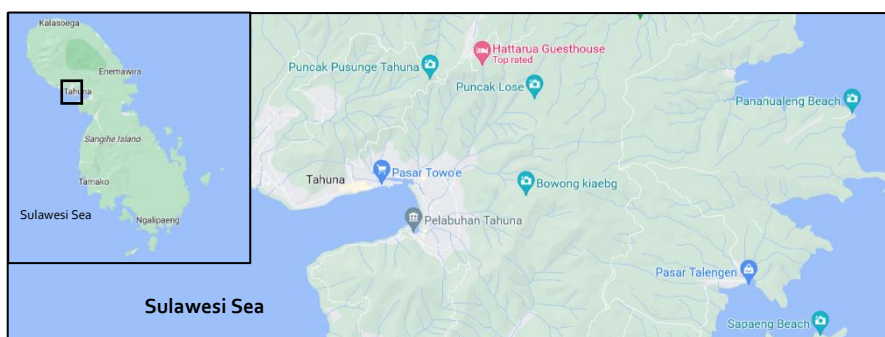


Fig. 1. Research site map.

(Sources: [31])

Macroscopical (morphological) observations of the gonad maturity stage were made the morphological characteristics of each male and female gonad maturity stage. Determination of the maturity level of bullet tuna gonads follows the criteria proposed by [32] which divides the maturity level of female and male gonads into five stages (Table 1).

Table 1. Determination of gonad maturity stage of bullet tuna

Stages	Female	Male
I (Immature)	Ovary threadlike, long to the front of the body cavity, clear colour, smooth surface.	Testes threadlike, shorter limited and visible ends in body cavity, clear colour.
II (Early maturing)	Ovary size larger, darker coloration, yellowish, eggs not yet clearly visible.	Larger testes size, milky white colour, clearer shape than level I.
III (Late maturing)	Yellow ovaries, the morphology of the egg begins to be seen with the eye.	The testes surface appears jagged, the colour is getting white, the testes in the preserved state are easily broken off.
IV (Ripe)	Ovaries getting bigger, yellow eggs, easy to separate, oil grains not visible, filling ½ - 2/3 of the abdominal cavity, intestines pushed out.	As in stage III, the appearance is clearer, the testes are more solid.
V (Spawned)	Ovaries wrinkled, thick walls, residual eggs near the anus.	Testes at the back are deflated and near the discharge are still full.

2.2 Data Analysis

Size structure was calculated based on the fish proportion in each size class. Growth patterns were analyzed using the fish weight length relationship formula [33]:

W = aL^b

where *W* was weight (grams); *L* was length (cmFL); *a* and *b* were constants.

Test for value of *b* = 3 or *b* ≠ 3 was conducted using the t-test with the hypothesis *H*₀: *b* = 3, the relationship between length and weight was isometric; and *H*₁: *b* ≠ 3, the relationship between length and weight was allometric. The hypothesis is used to estimate the growth pattern from the *b* value; *b* = 3, weight gain is equal to length gain (isometric); *b* < 3, length gain is faster than weight gain (negative allometric); and *b* > 3, weight gain is faster than length gain (positive allometric).

In order to determine the sex ratio, the number of male and female fish that were caught was compared. Sex ratio analysis of female fish and male fish using [33] formula:

Sex ratio = M / F

where *M* was male, and *F* was female.

The Spearman-Kärber method [34] was used to estimate length at first maturity:

m = X_k + (X / 2) {X ∑ P_i}

$$Pi = \frac{ri}{ni} \tag{4}$$

where m was the logarithm of fish L_m , X_k was the logarithm of the middle value of the length class when all fish were mature, and X was the difference in the logarithms of mean values; P_i was ratio of mature fish in the class to i ($p_i=ri/ni$); ri was the number of mature fish in the class to i ; ni was the fish number in the class to i ; and q_i was $1-P_i$.

Length at first capture (L_c) was estimated through the method of [35]:

$$S_{Lobs} = \frac{1}{a+\exp(S1-S2xL)} \tag{5}$$

By calculating the value of $L_{50\%}$, L_c was determined. The 50% point was selected because it is an inflection point where the logistic curve connected to the ogive curve selection inflection point is at 50%. In the calculation of L_c and L_m , the value of 50% is the optimum point of utilization of fishery resources, where 100% of the fish in the sea optimally only 50% can be caught and the other half must be released. From the amount that is released into the sea, it is expected that it can grow into an adult fish and can reproduce (produce new offspring). The formula for calculating L_c is:

$$L_{50\%} = L_c = \frac{S1}{S2} \tag{6}$$

where S_{Lobs} was cumulative frequency of retained proportion; $L_{50\%}$ was body length of fish where 50% was retained; $S1$ was intercept value a (the intersection of the linear line with the y-axis) and $S2$ was slope value b (angle of slope of the regression line).

