DOI: 10.2478/cjf-2022-0019

**CODEN RIBAEG ISSN 1330-061X (print)
1848-0586 (online)**

sciendo

GROWTH AND MORTALITY, RECRUITMENT AND EXPLOITATION RATE OF FRINGESCALE SARDINELLA *Sardinella fimbriata* (Valenciennes 1847) IN ROTE ISLAND IN THE SAVU SEA

Fanny Iriany Ginzel[1,2], Diah Permata Wijayanti[1], Subagiyo, Agus Sabdono[1*]

[1] *Marine Science Department, Fisheries and Marine Science Faculty, Diponegoro University, Semarang, Indonesia*

[2] *Aquatic Resource Management, Christian University of Artha Wacana, Kupang, East Nusa Tenggara, Indonesia*

*Corresponding Author: agus_sabdono@yahoo.com

ARTICLE INFO

Received: 9 June 2022
Accepted: 2 November 2022

Keywords:
Length-weight relationship
Population dynamics
Natural mortality
Fishing mortality

ABSTRACT

Fringescale sardinella is one of the largest fishery resources and has the highest economic value in the Savu Sea. The increasing demand for this fish makes it one of the main fishing targets, which allows overfishing to occur. Therefore, the purpose of this study was to determine the population dynamics of sardinella fringescale through growth and mortality, recruitment and exploitation rate of fringescale sardinella in Rote Island in the Savu Sea.

A total of 1095 fish sampled from Rote Island were assessed and showed the total length (TL) range from 90 mm to 157 mm. Further, the data were analyzed using FISAT II software with the following results: the length-weight relationship was $W= 0.0004L^{2.2523}$, while the negative allometric growth pattern and growth equation was $Lt = 165.26\ (1 - \exp^{1,500\ (t + 0.0585)})$. The age of *S. fimbriata* consisted of 1-2 cohorts. Recruitment of *S. fimbriata* in Rote Island occurred throughout the year with the highest peaks in May and August. The size of the first caught fish (Lc) was 96.98 mm TL. The total mortality rate (Z) was 2.41 yr^{-1}, natural mortality (M) was 1.45 yr^{-1} and fishing mortality (F) was 0.97 yr^{-1}. The exploitation rate of *S. fimbriata* is estimated at 0.40 yr^{-1}; this implies that the stock does not exceed the optimum exploitation rate (E = 0.5) or that overfishing has not occurred in the Savu Sea. Nevertheless, this study's results are sufficiently robust to anticipate that the unprecedented overexploitation of *S. fimbriata* in Rote Island has nearly occurred. Therefore, regular monitoring and surveillance of surface gillnet fishing gear are urgently needed.

How to Cite

Ginzel, F.I., Wijayanti, D.P., Subagiyo, Sabdono A. (2022): Growth and mortality, recruitment and exploitation rate of fringescale sardinella *Sardinella fimbriata* (Valenciennes 1847) in Rote Island in the Savu Sea. Croatian Journal of Fisheries, 80, 189-196. DOI: 10.2478/cjf-2022-0019.

INTRODUCTION

Indonesia is an archipelagic country with 17,500 islands and 99,093 km of coastline. This rich diversity of biological resources makes Indonesia one of the centers of megadiversity in the world (Ali and Sulistiyono, 2020). However, many obstacles are faced in managing, protecting and preserving coastal and marine bioresources. Several factors such as pollution, destructive fisheries and the development of land areas, industry and coastal settlements threaten to damage the marine environment. Many ways and efforts have been made by the government in maintaining and conserving this marine and coastal biodiversity. One way that is considered successful in efforts to preserve and protect the marine environment is to establish several forms of marine conservation areas, including fishery reserves, marine parks, marine reserves and protected coastal areas (Wiadnya et al., 2011). Experts believe that the proper management of marine protected areas can prevent a decline in fish populations and habitat destruction.

The Savu Sea as the center of the Marine National Park, which has been protected as a marine conservation area, is a marine area that has a fairly high diversity of fisheries and other marine resources. The Savu Sea Marine National Park (SMNP) was established through Ministerial Decree No. KP. KEEP. 38/MEN/2009. The area of the SMNP is more than 3.5 million hectares and is one of the largest marine national parks owned by Indonesia, even the largest in Southeast Asia (ASEAN Records, 2018). The SMNP extends from west to east along 600 km and from north to south along 250 km, in addition, it is located in the area of the Indonesian cross-flow trajectory (Arlindo) which is the confluence of two currents from the Pacific Ocean and the Indian Ocean. These two currents of the Savu Sea (currents flow into the Savu Sea from the west and northeast) are sites of upwellings and other oceanographic processes which benefit marine fish populations. The SMNP is very important and strategic for the development in East Nusa Tenggara Province because it can contribute more than 65% of the potential commercial fish resources from some districts/cities including Rote Ndao District (BKKPN Kupang, 2019).

