A population dynamic aspect of *Selaroides leptolepis* in the coastal waters of South Ternate Island, Indonesia

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Abstract. This research aimed to examine the population dynamic parameters of *Selaroides leptolepis* including age group, growth, mortality, exploitation and yield per recruit. The research was conducted in June-August 2015 in the Waters of Ternate Island and based in Sasa Village, Ternate Selatan Sub-district. The samples were measured in the Fishery Products Processing Laboratory, Muhammadiyah University of North Maluku. 1,043 individuals of *Selaroides leptolepis* which measured 8.2-21.7 cm in length were taken as samples. The research results showed that the population dynamic of *S. leptolepis* in the waters of Ternate Island consistsed of 11.77 cm, 15.97 cm, and 19.39 cm age groups measuring 22.78 cm in asymptotic length (L_∞), 0.28 cm in growth rate coefficient (K) and -0.64 in theoretical lifespan. *S. leptolepis* has total mortality rate (Z) of 1.43 per year, natural mortality rate (M) of 0.64 per year, fishing mortality rate (F) of 0.79 per year, and exploitation rate (E) of 0.55 and yield per recruit (Y/R) of 0.02 g per recruitment. The condition of *S. leptolepis* resource in the Waters of Ternate Island is nearly over fished, mainly caused by high exploitation rate, amount of fishing effort and unstable environmental condition.

Key Words: asymptotic length, growth, mortality, exploitation, Y/R.

Introduction. The waters of Ternate Island have very high potential of fish resources (Gill & Allen 2011; Hariey & Baskoro 2011), which consist of pelagic fish and demersal fish. Pelagic fish are a fishery resource most commonly exploited by fishermen in the waters of Ternate Island. According to the (DKP Ternate 2011), the waters of Ternate Island has a potential of sustainable fishery of 47,838.25 ton per year, while its current exploitation is 60.80% or approximately 28,703 tons, consisting of big pelagic fish such as skipjack tuna (*Katsuwonus pelamis*), mackerel tuna (*Euthynnus affinis*), swordfish (*Xiphias gladius*), Spanish mackerel (*Scomberomorus maculatus*), flying fish (*Cypselurus hiraii*), *Selaroides leptolepis*, red snapper (*Lutjanus vitta*), Lethrinidae, yellow tile (*Caesio cuning*) and various types of groupers (DKP Ternate 2011). An increasing exploitation will not only improve people's welfare and employment, but also result in negative impact if it is performed uncontrollably and out of consideration (Dalzell & Pauly 1990).

Selaroides leptolepis (Froese & Pauly 2018) is a highly exploited pelagic fish of which production value is 85% of the existing sustainable potential in the waters of Ternate Island (Sala et al 2018). In many places, like in Java, fishermen find it difficult to catch *S. leptolepis* (Syakila 2009; Andriani et al 2015). An increasing demand for this commodity and its relatively high price has resulted in over fishing (Van Oostenbrugge et al 2001), which cause *S. leptolepis* population to decline in nature. In addition, high intensity of spawning and young *S. leptolepis* catching may disturb its population stability and reproduction process, which eventually prevents its new stock or recruitment (Powers & Monk 2010; Munyandorero 2018).

Fish resources conservation is a management policy to restrict fish resources exploitation, which may be a regulation or guidance of biological (Parsons et al 2018), ecological (Dalzell & Pauly 1990), economic and social aspects (McLeod et al 2009; Nobre et al 2009; Yonvitner 2012). Fishery resources policy is intended to determine a balance of maximum production per unit effort (Effendie 1979; Campbell 2004; Powers & Monk 2010; Andriani et al 2015). Non-regulated continuous catching will cause an overfishing and then disturb fishery resources sustainability (Powers & Monk 2010; Munyandorero 2018). One of the important data we need to examine as our consideration in fishery regulation and management in the waters is the population dynamic aspect (Beverton & Holt 1957; Rochmady & Susiana 2014; Susiana & Rochmady 2018).