3 Results and discussions

3.1 Results

3.1.1 Size structure

Bullet tuna from Sulawesi Sea waters landed in Towo'e Market had ranged from 19-29 cmFL with an average size of 23.34 cmFL. The mode size of bullet tuna was 24 cmFL (28%) (Figure 2).

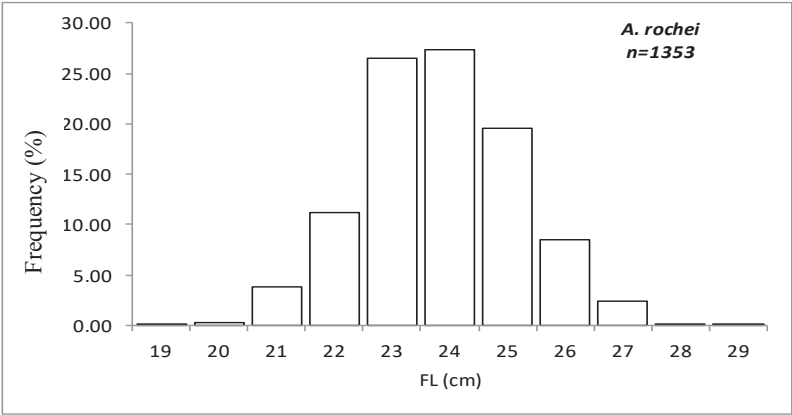


Fig. 2. Length size frequency of bullet tuna from Sulawesi Sea landed at Towo'e Market.

3.1.2 L-W relationship

The L-W relationship of bullet tuna in Sulawesi Sea waters landed at Towo'e Market follows the equation $W=0.001 \cdot L^{3.8365}$. The growth characteristics of the bullet tuna showed a positive allometric condition with a value of $b>3$. This condition shows that the growth of bullet tuna weight is faster than its length (Figure 3).

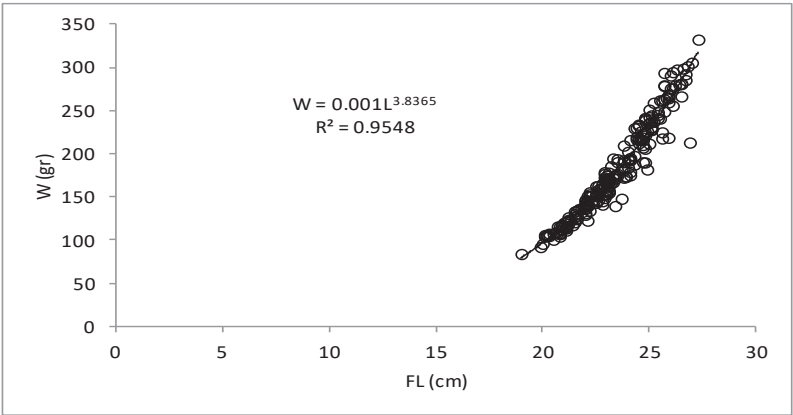


Fig. 3. L-W relationship of bullet tuna in Sulawesi Sea waters landed at Towo'e Market.

3.1.3 Sex ratio

Sex ratio of male and female bullet tuna in Sulawesi Sea waters landed at Towo'e Market showed an unbalanced condition. The female proportion bullet tuna was more dominant in the catch with a ratio of females to males of 1 : 0.97 (Figure 4).