Fringescale sardinella *Sardinella fimbriata* (Valenciennes 1847) is a small pelagic fish from the family Clupeidae. It is an important resource for commercial fisheries and can account for about one-third of marine fisheries production (Nelson et al., 2016). More than 2 million tonnes of Sardinella fish are caught annually in the world's waters, making this group the fourth largest contributor

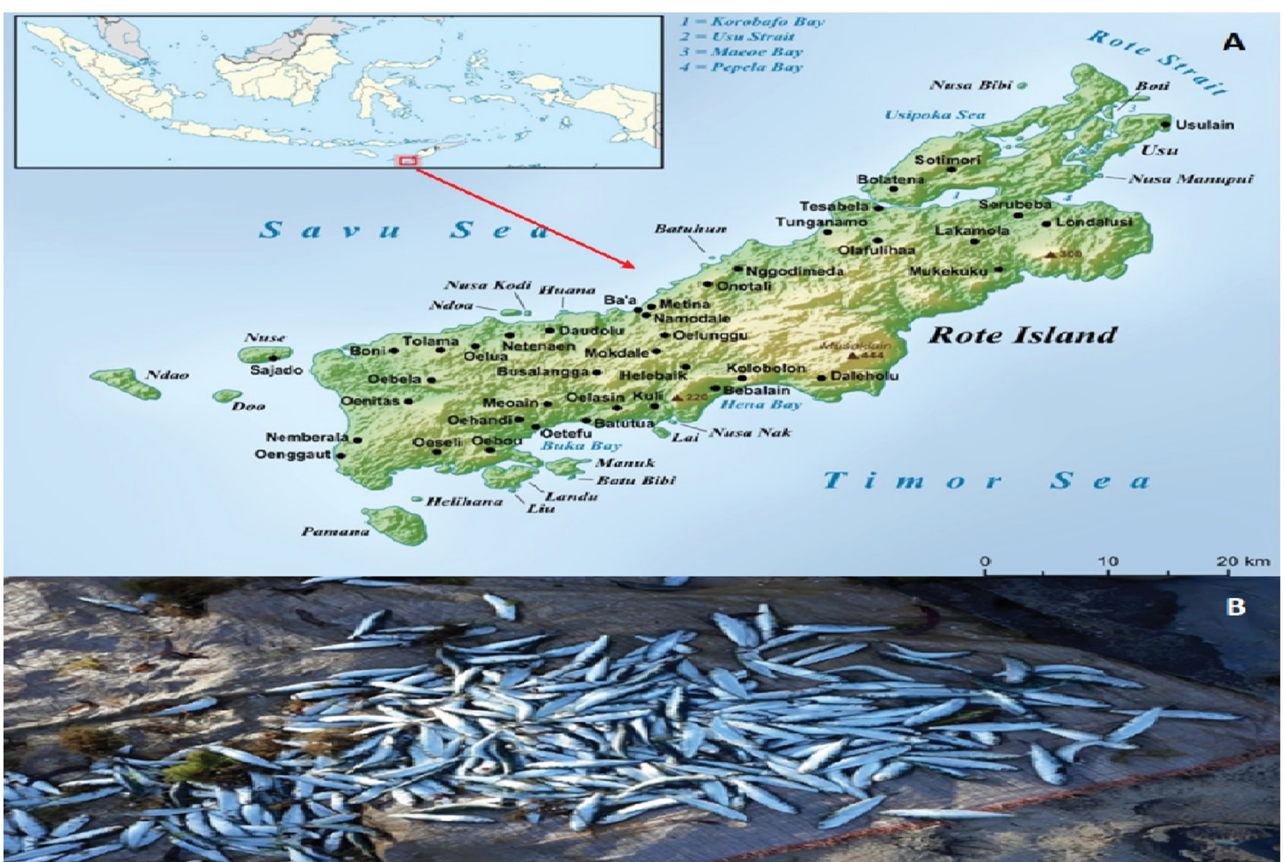

Fig 1. The location of sampling site and fishing ground of *S. fimbriata* samples in SMNP (Lancer, 2013). (Note: A. Rote Island; B. *S. fimbriata* samples in the Savu Sea.)

to marine catch production (Kripa et al., 2019). The body of this species is rather compact, with a scale number average of 31±1.4 vertical striae on scales, the hind part of scales with a few perforations and slightly produced posteriorly, and a dark spot at the dorsal fin origin (Froese and Pauly, 2013). The presence of *S. fimbriata* plays an important role in the food chain for large pelagic fish, marine mammals and other marine organisms (Sektiana et al., 2017). This species is distributed in the waters of the Indo-West Pacific, including Kuwait, southern India, Indonesia, the Philippines and Papua New Guinea (Wijayanto et al., 2021). The distribution of *S. fimbriata* based on its life cycle is found in oceanic waters, especially the epipelagic layer in the adult phase, neritic at a depth of 0-50 meters in the adult and juvenile stages, and the brackishwater mangrove area in larval conditions (FishBase and SeaLifeBase, 2021). *S. fimbriata* is the largest fisheries resource in coastal waters (Ghosh et al., 2013) and is a type of commercial fish that is frequently caught so these fish experience a fairly large pressure impact (Luceño et al., 2013). This species is also one of the economically important fish resources found in Savu waters. The increasing demand comes along with the high economic value of this fish, making it one of the main capture targets. Hence, the intensive utilization of this species might result in overfishing.

