Population dynamics of eastern little tuna (*Euthynnus affinis*) in Ternate Waters

U Tangke¹*, R Laisou¹, A Talib¹, Azis Husen¹, R Kota² and W A Z Umagap³

¹Universitas Muhammadiyah Maluku Utara, Ternate-Indonesia,
²Balai Bio Industri Laut Lombok - LIPI, Lombok-Indonesia,
³Institut Agama Islam Negeri Ternate, Ternate-Indonesia,

E-mail: umbakhaka@gmail.com

Abstract. Eastern little tuna production still depends on stocks from nature, so it is feared that if production continues to increase it will threaten the sustainability of tuna resources, therefore for the sake of sustainable management information is needed on population parameters so that research is carried out from January to April 2021 with the aim of assessing the dynamics of the population of these resources. The data collection procedure was carried out by measuring the total length of the fish caught per fishing trip for 4 months using a meter with a unit (centimeter) cm and an accuracy of 1 mm. The results of the research showed that tuna in the southern waters of Ternate Island had stable growth parameters including maximum length (*L*∞) 68.25 cm with a growth coefficient (K) of 0.25 per month, *t*0 -0.20, with total mortality, natural and fishing values respectively are 0.64, 0.43, 0.21 and the level of exploitation is 0.33 where this value indicates that the rate of exploitation is smaller so it is necessary to increase fishing effort until the optimum value reaches 0.38.

1. Introduction

Ternate Island fishery production is dominated by capture fisheries with fishing activities generally within 1-3 nautical miles by local fishermen and catches are dominated by Decapterus spp, *Euthynnus affinis*, Rastrelliger sp, Selaroides sp and other small pelagic fish species. Eastern little tuna (Figure 1), is an economically important type of fish with a high utilization rate from nature through quite intensive fishing activities using purse seine and gill net fishing gear, where the production of Eastern little tuna tends to increase every year.

![Figure 1. Eastern Little Tuna (*Euthynnus affinis*).](image-url)

Increased production of eastern little tuna will certainly have a good impact on economic activities and fishermen's income, but on the other hand it will have an effect on these fish resources. According
2nd International Conference on Fisheries and Marine  IOP Publishing
IOP Conf. Series: Earth and Environmental Science 890 (2021) 012053   doi:10.1088/1755-1315/890/1/012053

2nd International Conference on Fisheries and Marine  IOP Publishing
IOP Conf. Series: Earth and Environmental Science 890 (2021) 012053   doi:10.1088/1755-1315/890/1/012053

Growing activities are resource utilization activities that can threaten the extinction of fish resources, if using non-selective types of fishing gear. Purse seines and gill nets in Ternate Island waters are quite intense fishing gear in fishing operations [2], where fishing activities should be carried out with technology that pays attention to resource and environmental sustainability so that resources can be sustainable and not extinct and can be used sustainably [3].

Seeing the use of this type of tool and the intensive operation time of eastern little tuna fishing resources in the waters of Ternate Island, the population aspects of the eastern little tuna fish resources need to be studied so that they can be used continuously so their utilization and management must be carried out rationally. Information on the dynamics of the tuna population is expected to be the basis for its management.

Assessment of population dynamics parameters including asymptote length (L∞), growth coefficient (K), total mortality (Z), natural mortality (M), mortality due to capture (F), exploitation rate (E), size of first caught by fishing gear (Lc), and the relative yield per recruit (Y/R'). This information is very important to know as information for management so that tuna resources in the waters of Ternate Island can be maintained and provide benefits for fishermen.

2. Materials and method

This research was conducted from January to April 2021 in Ternate Waters (Figure 2) with the object of research being the catch of eastern little tuna (Euthynnus affinis) caught by purse seine dan gill net fishermen. The research data collection procedure was carried out by measuring the total length of the fish caught per fishing trip for 4 months using a meter with a unit (centimeter) cm and an accuracy of 1 mm.

![Figure 2. Map of sampling locations](image)

The length measurement of eastern little tuna was carried out on all purse seine dan gill net vessels operating by identifying the length of the fish starting from the forefront of the mouth to the tip of the tail. The data from the measurement results are then grouped per trip and the month of capture are then inputted to Microsoft Excel for further analysis of population parameters and displayed in tables and graphs using the Fisat-II software.

The population parameters analyzed are identification of age groups, estimation of age groups (cohort), analyzed using the Bhattacharya method in [4], with a mathematical formula:

\[
F_c = \frac{n dl}{s \sqrt{2\pi}} \exp \left[ \frac{-(x-\bar{x})^2}{2\sigma^2} \right]
\]

Description : \(n\) = number of samples, \(dl\) = change in length of fish, \(s\) = standard deviation, \(x\) = length of eastern little tuna \((i = 1, 2, 3, \ldots n)\) and \(\bar{x}\) = average length of eastern little tuna \(a\).