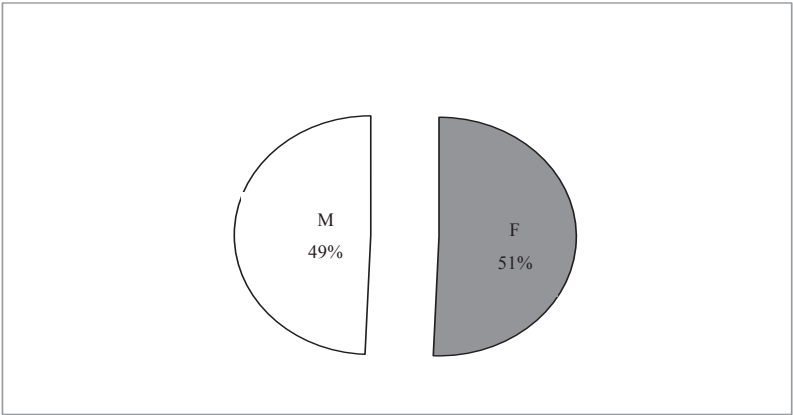


Fig. 4. Sex ratio of bullet tuna in Sulawesi Sea waters landed at Towo'e Market

3.1.4 Length at first maturity (Lm) and length at first capture (Lc)

Lm of bullet tuna in Sulawesi Sea waters landed at Towo'e Market was 22.82 cmFL (Figures 5), while the Lc was 23.3164 cmFL (Figure 6). Lm of bullet tuna in Sulawesi Sea waters landed at Towo'e Market is different from the results of study in several waters in Indonesia.

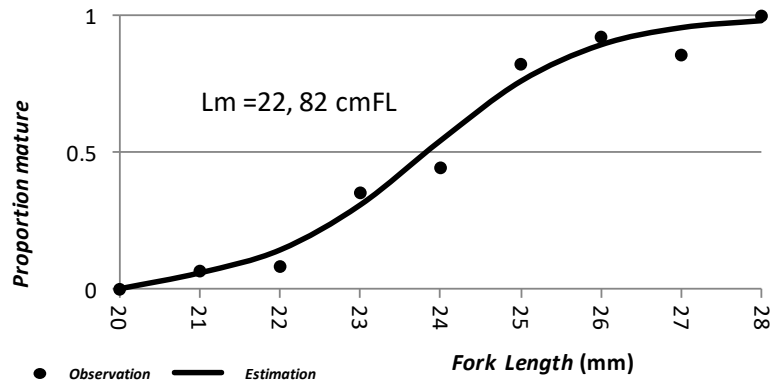


Fig. 5. Lm of bullet tuna in Sulawesi Sea waters landed at Towo'e Market.

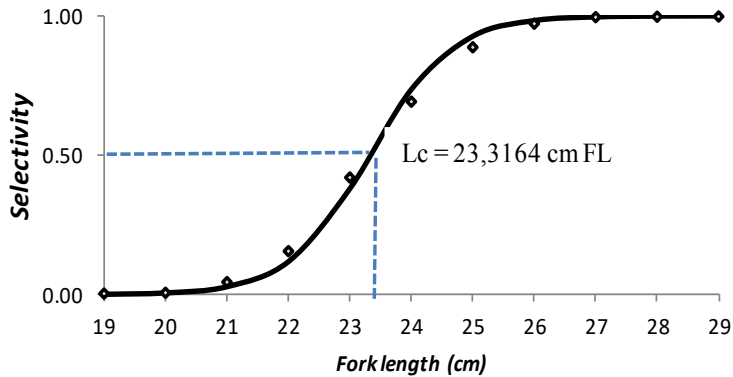


Fig. 6. Lc of bullet tuna in Sulawesi Sea waters landed at Towo'e Market

3.2 Discussions

Length of bullet tuna from Sulawesi Sea waters landed in Towo'e Market has range 19-29 cmFL, it was like from Banda Sea waters [18], but longer than other waters. [15] reported that bullet tuna from Indian Ocean waters south of East Java had an average length of 20.22 cm, while those from Indian Ocean waters west of Sumatra (Padang to Banda Aceh) had a length of 25-26 cmFL [9]. Meanwhile, [36] reported that bullet tuna in Bone Bay waters were larger with lengths reaching 41-42 cm.

Fish length is very important to know because it is used as an indicator to estimate the maturity of fish as well as the eligibility and fisibility of fish to be caught [37]. The length of bullet tuna from the Sulawesi Sea is different from bullet tuna from other waters. This is thought to be due to differences in the types of fishing gear and fishing grounds. The

fishermen based in Towo'e Market use mini purse seine where this gear has a low level of selectivity [38]. The variety of fish caught will be constrained by the gear [39]. Even though all of the fishing gears were made of net, the selectivity of each fishing gears different from other gear. Regarding the fishing grounds, [6] states that naturally adult fish are caught in coastal area and around islands. Meanwhile, juveniles swim more in oceanic waters [7]. [40] said that size differences may be related to fishing activities and the environment carrying capacity. Fishing activity was related to the amount of fishing gear and fishing gear types used so that it can cause differences in the size of the catch. The environment carrying capacity, which relates to environmental conditions and the availability of food, may cause differences in catch size. food may contribute to size distribution preferences [41].