The few studies on the population dynamics of *S. fimbriata* have not had an optimal impact on the sustainable management of the resources of this species. Empiric studies in the fields proved that the fishermen used surface gillnet fishing gear of a small size, resulting in immature fish caught. Some previous studies on the population dynamics of *S. fimbriata* during the last five years demonstrated trends in different growth patterns for each different location. Rilani et al. (2017) studied the growth parameters and fecundity of *S. fimbriata* in East Lombok, West Nusa Tenggara. They showed negative allometric growth patterns and fecundity ranges of 2801-60 578 eggs with a diameter range of 8-67 µm. In the study of biology and population dynamics in Bali strait waters, Bintoro et al. (2019) reported that the value of exploitation rate (E) was 0.79, meaning that the fisheries resources status is categorized as overfishing. Meanwhile, Bintoro et al. (2020) showed that the overfishing situation occurred in Prigi waters in Trenggalek, East Java. Rehatta (2021) in his dissertation reported that the utilization status of *S. fimbriata* has not experienced further ecological and economic capture. However, the effort to catch small pelagic fish has decreased, which is an indication of the abundance of these fish stocks, and the productivity of fishing gear has decreased. No studies on the population dynamics of *S. fimbriata* have been conducted in Rote Island in the Savu Sea, whereas the results of the stock assessment of this species in several regions demonstrated an overfishing situation. Therefore, it is necessary to anticipate the management of the resources of this species using a population dynamic approach through length frequency data collected from fishermen's catches.

MATERIALS AND METHODS

Samples were taken from the smallest to the largest size, and the total length (mm) was measured using a digital caliper with an accuracy of 0.1 mm. The length of the fish was measured from the tip of the head to the tip of the tail, then the weight (grams) was measured using an analytical balance with an accuracy of 0.01 grams. The length distribution was obtained from the total length measurement data, then the class interval was determined using data analysis in the Microsoft Excel. After that, it continued with the determination of the cohort of long-frequency distribution data using the Batthacharya method (Sparre and Venema, 1998 in Tangke et al., 2021). Analysis of the long-weight relationship was done using the Pauly equation (Bintoro et al., 2019; Bintoro et al., 2020) with the equation W = aLb, where W is the body weight of the fish, L is the total length, a is the intercept and b is the slope. This equation is then converted into a linear equation to obtain the values of a and b, namely Log W = Log a + b Log L. Estimated parameters a and b are obtained using regression analysis with Log W as Y and Log L as x with the equation y=a+bx. The value of b is used to determine the growth pattern with the hypothesis H0: b = 3, which means that the growth is isometric (weight growth is proportional to the length growth pattern), H1: b 3, which means that the growth pattern is allometric (weight growth is not proportional to the length growth pattern). The value of b 3 can be divided into 2, namely if the value of b > 3 then the growth pattern is positive allometric (body weight growth is more dominant), and vice versa if b < 3 then the allometric growth pattern is negative (length growth is more dominant). Population dynamic parameters such as growth parameters (K, L∞, t_0) were analyzed using ELEFAN I with the help of FISAT II software. The total Mortality Rate (Z) was calculated using the catch curve converted into length data that had been entered in the FISAT II software (Sparre and Venema, 1998; Gayanilo and Pauly, 2001 in Ghofar et al., 2021). The natural mortality rate (M) was analyzed using an empirical relationship (Pauly, 1993 in Ghofar et al., 2021). Furthermore, fishing mortality (F) was determined by subtracting M from Z and then the exploitation rate (E) was determined from Z/F. Recruitment patterns are usually analyzed using the FISAT II software. In that application, there is a recruitment pattern sub-program which only requires L∞, K and t_0 data from the previous analysis (Agustina et al., 2016; Mawarida et al., 2022), while the analysis of the size of the first catch (LC_{50}) is determined based on the equation followed by Kamal et al. (2020), $isp = [1 + e^{-r(x-x_{50})}]^{-1}$.

RESULTS

Size distribution

The total sample obtained was 1095 fish taken at random from August to November 2020. In detail, the number of samples in August, September, October and November were 301, 313, 295 and 186 fish, respectively. Most samples were obtained in September. The measurement results showed that *S. fimbriata* fish sample had a length range of 90 – 157 mm TL, with the dominant length being 125.9-132 mm TL (Figure 2). Based on research results and information from fishermen, it is known that the target fish (*S. fimbriata*) is found in the east monsoon from April to October and before the west monsoon in November. However, the peak occurred in August, September and October, while the other months are other pelagic fishing seasons, such as tuna in April, May, June, July and August. The fishing habits of fishermen depend on the fishing season and the target fish.

Estimation of age or cohort

The cohort value was determined by collecting data on the total length of the fish, then grouped into size classes. After that, the cohort was separated using the Bhattacharya method contained in the FISAT II application (Sparre and Venema, 1989). Based on the results of the separation, it is known that August, September and October had only 1 cohort, while November had 2 cohorts with the first peak at 100.2 mm in length and the second peak at 124.4 mm in size (Figure 3).