Growth parameters \((L, \infty, K)\) and \(t_0\), estimation of growth parameters was carried out using the Ford and Walford method in [4], namely by plotting \(L(t + \Delta t)\) and \(L(t)\) with the mathematical formula:

\[
\frac{dL}{dt} = K(L - L_m)
\]

Description : \(L\) = length of eastern little tuna \((i = 1, 2, 3, \ldots n)\), \(t\) = time of capture, \(K\) = growth coefficient, \(L_m\) = mean length of eastern little tuna, \(L_0\) = initial length of eastern little tuna, \(\Delta t\) = time interval.
\[ L(t + \Delta t) = a + b \cdot L(t) \quad (2) \]

After getting the regression equation from the two relationships then it is entered into the linear equation, namely:

\[ Y = a + bX, \text{ with } a = L_\infty (1-b) \text{ and } b = \exp (-K \cdot \Delta t), \quad (3) \]

So that it is obtained:

\[ L_\infty = \frac{a}{1-b} \text{ and } K = \frac{-1}{\Delta t} \ln b \quad (4) \]

Furthermore, the estimation of the theoretical age when the length of eastern little tuna is equal to zero \((t_0)\), the Pauly empirical formula in [4] is used, with the mathematical formula:

\[ \log (t_0) = -0.3922 - 0.2752 \log L_\infty + 1.308 \log K \quad (5) \]

Description : \(L_t = \) length of fish at age \(t\) (unit of time), \(L_\infty = \) asymptotic length, \(K = \) growth coefficient and \(t_0 = \) theoretical age when length equals zero.

Estimation of natural mortality, natural mortality rate \((M)\) is estimated using the empirical formula of [5] in [4], with a mathematical formula:

\[ \ln M = -0.0152 - 0.279 \cdot \ln L_\infty + 0.6543 \cdot \ln K + 0.463 \cdot \ln T \quad (5) \]

Description : \(M = \) natural mortality, \(L_\infty = \) asymptotic length, \(K = \) growth coefficient and \(T = \) mean surface temperature \(^{\circ}\)C

Estimation of total mortality \((Z)\), estimation of total mortality \((Z)\) were analyzed using the Baverton and Holt methods in [4], where the mathematical formula used is:

\[ Z = K \left[ \frac{L_\infty - L}{L - L'} \right] \quad (6) \]

Description : \(Z = \) total mortality rate (per year), \(L_\infty = \) length of eastern little tuna asymptote (cm), \(K = \) growth rate coefficient (per year), \(L = \) average length of caught eastern little tuna (mm) and \(L' = \) smallest limit of length of fully caught eastern little tuna (cm).

Estimation of fishing mortality \((F)\) and exploitation rate, catch mortality is obtained by the equation \(Z = F + M\), so that \(F = Z - M\) and exploitation rate \((E)\) are obtained using the Beverton and Holt formulas, namely \(E = F / Z\), where \(F\) is capture mortality value and \(Z\) is total mortality [4]. The optimum exploitation rate according to [6]:

\[ F_{opt} = M \text{ dan } E_{opt} = 0.5 \quad (7) \]

Yield per Recruitment, \(Y/R\) was analyzed using the Beverton and Holt method (Sparre and Venema, 1999), using the formula:

\[ Y/R = E \cdot U \cdot \frac{M}{1 + m} \cdot \frac{3U^2}{1 + 2m} + \frac{U^3}{1 + 3m} \quad (8) \]

With :

\[ U = 1 - \frac{L_t}{L_\infty} ; \quad m = \frac{1 - E}{M/K}; \quad E = F/Z \quad (9) \]

Where : \(E = \) Exploitation Rate, \(L' = \) Minimum length of fish caught in full, \(M = \) Natural mortality rate, \(K = \) Coefficient of growth rate, \(L_\infty = \) Asymptote length, \(F = \) Catch mortality

3. Results and discussion

3.1. Size structure

Fork length measurements were randomly carried out on 1,282 fish from January to April 2021, with the frequency distribution of fork lengths per month during the study shown in Figure 3. In Figure 3, it
can be seen that the population structure of eastern little tuna in January to April 2021 has the long mode changes to the right significantly, which shows that the population of eastern little tuna in the waters of Ternate Island continues to grow every month during the study.