A research on population dynamic status related to the management and exploitation of *S. leptolepis* resource in the waters of Ternate Island has never been conducted. This research may become an effort to manage and exploit *S. leptolepis* resource by observing several population dynamic parameters. The population dynamic parameters include age group, growth, mortality and yield per recruitment in the coastal waters of Ternate Island. This research aimed to examine the population dynamic aspect of *S. leptolepis* in the waters of Ternate Island.

Material and Method. This research wass conducted in June-August 2017 and based in Sasa Village, Ternate Selatan Sub-district. The samples were measured in the Fishery Products Processing Laboratory, Faculty of Agriculture Muhammadiyah University of North Maluku, Ternate, Indonesia.

Equipment and materials. This research employs 1 unit of computer to process and analyze the data and stationery, fish measuring board and thermometer as its equipment and caught *S. leptolepis* and ice cubes for fish preservation as its materials.

Working method. A number of *S. leptolepis* caught by fishermen were taken as research samples and measured two to three times within three months. The samples were then identified and measured on a fish measuring board in the Fishery Products Processing Laboratory.

Data analysis. Growth was estimated using a formula proposed by Von Bertalanffy (Sparre & Venema 1999) with the following equation:

$$L_t = L\infty(1-\exp^{-K(t-t_0)})$$

Description: L_t = length (cm) at the age of (t), L_∞ = asymptotic length (cm), K = Growth coefficient (per year), t_o = theoretical age when its length is equal to zero (year), t = age (year).

Meanwhile, the method of Ford & Walford in Sparre & Venema (1999) was used to determine asymptotic length and growth rate coefficient (K) by plotting L(t + Δt) and L(t) using an equation.

$$L(t+\Delta t) = a + b.\ L(t)$$

The regression equations obtained from both correlations are then inserted into the following linear regression equation: Y = a + b X, where: a = L_∞ (1-b) and b = exp (-K. Δt).

$$L\infty = \frac{a}{1-b}$$

$$K = \frac{-1}{\Delta t}\text{Ln } b$$

To estimate the theoretical age when the length is equal to zero (t_0) the Pauly's empirical formula is used provided by Sparre & Venema (1999).

$$\text{Log}(-t_0) = -0.3922 - 0.2752 \text{ Log } L\infty - 1.308 \text{ Log } K$$

Description: L_∞ = asymptotic length (cm), K = Growth coefficient (per year), t_0 = theoretical age when its length is equal to zero (year).

Natural mortality estimation (M) was estimated using Pauly (1984) empirical formula:

$$\text{Ln } M = -0.152 - 0.279 \text{ Ln } L\infty + 0.6543 \text{ Ln } K + 0.4634 \text{ Ln } T$$

Description: M = Natural mortality (per year), L∞ = asymptotic length (cm), K = Growth coefficient (per year), T = Average annual surface temperature (°C)

Total mortality estimation (Z) was analyzed using a method of Beverton & Holt (Sparre & Venema 1999) with the following formula:

$$Z = K\left[\frac{L\infty - \bar{L}}{\bar{L} - L'}\right]$$

Description: Z = Total mortality rate (per year), L_∞ = asymptotic length (cm), K = Growth coefficient (per year), $\bar{L}$ = Caught average length (cm), L' = Lowest limit of caught full length (cm).

Catching mortality (F) was measured using the equation Z = F + M, thus F = Z – M and exploitation rate (E) by measured using Beverton & Holt formula: E = F/Z, in which F is catching mortality value and Z is total mortality (Sparre & Venema 1999).

Yield per recruitment was measured using Beverton & Holt formula (Sparre & Venema 1999):

$$Y/R = E.U^{M/K}\left(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right)$$

$$U = 1 - \frac{L'}{L\infty}$$

$$m = \frac{1-E}{M/K}$$

Description: M = Natural morality (per year), L' = Lowest limit of caught full length (cm), L_∞= asymptotic length (cm), K = Growth rate coefficient (per year).

Result and Discussion

Age group. The research samples taken were 1,043 individuals of *S. leptolepis* which measure in length 8.2-21.7 cm. They were classified according to size class and then the frequency was calculated according to age group (Figure 1). From the existing size groups, 78 individuals measuring 16-16.4 cm in length were found to be the highest number of length frequency, while 5 individuals measuring 8-8.4 cm and 21.5-21.9 cm in length were found to be the lowest number of length frequency out of the total research results. Three age groups of *S. leptolepis* were found according to the results of analysis conducted by Bhattacharya (Sparre & Venema 1999) using the result of mapping of the difference of natural logarithm of theoretical frequency with classes' mean value.