The bullet tuna growth characteristic showed a positive allometric. This condition shows that the bullet tuna growth weight is faster than its length. The results of this study are in line with the results of research conducted [42] in the western waters of Sumatra and [43] the southern waters of Bali which has a positive allometric. However, in contrast to the research results conducted [18] in Banda Sea had an isometric growth pattern and [44] Karangasem waters which has a negative allometric growth pattern. Different growth patterns may result from ecological and biological factors. Season, water quality, temperature, pH, salinity, geographical position, and sampling technique included ecological factors [45]. While gonadal development, feeding habits, growth phase and sex included biological factors [46-47]. Fish conditions can change so that the LW relationship will deviate from the cubic law, it is causing changing environmental conditions [48].

Sex ratio of bullet tuna in Sulawesi Sea waters landed at Towo'e Market can be categorised in a non-ideal condition. The deviation from ideal conditions is due to differences in the pattern of schooling behaviour between male and female fish, differences in mortality rates, and differences in growth [49]. [50] said that sex ratio can change before and during spawning. In fish ranges for spawning there is a regular change in sex ratio, at first the male is dominant, the sex ratio changes to 1.00 : 1.00, and then followed by the dominance of female fish. Another factor that can influence sex ratio is food availability, if food is abundant, female fish will be dominant. Conversely, male fish will be dominant if food is limited [50]. [51] stated that with more female fish than male fish, the population can still be maintained even if there is natural mortality or due to fishing activities.

The results of study by [42] in western Sumatra waters obtained 27.16 cmFL, [24] in Palabuhanratu 23.2 cmFL and western part of Sumatra [9] 24.6 cmFL, while in Banda Sea waters 23.6 cmFL [18]. Each fish has a different size distribution that can be caused by external or environmental influences, which is assumed to be the source of the discrepancy in the length value of the initial maturity with several prior research. In addition, another reason for the difference in the value of Lm because the bullet tuna is a partial spawner so that the eggs released in the female are not immediately released at that time but gradually during one reproductive cycle [52].

Based on these results, Lc is greater than Lm ($L_c > L_m$). This condition shows that most of the bullet tuna caught after spawning so it needs to be careful in its utilization because it can inhibit the addition of new bullet tuna. [53], catchable fish are defined as fish that have a length greater than Lm of the gonads. The number of gonadally mature fish when caught indicates that there is no growth in overfishing. [51] stated that when young fish were dominant of the catch, overfishing has taken place. The value of Lc should be greater than Lm to maintain a sustainable resource [54].

4 Conclusions

The bullet tuna from Sulawesi Sea waters landed in Towo'e Market had ranged from 19-29 cmFL with an average size of 23.34 cmFL and a mode at 24 cmFL, have positive allometric growth patterns (weight growth of bullet tuna is faster than its length). Sex ratio of male and female bullet tuna showed an unbalanced condition where females were more dominantly caught. $L_m > L_c$, this condition indicates that most of the bullet tuna caught are already spawning, so caution is needed in their utilization because it can prevent the recruitment pattern of bullet tuna.