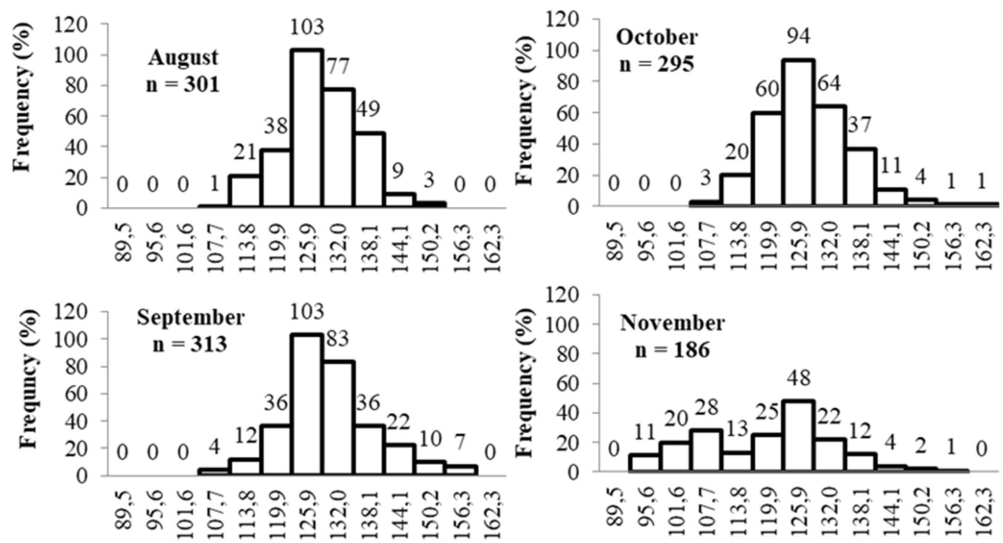

Fig 2. Length-frequency distribution of *S. fimbriata* in Rote Island in the Savu Sea

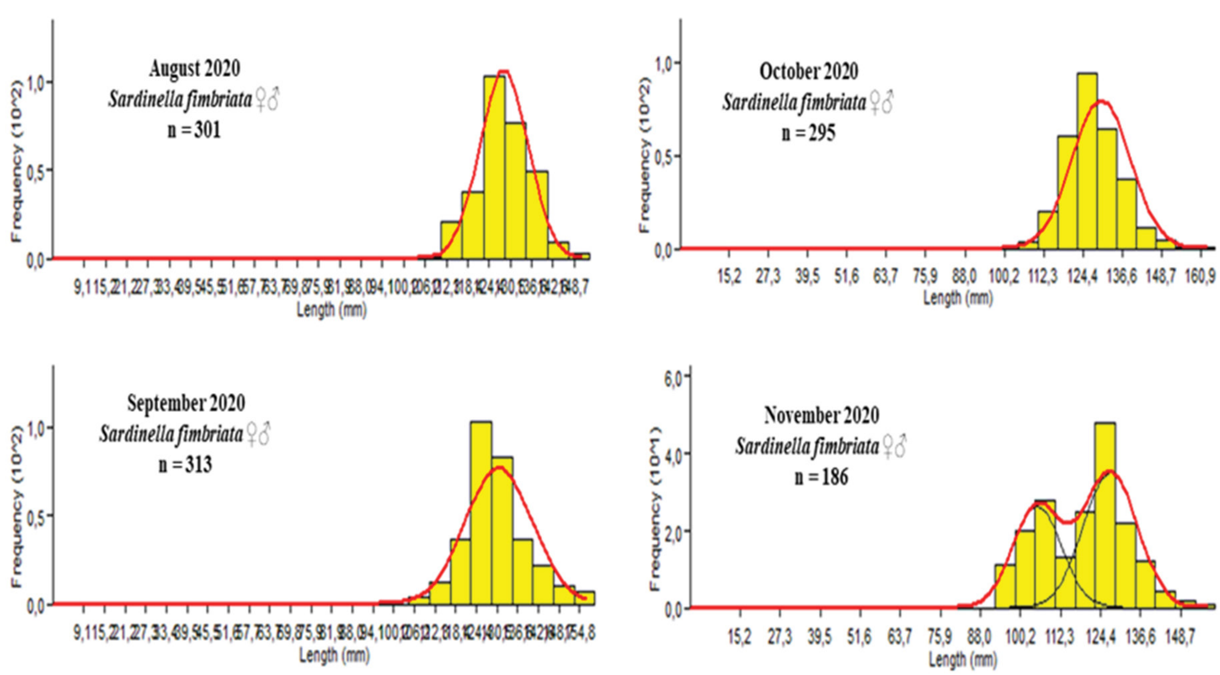

Fig 3. The cohort of *S. fimbriata* in Rote Island in the Savu Sea

Length-weight relationship

The analysis of the *S. fimbriata* length-weight relationship obtained: a (intercept) = 0.0004; b (slope) = 2.2523 and written as: $W = 0.0004L^{2,2523}$ (Figure 4). The t-test resulted in the b value not being equal to 3, thus the growth pattern of *S. fimbriata* was negative allometric where length growth was faster than weight growth.