**Figure 3.** Fork length distribution of eastern little tuna in Ternate Island waters during January to April 2021.

The actual distribution of eastern little tuna length in the waters of the island of Ternate is greater than the length of eastern little tuna presented in Table 1 including in Pelabuhan Ratu [7], the coast of the Persian Gulf and the sea of Oman [8], Indian waters [9], and smaller if compared with the catch of tuna in the waters of Morotai Island [10], Natuna waters [11] and Java Sea [12]. The results of these studies show that the frequency distribution of the length of eastern little tuna is different in each waters. The difference in the length of the fish caught is thought to be due to differences in the fishing gear used, environmental conditions and variations in fishing intensity [13].

**Table 1.** Several research results regarding the growth parameters of eastern little tuna (*Euthynnus affinis*) in various waters.

| Source               | Location                  | Growth Parameters | Length (Cm) |
|----------------------|---------------------------|-------------------|-------------|
|                      |                           | **K**             | **L∞ (Cm)** | **t₀** | **Min** | **Maks** |
| Nurhayati (2001)     | Pelabuhan Ratu            | 0.48              | 75.12       | -0.26  | 20      | 60       |
| Motlagh et al, (2010)| Persian Gulf and Oman sea| 0.51              | 87.6        | -0.23  | 41      | 85       |
| Rohit et al (2012)   | Indian waters             | 0.56              | 81.20       | -0.03  | 14      | 80       |
| Fayerti et al, (2013)| Natuna waters             | 0.23              | 54.0        | -0.27  | 30.5    | 49.5     |
| Chodrijah et al, (2013)| Java waters           | 0.91              | 59.63       | -0.178 | 11.7    | 55.4     |
| Tangke (2014)        | Morotai island waters     | 0.5               | 42.53       | -0.32  | 16.0    | 41.3     |
| Penelitian ini (2014)| Ternate island waters     | 0.25              | 68.25       | -0.20  | 8.7     | 64.5     |
3.2. Growth parameters

The results of the analysis of the growth parameters of tuna using the Von Bertalanffy formula with ELEFAN I software, the asymptote length ($L_\infty$) was 68.25 cm, the growth coefficient ($K$) was 0.25 and the theoretical age of the fish at zero length ($t_0$) was -0.20, where with the value of the growth parameters above, the Von Bertalanffy eastern little tuna growth rate curve is obtained as shown in Figure 4.

![Figure 4](image)

Based on the value of these growth parameters, a mapping of the growth rate of eastern little tuna in the waters of Ternate Island was carried out with the equation $L_t = 68.25(1 - \text{Exp}^{-0.28(t-(t_0))})$ with a picture of the growth rate per month can be seen in Figure 5. Condition value The growth parameters of eastern little tuna in the waters of Ternate Island compared with the results of other studies (Table 1) are also thought to be due to differences in the length of fish caught, differences in fishing gear used, environmental conditions and variations in fishing intensity [13]. Based on the three growth parameter values obtained in the waters of Ternate Island, if using the Von Bertalanffy growth equation, the growth equation for tuna (Euthynnus affinis) in Ternate Island waters is $L_t = 68.25(1 - \text{Exp}^{-0.28(t-(t_0))})$. The growth equation was used to analyze the length of eastern little tuna (Euthynnus affinis) in the waters of Morotai Island for each relative age so that the annual increase in length can be calculated until it reaches its asymptotic length (Figure 5).

![Figure 5](image)

3.3. Mortality

Mortality for exploited fish is a combination of natural mortality and fishing mortality ([6]; [4]; [14]). Natural mortality ($M$) was calculated based on the empirical formula [5] using data on fish growth parameters and average annual water surface temperature. The results of the analysis show that the natural mortality value of eastern little tuna using the average annual temperature of the Ternate Island
waters of 28°C is 0.43 per year, with the total mortality (Z) calculated from the length converted catch curve. 0.64 per year.

Table 2. Mortality Value and Exploitation Rate of eastern little tuna in Ternate Island Waters

| Parameter                | Estimated Value |
|--------------------------|-----------------|
| Total mortality (Z)      | 0.72            |
| Natural mortality (M)    | 0.42            |
| Catch mortality (F)      | 0.21            |
| Exploitation rate (E)    | 0.33            |

The results of the analysis carried out using fishing data for 4 months can be concluded that in the waters of Ternate Island the mortality of eastern little tuna fishing is lower in natural mortality (M = 1.05 and F = 0.93), this is presumably due to the lack of trips and vessels carrying out fishing activities, because low fishing activity.

3.4. Catch probability

The probability of fish escaping and being caught by the net depends on the dimensions of the fish, where if the relationship between the probability of being caught by the net and the dimensions of the fish's body is plotted in graphical form, a pattern called the catch probability curve will be obtained. The probability curve in Figure 6 shows that a fish size of 48.34 cm has a 25% chance of being caught, while a fish size of 52.23 cm and 56.63 cm has a 50% and 75% chance of being caught, respectively. This curve is then used to estimate the length of the fish when it was first caught by the net (Lc). for non-selective nets, the probability for this Lc is assumed to be 50%.