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References

1. Jasmine, S., Rohit, P., Abdussamad, E.M., Koya, K.P., Joshi, K.K., Kemparaju, S., Sebastine, M. *Indian J. Fish.* **60**(2), 13-20. (2013)
2. Dahlan, M.A., Yunus, B., Umar, M.U., Nur, M. *Proceedings of the VI National Marine and Fisheries Symposium*. Hasanuddin University Makassar, Indonesia. (2019)
3. Collette, B.B. C.R. Aadland. *Fish. Bull.* **94**(3), 423-441. (1996)
4. Riede, K. *Final Report of the R&D-Projekt 808 05 081*. Federal Agency for Nature Conservation, Bonn, Germany. 329 p. (2004)
5. FAO, Fisheries Department. *FAO Fish. Tech. Pap. No. 337*. Rome, FAO. 70 p. (1994)
6. Collette, B.B. In W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter, V. Niem (eds.) *Guia FAO para Identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental*. **3 Vols**. FAO, Rome. (1995)
7. Collette, B.B. In P.J.P. Whitehead, M.L. Bauchot, J.C. Hureau, J. Nielse, E. Tortonese (eds.) *Fishes of the north-eastern Atlantic and the Mediterranean*, **Vol. 2**. Unesco, Paris. (1986)
8. Neves, D.S., A. Garcia. *ICCAT. Coll. Vol. Sci. Pap.* **59**(3), 802-812. (2006)
9. Noegroho, T., Chodriyah, U. *BAWAL Widya Res. on Capt. Fish.* **7**(3), 129-136. (2015)
10. Dahlan, M.A., Yunus, B., Umar, M.U., Nur, M., Jufri, A. *SIGANUS: J. of Fish. and Mar. Sci.* **1**(1), 32-35. (2019)
11. Hasanah, N., Restiangsih, Y.H., Nurdin, M.S. *Sci. J. of Ocean Aqua.* **3**(1), 1-5. (2019)
12. Kantun, W., Cahyono, I., Arsana, W.S. *Croatian J. of Fish.* **7**, 118-125. (2019)
13. Yuliana, E., Nurhasanah., Yani, D.E., Agustina, S. *J. of Trop. Mar. Sci. and Tech.* **12**(3), 659-672. (2020)
14. Rahmatullah, G.N., Pertami, N.D., Pratiwi, M.A. *Current Trends in Aqua. Sci.* **V** (2), 127-134. (2022)
15. Agustina, M., Rachman, F. *Proceedings: XVI Annual National Seminar on Fisheries and Marine Research Results*. Department of Fisheries Gadjah Mada University Yogyakarta. (2019)
16. Asrial, E., Fathurriadi, Arapat, Y., Hadi, U.K., Kalih, L.A.T.T.W.S., Rizal, L.S., Liliyanti, M.A., Rosadi, E., Khasanah, R.I., Setyohadi, D., Junaidi, M., Rathnayake, I.N. *Sci. J. of Fish. and Mar.* **13**(2), 1-10. (2021)
17. Wahana, S., Suyuti, Y.D.M., Nur, M., Nasyrah, A.F.A. *J. of Airaha.* **10**(2), 241-247. (2021)
18. Amri, K., Novalina, A., Setyadji, B. *Ind. Fish. Res. J.* **25**(2), 103-112. (2019)
19. Amri, K., Muhklis, N.A., Rahmat, E., Restiangsih, Y.A., Novalina, A., Hasanah, A., Mutoharoh, A.A. *Final Report of Research on Biological Characteristics of Fisheries*,