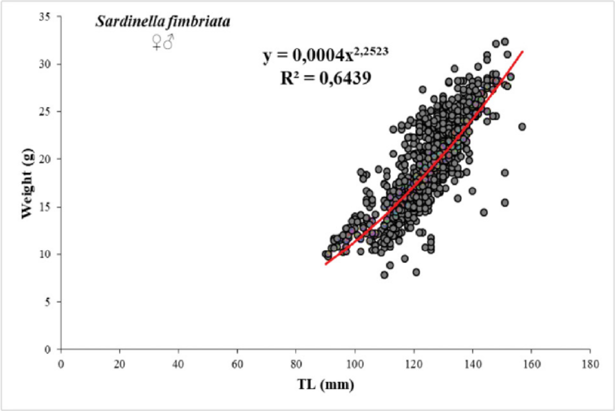

Fig 4. Length-weight relationship of *S. fimbriata* in Rote Island in the Savu Sea

Growth parameters

The fish growth parameter model used in this study was based on the von Bertalanffy method. The results of von Bertalanffy's calculation obtained a maximum length ($L\infty$) of 165.26 mm TL, a growth coefficient value (K) of 1.500 per year and a length at zero age (t_0) of -0.0585 per year. Based on the value of these growth parameters, the growth curve for *Sardinella fimbriata* is formed, namely $Lt = 165.26 (1 – e[-1,500(t + 0.0585)])$ (Figure 5).

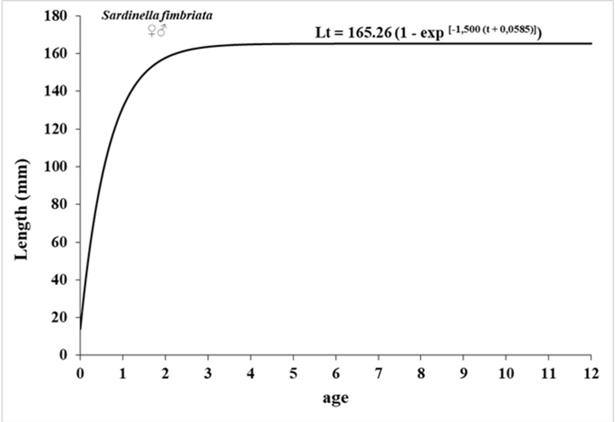

Fig 5. Growth parameters of *S. fimbriata* in Rote Island in the Savu Sea

Mortality rate

In this study, the estimation of the total mortality rate (Z), natural mortality (M) and fishing mortality (F) was 2.41 yr^{-1}, 1.45 yr^{-1} and 0.96 yr^{-1}, respectively. Based on the Z value, the *S. fimbriata* exploitation level in Rote Island was 0.40 < E=0.5 (optimum exploitation rate), or overfishing has not occurred in Rote Island (Figure 6).

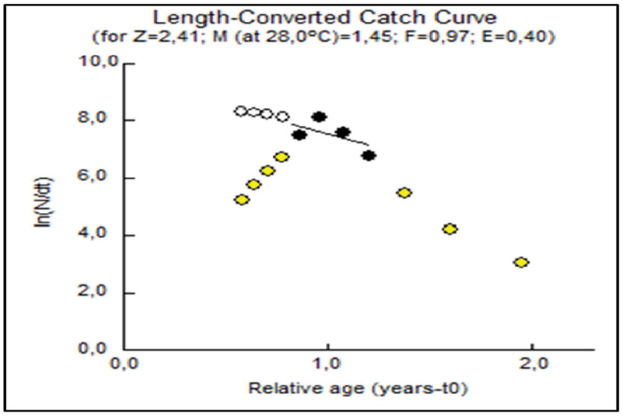

Fig 6. The length-converted catch curve of *S. fimbriata*

Recruitment pattern

The analysis of the recruitment pattern of *S. fimbriata* in this study used recruitment pattern analysis in the FISAT II software by entering the $L\infty$ and K values. The results of the analysis showed that the recruitment pattern in the waters of Rote Island occurred every month, with two peaks in the recruitment pattern. The first peak occured in June at 14.17% and the second peak in August at 19.51%. The recruitment pattern is characterized by the addition of new individuals to the population of *S. fimbriata* fish in the waters every month (Figure 7).

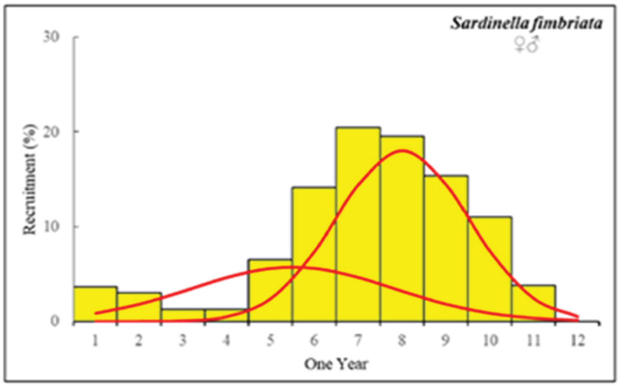

Fig 7. Recruitment pattern of *S. Fimbriata*

The length at the first capture (LC)

The estimated probability of length size in the first catch (Lc) using the FISAT II software was 96.98 mm TL (Fig. 8).