![Probability curve of eastern little tuna catches in Ternate Island waters](image)

The estimated value of Lc above shows that the average size of fish caught by operating fishing gear is a group of fish that have already spawned, so to maintain the availability of eastern little tuna species stocks in the waters of Ternate Island, the Lc value is maintained so that population conditions are maintained. fish can stay awake.

3.5. Exploitation rate and yield per recruit

After obtaining the total mortality and natural mortality values, then using equation [5], the capture mortality (F) and exploitation rate (E) are 0.21 and 0.33 respectively (Table 2). The results of the analysis of the exploitation rate of eastern little tuna (Euthynnus affinis) in the waters of Ternate Island is 0.33, this result indicates that the exploitation rate of eastern little tuna in Ternate Island is close to
the optimum level. In order to keep the fish population stable in the waters of Ternate Island, the exploitation rate is suggested to be maintained or increased until it reaches the optimum level, namely \( E_{\text{opt}} = 0.5 \). Optimum capture occurs, if and only if the population is in a state of balance (rejuvenation number = mortality, migration and emigration) [15].

Yield per recruit in the Beverton & Holt model is a function of the exploited age composition. Estimation of yield per recruitment is a commonly used model as the basis for fisheries management strategies, because this model provides an overview of the effects of management activities (Gulland, 1983). The results of the analysis showed that the \( Y/R \) value was 0.06, which means that the number of tuna that entered the waters and was caught by fishermen was 6.0%.

4. Conclusion
Condition parameters of the eastern little tuna population in Ternate Island waters are still relatively stable, this can be seen from the population parameters, namely the maximum length of 68.25 cm, growth coefficient of 0.25 per month, total mortality of 0.72 with fishing mortality which is smaller than natural mortality, namely 0.21 and a higher exploitation rate. just reached 0.33 smaller than 0.5.

References
[1] Pramesthy T D, Ratu S, Mardiah, Shalichaty, Arkham S M N, Kusuma, Haris R B, Kelana, P P Djunaidi 2020 J. Aurelia. 1 (2): 103-112.
[2] DKP Kota Ternate 2018. Laporan Tahunan Statistik Perikanan Tangkap Kota Ternate (Ternate: Maluku Utara)
[3] Rofiqo I S, Zahidah, Kurniawati N, Dewanti L P 2019. J. Perikanan dan Kelautan, X (1) : (64-69).
[4] Saprre P dan S C Venema 1999 Introduksi Pengkajian Stok Ikan Tropis. Pusat Penelitian dan Pengembangan Badan Penelitian dan Pengembangan Pertanian Jakarta (Jakarta: Indonesia)
[5] Pauly D 1983 Some Simple Method For The Assessment of Tropical Fish Stock (FAO Fisheries Technical Paper) 52p
[6] Gulland J A 1983. Fish Stock Assessment A Manual Basic Methods. Willey. New York.
[7] Nurhayati S 2001 Analisis Beberapa Aspek Potensi Ikan Tongkol (Euthynnus affinis) di Perairan Pelabuhan Ratu (Institut Pertanian Bogor)
[8] Motlagh T S A, Hashemi S A, Kochanian P 2010 Population Biology and Assessment of Kawakawa (Euthynnus affinis) in Coastal Waters of the Persian Gulf dan Sea of Oman (Hormozgan Province). Iranian J. of Fisheries Sciences 9 (2) : 315-326.
[9] Rohid P, Chellapappan A, Abdussamad EM, Joshi KK, Koya KPS, Sivadas M, Ghosh little tuna, Euthynnus affinis (Cantor, 1849) exploited from Indian Waters . Indian J. Fish. 59 (3): 33-42.
[10] Tangke U 2014 J. AGRIKAN 7 (2): 8-14.
[11] Fayertj W R, Efrizal T, Zulfikar 2013 J Umrah. WAN-RITA-FAYETRI-090254242071.pdf
[12] Chodrijah U, Thomas H dan Teguh N 2013 J. Bawal Vol 5 (3) Des. 2013: 167-174
[13] Motlagh, T.S.A., S.A. Hashemi, and P Kochanian 2010 Iranian. J. of Fisheries Sciences, 9(2):315-326.
[14] Effendie M I 2002 Biologi Perikanan (Yayasan Pustaka Nusatama. Yogyakarta)
[15] Susilo S B 1995 Model-Model Penting dalam Dinamika Populasi dan Pengelolaan Stok IKan. Komplemen Diktat Kuliah Dinamika Populasi Ikan dan Biologi Perikanan (Fakultas Perikanan dan Ilmu Kelautan. IPB. Bogor)