- Fish Resource Ecosystems and Fish Stocks in FMA 714 (Banda Sea and Tolo Bay)*. Research Institute for Marine Fisheries. Agency for Marine and Fisheries Human Resources. Jakarta. (2016)
20. Kuswoyo, A. Surahman, A. *Bull. of Resources and Capture Engineering*. **18**(1), 1-5. (2020)
 21. Restiangsih, Y.H., Hidayat. *BAWAL Widya Ris. on Capt. Fish*. **10**(2), 111-120. (2018)
 22. Pramulati, I., Sukmaningsih, A.A.S.A., Sudaryanto F.X. *BAWAL Widya Res. on Capt. Fish*. **14**(1), 21-37. (2022)
 23. Hasanah, N., Restiangsih, Y.H., Omar, S.B.A., Nurdin, M.S. *Proceedings of the VI National Marine and Fisheries Symposium*. Hasanuddin University Makassar, Indonesia. (2019)
 24. Febrianty, E., Amri, K., Restiangsih, Y.H. *In Anthology Book: Status of fish resource utilization in the Indian Ocean (FMA 572 & 573) and Pacific Ocean (FMA 717)*. Ref Grafika. Jakarta. 311-321. (2014)
 25. Setyadji, B., Novianto, D., Bahtiar, A. *IOTC Third Working Party on Neritic Tuna*. **30**, 1-10. (2013)
 26. Widodo, A.A., Satria, F., Sadiyah, L. *Ind. Fish. Policy J*. **6**(1), 23-28. (2014)
 27. Asrial, E., Arapat, Y., Hadi, U.K., Kalih, L.A.T.T.W.S., Liliyanti, M.A., Rosadi, E., Khasanah, R.I., Rathnayake, I.N. *Sci. J. of Fish. and Mar*. **13**(1), 116-123. (2021)
 28. Noegroho, T., Hidayat, T., Amri, K. *IOTC Third Working Party on Neritic Tuna, IOTC-WPNT*. **19**, 1-13. (2013)
 29. Salmarika, S., Wisudo, S.H. *Ind. Fish. Res. J*. **24**(4), 263-272. (2019)
 30. Zamroni A, Suwarso. *Bawal Widya Ris. on Capt. Fish*. **3**(5): 337-334. (2011)
 31. <https://www.google.com/maps/>
 32. Schaefer, M.B. C.J. Orange. *Bull. IATTC*. **1**(6), 282-349. (1956)
 33. Effendie, M.I. *Fisheries Biology*. Yayasan Pustaka Nusatama. Yogyakarta. 163 p. (2002)
 34. Udupa, K.S. ICLARM. Metro Manila. *Fishbyte*. **4**(2), 8-10. (1986)
 35. Sparre, P., Venema, S.C. *FAO Fisheries Technical Paper*. No. 306/2, Rev. 2. Rome, FAO. 94 p. (1999)
 36. Kantun, W., & Amir, M.F. *J. of Balik Diwa*. **7**, 1-12. (2016)
 37. Asrial, E., Rosadi, E., Fathurriadi. *Ind. J. of Aqua. and Fish*. **2**(1), 19-28. (2020)
 38. Sumardi, Z., M.A. Sarong, M. Nasir. *Agriseip*. **15**(2), 10-18. (2014)
 39. Fauconnet, L., Rochet, M.J. *Marine Policy, Elsevier*. **64**(C), pages 46-54. (2016)
 40. Hasanah, N., Putra, A.E., Nurdin, M.S. *Proceedings of Politani Pangkep National Seminar Vol 3 "Multifunctional Agriculture for Food, Renewable Energy, Water, and Air Security"*. (2022)
 41. Kantun W., Darris L., Arsana W.S. (2018). *J. of Mar. Fish*. **9**(2), 157-167.
 42. Tampubolon, P.A.R.P., D. Novianto., H. Hartaty., R. Kurniawan., B. Setyadji, B. Nugraha. *IOTC-2016-WPNT06-19*. 9 p. (2016)
 43. Suryati, Y.D., Setyawati, I., Yusup, D.S. *Metamorfosa: J. of Biol. Sci*. **10**(1), 28-39. (2023)
 44. Guna I.M.A.J., Watiniasih N.L., Puspitha N.L.P.R. *J. of Mar. and Aqua. Sci*. **7**(2), 129-139. (2021)
 45. Zargar, U.R., A.R. Yousuf, B. Mushtaq., D. Jan. *Turkish J. of Fish. and Aqua. Sci*. **12**, 685-691. (2012)
 46. Froese, R. *J. of Appl. Ichthyology*. **22**(4), 241-253. (2006)
 47. Tarkan, A.S., Gaygusuz, Ö., Acipinar, P., Gursay, C., Özulug, *J. of Appl. Ichthyology*. **22**(4), 271-273. (2006)
 48. Merta, I.G.S. *Ind. Fish. Res. J*. **73**, 35-44. (1993)
 49. Ball, D.V., K.V., Rao. *Marine Fisheries*. Tata McGraw-Hill Publishing Company, Limited New Delhi. 521 p. (1984)

50. Nikolsky, G.V. *The Ecology of Fishes*. Academic Press.London. 352 p. (1963)
51. Saputra, S.W., P., Soedarsono, G.A., Sulistyawati. *J. of Fish. Sci. and Tech.* **5**(1), 1-6. (2009)
52. Fitriah, R.T.M. *Thesis*. Department of Fisheries Resource Utilization, Division of Fisheries and Marine Resources Utilization, Faculty of Fisheries and Marine Science, Brawijaya University Malang. Xvi + 120 p. (2018)
53. Fergiawan, D.G. *Thesis*. Faculty of Fisheries and Marine Science, Brawijaya University Malang. (2017)
54. Panda, D., S.K. Chakraborty, A.K. Jaiswar, A.P. Sharma, B.C. Jha, B.T. Sawant, S.K. Bhagabati, T. Kumar. *Indian J. Fish.* **59**(4), 53-60. (2012)