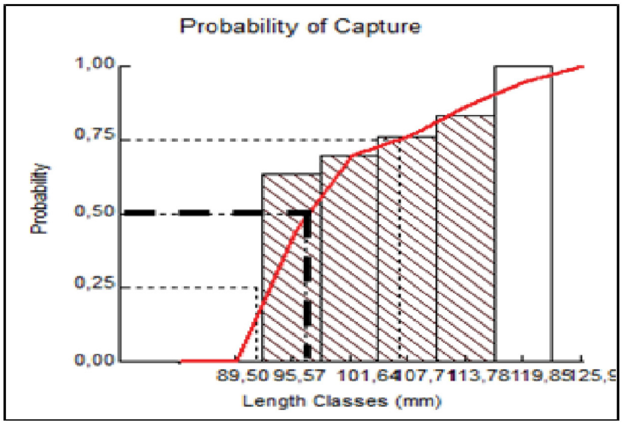

Fig 8. The length at LC_{50}% of *S. fimbriata*

DISCUSSION

Estimates of growth and other population parameters can be obtained reliably if the length frequency data is accurate. The shift of peaks from time to time can be well demonstrated if the obtained data are adequate on raw length-frequency data, number of monthly samples and a total sample of at least 1500 collected over 6 months (Etim and Sankare, 1998). In this study, the length-frequency data set did not meet all these criteria due to the bad weather with high tides and currents in the monsoon season. However, the data demonstrated well-defined modes through time even though only 1095 samples were collected over 4 consecutive months. The previous study with fewer criteria was also showing clear modes (Syakila, 2009; Aswar, 2011; Sari et al., 2017). The asymptotic length of species could be reached in their specific habitat. In this study, *S. fimbriata* reached asymptotic length ($L\infty$) = 165.26 mm FL, K = 1.50 per year and t_0 = -0.0585 years in Rote Island.

The relationship between the length and weight of *S. fimbriata* was $W = 0.0004*L^{2.25}$, r = 0.64 with a value of b (slope) = 2.25 (b < 3) or negative allometric, meaning that the growth in length is faster than weight growth. Compared to previous studies, similar results were obtained from Banda Aceh with negative allometric growth (b < 3), which was 2.44 (Perdana et al., 2018). Bintoro et al. (2019) also reported a negative allometric growth (b = 2.804), whereas research on the southeastern coast of India, the Bay of Bengal and the East Indian Ocean showed 3.14 (b > 3) (Karuppiah et al., 2020). The differences in the b values were due to differences in environmental conditions and the caught fish size. According to Bintoro et al. (2019), the growth pattern is allometric perhaps due to changes related to gonadal maturity.

In this study, the estimated average total mortality rate (Z), natural mortality (M) and fishing mortality (F) for *S. fimbriata* were 2.17, 1.34 and 0.83 per year, respectively. These results showed that the mortality of *S. fimbriata* fish in Rote Island was caused by natural mortality. The estimated exploitation rate of *S. fimbriata* fish is 0.40 lower than the optimum exploitation level (E = 0.50), indicating that exploitation has not occurred. Nevertheless, the result obtained is sufficiently robust to anticipate that the unprecedented overexploitation of *S. fimbriata* in Rote Island has nearly occurred. Therefore, consistent monitoring is constantly needed.

CONCLUSION

In this study, *S. fimbriata* reached asymptotic length ($L\infty$) = 165.26 mm FL and the growth coefficient (K) = 1.50 per year. The values of fishing mortality (F) and natural mortality (M) were 1.34 and 0.83 per year, respectively, showing that the mortality of *S. fimbriata* fish in Rote Island was due to natural mortality. The whole recruitment occurred almost throughout the year with two major peaks of recruitment. The exploitation level (E) of *S. fimbriata* in Rote Island is very close to the optimum level of exploitation.

RAST, SMRTNOST, REGRUTIRANJE I STOPA ISKORIŠTAVANJA RESASTE SRDELE (*Sardinella fimbriata*, Valenciennes 1847.) S OTOKA ROTE U SAVSKOM MORU

SAŽETAK

Resasta srdela je jedan od najvažnijih ribolovnih resursa i ima najveću gospodarsku vrijednost u Savskom moru. Zbog sve veće potražnje za ovom ribom ona postaje jednom od glavnih ribolovnih meta, što dovodi do prekomjernog izlova. Stoga je svrha ovog istraživanja utvrditi dinamiku populacije resaste srdele kroz rast i smrtnost, novačenje i stopu iskorištavanja na otoku Rote, Savsko more.

Ukupno je uzorkovano 1095 jedinki s otoka Rote u Savskom moru koje su pokazale raspon ukupne duljine (TL) od 90 mm do 157 mm. Nadalje, podaci su analizirani pomoću softvera FISAT II i dali su sljedeće rezultate: dužinsko-maseni bio je $W= 0,0004L^{2,2523}$. Dok su negativni alometrijski obrazac rasta i jednadžba rasta bili Lt = 165,26 $(1 – exp^{1,500\,(t + 0,0585)})$. Starost *S. fimbriata* sastojala se od 1-2 kohorte. Regrutacija *S. fimbriata* na otoku Rote u Savskom moru događala se tijekom cijele godine s najvišim vrhuncima u svibnju i kolovozu. Veličina prve ulovljene ribe (Lc) bila je 96,98 mm TL. Ukupna stopa mortaliteta (Z) iznosila je 2,41 god^{-1}, prirodna smrtnost (M) 1,45 god^{-1}, a ribolovna smrtnost (F) 0,97 god^{-1}. Stopa iskorištavanja *S. fimbriata* procijenjena je na 0,40 god^{-1}, što znači da stok ne prelazi optimalnu stopu iskorištavanja (E = 0,5) ili da u Savskom moru nije došlo do prekomjernog izlova. Unatoč tome, rezultati ove studije dovoljno su jasni da se predvidi da je skoro došlo do prekomjernog iskorištavanja vrste *S. fimbriata* bez presedana na otoku Rote u Savskom moru. Stoga je hitno potrebno redovito praćenje i nadzor površinskih ribolovnih alata mrežama stajaćicama.