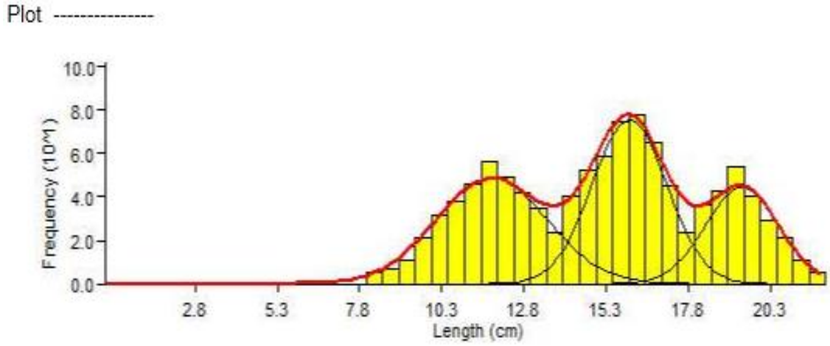

Figure 1. Mapping of classes' mean value with the difference of natural logarithm of *Selaroides leptolepis* cumulative frequency in each age group using FISAT II program.

According to the results of research conducted by Hardiyansyah (2015), the 600 individuals of *S. leptolepis* caught by TPI Barek Motor, Kijang Village, Bintan Regency found length range of 16-30 cm. Different results were obtained in the waters of Ternate Island, where the smallest *S. leptolepis* measured 8.2 cm in length in the present research. This is expectedly because of catching and environmental factors, which cause only small sized *S. leptolepis* to be caught, while no large *S. leptolepis* are caught since they have been caught before reaching certain size. The mapping of total length logarithm against the classes' mean value in this research resulted in 3 average lengths, respectively measuring 11.77 cm, 15.97 cm, and 19.39 cm in length.

The relationship of length range, relative age and average length of *S. leptolepis* in Ternate waters may be viewed in Table 1, while the chart of mapping of the difference of natural logarithm of theoretical frequency with classes' mean value may be viewed in Figure 1.

Table 1

Relationship of length range, average length and relative age of *Selaroides leptolepis* in the waters of Ternate Island

Relative age (year)	*Length range (cm)*	*Average length (cm)*
I	8-13.9	11.77
II	13.5-17.9	15.97
III	18-21.9	19.39

Fishbase recorded the first length of maturity of 11.9 cm, in the range of 9-11 cm, max length of 22.0 cm, weight 625.0 g. Meanwhile, Sala et al (2018) recorded the first length of maturity of 14.90 cm (SD 3.20 cm). Thus, the length of *S. leptolepis* in Ternate Island waters is higher than those previously recorded. So the results of the present study provide new information about the length range of *S. leptolepis* in three age groups.

The existence of differences in recruitment patterns is likely due to differences in environmental conditions and the fertility of the waters of Ternate Island compared with other waters. More fertile waters can cause the spawning period of yellow tail fish to occur more than once per year (Jalil & Ali 2001).

Growth. An analysis using Ford-Walford method (Sparre & Venema 1999) resulted in the asymptotic length (L_∞) of *S. leptolepis* in the waters of Ternate Island of 22.78 cm and the growth coefficient (K) of 0.28 per year. Meanwhile, the t_0 value obtained by using formula of Pauly (1980) is -0.642. Based on the L_∞, K, and t_0 values obtained by using Von Bertalanffy equation, an equation of the growth of *S. leptolepis* in the waters of Ternate Island is obtained as follows $Lt = 22.78\ (1\text{-}exp^{0.28(t+0.64)})$ (Figure 2). From the growth equation, we may examine the length of *S. leptolepis* of different relative ages, thus its annual accretion of length until its asymptotic length may be calculated.

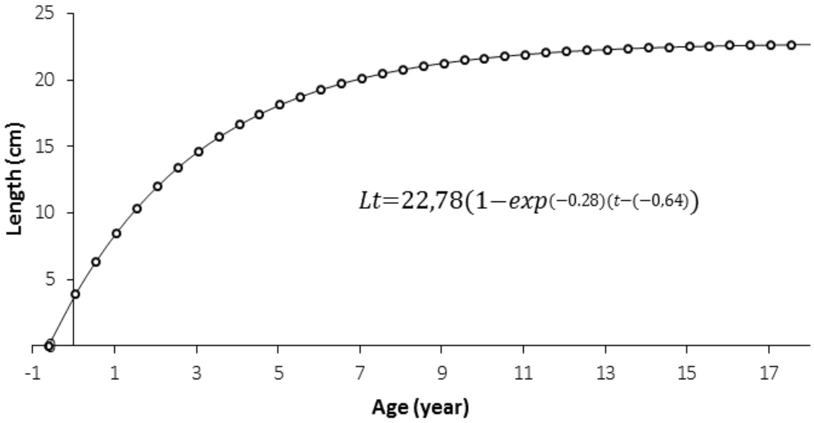

Figure 2. Growth of *Selaroides leptolepis* around the waters of Ternate Island. Lt is growth, exp is exponential, and t is time (year).

The research results, as reflected in the growth chart of Figure 2, which show that *S. leptolepis* growth is quite rapid when they are young, which is in line with Azis (1989) which proposes that *S. leptolepis* length growth occurs when they are young and gets slower when they get adult until they reach their asymptotic length. In addition, young *S. leptolepis* rapid growth occurs since their feed-based energy is mostly used for growth, while old *S. leptolepis* feed-based energy is not used for their growth, but only for self-protection and cell regeneration (Jalil & Ali 2001).

The growth rate of *S. leptolepis* which live around Ternate waters is low, which is 0.28 per year and *S. leptolepis* maximum length value (L_∞) is 22.78 cm, thus it takes long time for them to reach their maximum length. This is in line with a statement of Sparre & Venema (1999) that it takes short time for a fish with high growth rate coefficient value to reach its asymptotic length or maximum length, while it takes long time for a fish with low growth rate coefficient value to reach its asymptotic length.

Another research conducted by Hardiyansyah (2015) in TPI Barek Motor, Bintan Regency states that K = 0.139 (per year) and L_∞ = 34 cm, while in the present research, the growth rate of *S. leptolepis* in the Waters of Ternate Island was 0.28 (per year) and L_∞ = 22.78.

Mortality. The total mortality rate estimation (Z) was analyzed using a method of Beverton & Holt (Sparre & Venema 1999). *S. leptolepis* expected total mortality value (Z) is 1.43 per year, while the expected natural mortality value (M), analyzed using empirical formula of Pauly (1980) by inserting K value = 0.28 per year, L_∞ = 22.78 cm and waters average temperature of 28°C, is 0.64 and the catching mortality rate value (F) is found 0.79 per annum by subtracting M from Z. The exploitation rate value (E) is obtained by dividing F by Z, resulting in E = 0.55 per year.

According to Table 2, we may view that the natural mortality value (M) is lower than the catching mortality (F), and this shows that the death of *S. leptolepis* in the waters of Ternate Island is caused more by catching factor, which makes its stock significantly decline.

Non-regulated continuous catching will cause an overfishing and then disturb *S. leptolepis* resource sustainability.

Another research conducted by Hardiyansyah (2015) in TPI Barek Motor, Bintan Regency shows that the total mortality value (Z) is 0.644, the natural mortality value (M) is 0.379, the catching mortality value (F) is 0.27 and the exploitation (E) is 0.41. Meanwhile, *S. leptolepis* in the waters of Wondama Bay (Cendrawasih Bay National Park) reported naturally mortality (M) of 4.19 per year, fishing mortality (F) of 5.01 per year, and total mortality (Z) of 9.20 per year (Sala et al 2018). In comparison to the results of the present research, we may examine an indication that the exploitation rate in the waters of Ternate Island is very high, which is influenced by overfishing and makes the population of *S. leptolepis* in the waters of Ternate Island continuously decline and they have not reached certain length for appropriate catching.