Ključne riječi: dužinsko-maseni odnos, populacijska dinamika, prirodna smrtnost, ribolovna smrtnost

ACKNOWLEDGEMENT

The authors are grateful to Nenik, Tamara and Nining (Tropical Marine Science Lab.) for their help in the laboratory and data processing. The authors are also grateful to Cornelis, Richard, Yasinta, Ali, Yunus, Hendrikus, Steven, Saverius, La Takbir, Semi and Sahir (Christian University of Artha Wacana) for their help in the field. The authors are grateful to the Directorate General of Higher Education, the Ministry of Education and the Culture Republic of Indonesia for the financial support under Penelitian Disertasi Doktor scheme No.: 187-45/ UN7.6.1/PP/2021

REFERENCES

Agustina, S, M Boer, A Fahrudin (2015):Population dynamics of layur fish (*Lepturacanthus Savala*) in Sunda Strait Water. Marine Fisheries, Journal of Marine Fisheries Technology and Management 6, 1, 77–85.

Ali, I., S. T. Sulistiyono (2020): A Reflection of “Indonesian Maritime Fulcrum” Initiative: Maritime History and Geopolitical Changes. Journal of Maritime Studies and National Integration 4, 1, 12-23.

ASEAN Records (2018): The Savu Sea National Marine Park Indonesia – The largest Marine Park in Southeast Asia. https://aseanrecords.world/asean-records-the-savu-sea-national-marine-park-indonesia-the-largest-marine-park-in-southeast-asia/

Aswar (2011). Population Structure and Exploitation Pressure of Tembang Fish (*S. fimbriata*) in Flores Sea Waters Regency Bulukumba) (In Indonesian). 57 p. https://adoc.pub/struktur-populasi-dan-tekanan-eksploitasi-ikan-tembang-sardi.html. 7/6/2022

Bintoro, G., D. Setyohadi, T.D. Lelono, F. Maharani (2019). Biology and Population Dynamics Analysis of Fringescale Sardine (*Sardinella fimbriata*) in Bali Strait Waters, Indonesia. IOP Conference Series: Earth and Environmental Science 391 (1).

Bintoro, G., T. D. Lelono, L. Deafatmi (2020). Biological Aspect and Dynamic Population of Fringescale Sardine (*Sardinella fimbriata*: Valenciennes, 1847) in Prigi Waters Trenggalek, East Java, Indonesia. IOP Conference Series: Earth and Environmental Science 493 (1).

Balai Kawasan Konservasi Perairan Nasional Kupang (BKKPN)/ Kupang National Water Conservation Areal Post (2019): Increasing the Capacity of MPA Management Units in East Flores (In Indonesian)

Effendie, M. I. (2002): Fisheries Biology (In Indonesia). Yayasan Pustaka Nusantara. Yogyakarta. 122.

Etim, L., Y. Sankare (1998): Growth and mortality, recruitment and yield of the fresh-water shrimp, *Macrobrachium völlenhovenii*, Herklots 1851 (Crustacea, Palaemonidae) in the Fahe reservoir, Côte d'Ivoire, West Africa. Fisheries Research, 38,3, .211-223.

FishBase, SeaLifeBase (2021): FishBase-SeaLifeBase symposium Patrice Pruvost, Philippe Béarez, Romain Causse, Valérie Gaudant (SFI) & Fabrice Teletchea. https://fishbase2021.sciencesconf.org/

Froese, R., D. Pauly (2013): FishBase. World Wide Web electronic publication.; http://www.fishbase.org/Country/CountrySpeciesSummary.php?c_code=356&id=1507, version12/2013

Ghofar, A., Saputra S.W, Sabdono A, Solichin A, Taufani W.T and Febrianto S. (2021): Population dynamics of Yellowfin Tuna *Thunnus albacares* (Bonnaterre, 1788) in fisheries management area 573 in the Indian Ocean. Croatian Journal of Fisheries, 79, 53-60.

Ghosh, S., M.V.H. Rao, S. Sumithudu, P. Rohit and G. Maheswarudu (2013): Reproductive biology and population characteristic of *Sardinella gibbosa* and *Sardinella fimbriata* from North West Bay of Bengal. Indian Journal of Geo-Marine Science. Vol. 42(6): 758-769.

Hamdan, F.D., N. M. Sarbon (2019): Isolation and characterization of collagen from fringescale sardinella (*Sardinella fimbriata*) waste materials. International Food Research Journal. 26, 1, 133-140.