Table 2
Expected mortality value and exploitation rate of *Selaroides leptolepis* in the waters of Ternate Island

Population parameters	*Estimation value (per year)*
Total Mortality (Z)	1.43
Natural Mortality (M)	0.64
Fishing Mortality (F)	0.79
Exploitation rate (E)	0.55

Exploitation rate and yield per recruitment. Expected stock yield per recruitment (Y/R) is a model commonly used as the basic strategy for fishery management (Munyandorero 2018). This analysis is necessary in fishery resources management (Mous et al 2018), as this model provides an overview of short-term and long-term influences of different actions (Gulland 1983). The expected Y/R value is then analyzed using Beverton & Holt method in Sparre & Venema (1999) by inserting the values given in Table 3.

Table 3
Expected parameters used as input in the analysis on yield per recruitment of *Selaroides leptolepis* in the waters of Ternate Island

Population parameters	*Value (per year)*
Growth rate coefficient (K)	0.28
Asymptotic Length (L_∞)	22.78
Total Mortality (Z)	1.43
Natural Mortality (M)	0.64
Fishing Mortality (F)	0.79
Exploitation Rate (E)	0.55

According to the analysis results in Table 3, we may examine that the expected Y/R value is 0.02 g per recruit. This means that 0.79 g is taken as catching yield for any occurring recruitment. The current E value is 0.55 with Y/R = 0.02 g per recruitment, the E_{opt} = 0.70 and current E = 0.55 as we may view in the Figure 3.

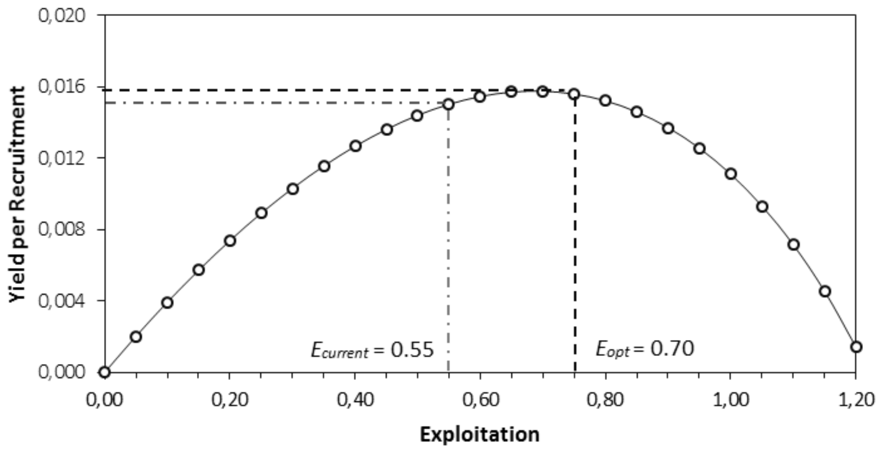

Figure 3. Relationship of yield per recruitment (Y/R) with exploitation rate value (E) of *Selaroides leptolepis* in the waters of Ternate Island. $E_{current}$ is exploitation rate current, E_{opt} is exploitation rate optimum.

In Figure 3, we may view that the current E value is 0.55 and E_{opt} is 0.70. This means that the exploitation rate in the waters of South Ternate is high. The total mortality of the findings (Z=1.43) (Table 3) was lower than total deaths on the eastern coast of Bintan Island, Z=4.45 (Sudradjat 2006), while the *S. leptolepis* in the area has only one recruitment peak in one year. However, the catch of *S. leptolepis* in the waters of Ternate Island is relatively the same as the *S. leptolepis* in the waters of the Sunda Strait, experiencing excessive catch (Nirtiawa 2016). The capture of *S. leptolepis* in the waters of Ternate Island without regulation makes resources decrease.

Conclusions. The *S. leptolepis* population in the coastal waters of South Ternate Island, Indonesia consists of three age groups, has an asymptotic length value (L_∞) of 22.78 cm, a slow growth rate and a catching mortality rate higher than natural mortalities. The sustainability is threatened by overfishing, as the result of exploitation rate and relatively unstable environmental factors such as temperature and chlorophyll-a.

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