Kamal, M.M, Y. Ernawati, Dewi. N.N. (2020): Length at first maturity, spawning time, and reproductive output in the females of Hamilton’s Anchovy (Thryssa Hamiltonii Gray, 1835). Jurnal Biologi Tropis 20 (1): 1–6.

Karuppiah, K., K. Ethiraj, K. Paramasivam, K. Rajendran, M. Krishnamoorthy, D. Dharmaraj, (2020): Length-weight relationships of three Clupeiformes species from the Southeast coast of India, Bay of Bengal, Eastern Indian Ocean. Journal of Applied Ichthyology, 36, 6, 860-862.

Kripa, K.S., Mohamed, S., Padua, R., Jeyabaskaran D., Prema V. (2019): Similarities between Indian Oil Sardine Sardinella Longiceps Valenciennes, 1847 and global sardine fisheries and its management. 61 (1): 05–18.

Lencer (2013): Map of Rote Island, Indonesia. Avaiable on 08/06/2022 https://en.wikipedia.org/wiki/ Rote_ Island #/media/File:Rote_Island_en.png

Luceño, A.J.M, Torres M.A.J, Abugo, S.R. T, Demayo C.G. (2013): Describing the body shape of three populations of *Sardinella fimbriata* (Valenciennes, 1847) from Mindanao Island, Philippines using relative warp analysis. Annals of Biological Research, 4 (10): 29–39.

Luceño, A.J.M., Torres, M.A.J., Tabugo, S.R.M. Demayo, C.G. (2014): Describing the body shapes of three populations of *Sardinella lemuru* (Bleeker, 1853) from Mindanao Island, Philippines using relative warp analysis. International Research Journal of Biological Sciences, 3 ,6, 6-17.

Mawarida R., Tumulyadi A., Setyohadi D. (2021): Analysis of population dynamics of skipjack (*Katsuwonus pelamis*) in WPP 573 which landed at landing fish Podokdadap, Sendangbiru, Malang, East Jawa. Proceeding of the National Seminar On Fisheries and Marine Sciences, Fakulty of Fisheries and Marine Sciences, Brawijaya University.

Mukhopadhyay A., Giri S., Hazra S., Das S., Chanda A. (2020). Influence of oceanographic variability on the life cycle and spawning period of *Sardinella fimbriata* in the Northern Part of Bay of Bengal. In Proceedings of the Zoological Society, 73, 3, 285-295. Springer India.

Perdana, A. W., Batubara, A. S., Aprilla, R. M., Nur, F. M., Iqbal, T. H. (2018). Length-weight relationships of three popular fishes from Banda Aceh, Indonesia. In IOP Conference Series: Earth and Environmental Science, 216, 1, 012053. IOP Publishing.

Rehatta, B.M. (2021). Management of Small Pelagic Fisheries with an Ecosystem Approach in the Ombai Strait, The Border Region of Republic of Indonesia (RI) and The Democratic Republic of Timor Leste. Coastal and Marine Resource Mangement Study Program, Graduate School, Bogor Agricultural Institute. Indonesia. pp 184

Rilani, V., Mulyanto, D. Setyohadi (2017): Growth Parameter and Fecundity of Fringe Scale Sardine (*Sardinella fimbriata* Cuvier Valenciennes) in Alas Strait, East Lombok, West Nusa Tenggara. The Journal of Experimental Life Sciences, 7, 1, 22–26.

Sari, R., Efrizal T., Zulfikar A. (2017): Long-Based Study of Tembang Fish (*Sardinella fimbriata*) Stocks Heavy in Hard Waters Landed at Tanjungpinang City KUD Landing Fish Landing Points (In Indonesia) Jurnal Universitas Maritim Raja Ali Haji, 1-8.

Sektiana, S.P., Andriyanto S., Kim H.W. (2017): Characterization of the complete mitochondrial genome of Mauritan Sardinella, *Sardinella jussieu* (Lacepède, 1803), collected in the Banten Bay, Indonesia. Journal Fisheries and Aquatic Sciences, 20, 26.

Syakila, S. (2009): Study of Stock Dynamics of Tembang Fish (*S. fimbriata*) in Palabuhanratu Bay, Sukabumi Regency, West Java Province (In Indonesian) Available on https://repository.ipb.ac.id/handle/123456789/14154, 08/05/2022

Sparre, P., Venema C. (1998): Introduksi pengkajian stok ikan tropis (Translate edition) (FAO Fish Tech). Jakarta. 438

Tangke, U., Laisouw R., Talib A., Husen A., Kota R., Umagap W. A. Z. (2021): Population Dynamics of Eastern Little Tuna (*Euthynnus affinis)* in Ternate Waters. *IOP* Conference Series: Earth and Environmental Science 890 (1)..

Wiadnya, D. G. R., Syafaat R., Susilo E., Setyohadi D., Arifin Z., Wiryawan B. (2011): Recent development of marine protected areas (MPAs) in Indonesia: Policies and governance. Journal of Applied Environmental and Biological Sciences, 1, 12, 608-613.

Wijayanto, D., Bambang, A. N., Kurohman, F. (2021): The multi-species competition model of Bali sardinella and fringescale sardinella in Pati Regency, Indonesia. AACL Bioflux, 14(4), 2335-2342.

