Population dynamics of narrow-barred Spanish mackerel *Scomberomorus commerson* (Lacepede, 1800) in Bone Bay waters, South Sulawesi, Indonesia

Achmar Mallawa, Faisal Amir

Department of Fishery Faculty of Marine and Fishery Sciences, Hasanuddin University, Makassar, South Sulawesi, Indonesia. Corresponding author: A. Mallawa, achmar_mallawa@yahoo.co.id

Abstract. Spanish mackerel is an economically important fish in Bone Bay waters, Indonesia. The population is declining due to overfishing; thus, research on population dynamics is needed. The study aims to estimate the dynamic parameters of the Spanish mackerel populations. The fork length was measured for 551 fish, captured by trolling lines, hand lines, surface gill nets and boat lift nets, from January to December 2018. Von Bertalanffy's growth parameters were estimated using ELEFAN-1 with the help of the FISAT II software. Natural mortality was determined by the Pauly method. Total and fishing mortality were also determined. The yield per recruitment (Y/R) was determined by the Beverton and Hold method. The infinity length and growth rate were 167 cm and 0.55 year^{-1}, respectively. The growth performance index was 4.19. Total, natural and fishing mortality and exploitation rates were 1.84, 0.76, 1.08 and 0.59 year^{-1}, respectively, without an optimal recruitment process. The results can be used as primary information when managing Spanish mackerel in the Bone Bay waters.
Key Words: exploitation rate, growth, mortality, *Scomberomorus commerson*.

Introduction. Narrow-barred Spanish mackerel (*Scomberomorus commerson*) is one of the large pelagic fish that has high value in Indonesian waters, especially in Bone Bay waters. According to the Indian Ocean Tuna Commission (IOTC), the management and utilization of mackerel include an overall management program, with other fish like tuna (*Thunnus* spp.), skipjack (*Katsuwonus pelamis*), marlin (*Maikara* spp.) and sailfish (*Istiophorus platypterus*). According to the General Directorate for Capture Fisheries of the Republic of Indonesia, DGFC-RI (2014), narrow barred Spanish mackerel ranked 7th out of 10 fish species with the highest production, with an annual production of 15300 tons, in 2014. The production place is the Fisheries Management Region of the Republic of Indonesia 713 (WPP RI 713), which includes Bone Bay, Makassar Strait and Flores Sea waters. Furthermore, large pelagic fish, including narrow-barred Spanish mackerel in the waters of WPP RI 713 have been fully exploited and even overexploited. The IOTC (2017) reported that the production of narrow-barred Spanish mackerel increased significantly, from 50000 tons in 1970 to 100000 tons in 1990 and 168350 tons in 2016. Annual average production of mackerel from 2007 to 2016 is 147461.1 tons. Furthermore, it was explained that in the Indian Ocean and its surroundings, including Bone Bay waters, the maximum sustainable yield (MSY) value for narrow-barred Spanish mackerel is 131000 tons per year (plausible range of 96000 to 180000 tons). If the value of MSY is compared with the production from 2016, it can be concluded that the narrow-barred Spanish mackerel was overexploited in Indian Ocean waters, so that rational and sustainable management and utilization policies are needed and must be carried out carefully (FAO precautionary approach). FAO explained in the Code of Conduct for Responsible Fisheries (1995) that the main principle of the precautionary approach is to use scientific evidence and research results in determining and implementing policies for the management and utilization of the fish resource. Data about the population biology and dynamics is the

basic scientific condition for determining policies for management and utilization of narrow-barred Spanish mackerel.

Research conducted on population dynamics of narrow-barred Spanish mackerel in Indonesian waters is still scarce, some examples being studies regarding population dynamics in Kwandang Bay, Sulawesi Sea (Nugroho & Hidayat 2014). Research on the rate of exploitation in Karimunjawa waters, Java Sea has also been carried out (Yuliana & Nurjannah 2017). Research related to population dynamics of narrow-barred Spanish mackerel in the Indian Ocean has been carried out in Iranian coastal waters (Shojaei et al 2007), in the coastal waters of Oman (Motlagh et al 2008), in the Persian Gulf and Sea of Oman (Motlagh & Shojaei 2009) and in the waters of the North Persian Gulf (Niamaimandi et al 2015).

Research related to the aspects of biology and population dynamics of narrow-barred Spanish mackerel in the Bone Bay waters are scarce, thus this study brings new information to the scientific community. The results of this study could be used as a preliminary scientific base in creating the policy of management and utilization of narrow-barred Spanish mackerel resources in the WPP RI 713, specifically in the waters of Bone Bay.

Material and Method

Period and location of the research. The study was conducted from January to November 2018. Data collection was carried out at four fish landing sites in the north part of Bone Bay, South Sulawesi, Indonesia (Figure 1). The following materials and equipment have been used in this research: labeling paper, measuring boards specifically designed for large pelagic fish, digital thermometers to measure seawater temperature, a set of computers and software such as FISAT II, SPSS and Microsoft excel for data analysis. Fish fork length (FL) data was collected every week by the research team and students. The FL is the distance from the tip of the mouth to the fork of the fish tail. FL may be used for fish with stiff caudal fins (special shoots) or fin shapes (Nemioteridae) (Sparre et al 1989). Narrow-barred Spanish mackerel were captured with trolling lines, hand lines, drift surface gill nets and boat lift nets. When the number of catches was small, the measurements were conducted for all fish; when the catch was large, stratified random sampling was used to select fish to be measured. The length frequency classes were grouped in 5 cm intervals, starting from the smallest fish in the sample to the biggest fish. There were 551 specimens measured in this study. The narrow barred Spanish mackerel fishing area is located between 2°30' north latitude and 6° south latitude, and between 120° west longitude and 122° east longitude. It has a water depth of 50 to 200 meters.

Data Analysis. Fish growth was calculated using Von Bertalanffy's growth formula as follows:

$$Lt = L\infty[1-e^{-K(t-to)}]$$

For estimating t_0 (length at age 0 years) the equation of Pauly (1984) was used:

$$\text{Log}(-t_0) = 0.3992 - 0.2572 \text{ Log}(L) - 1.038 \text{ Log}(K)$$

The value of the growth performance index was used to compare the growth of narrow-barred Spanish mackerel in the waters of Bone Bay with the growth of narrow-barred Spanish mackerel from other research. The index is also known as phi-prime (Sparre et al 1989):

$$Ø = \log K + 2 \log(L\infty)$$

The total mortality rate (Z) is estimated from the length converted catch curve, using FISAT II software (Gayanilo et al 2005).

The natural mortality rate (M) was determined using the Pauly empirical model (Pauly 1980; Sparre et al 1989):

$$M = 0.8 \times \text{Exp}(-0.152 - 0.279 \log L\infty + 0.6543 \log K + 0.4634 \log T^0C)$$

The average seawater temperature was 29^{0}C.

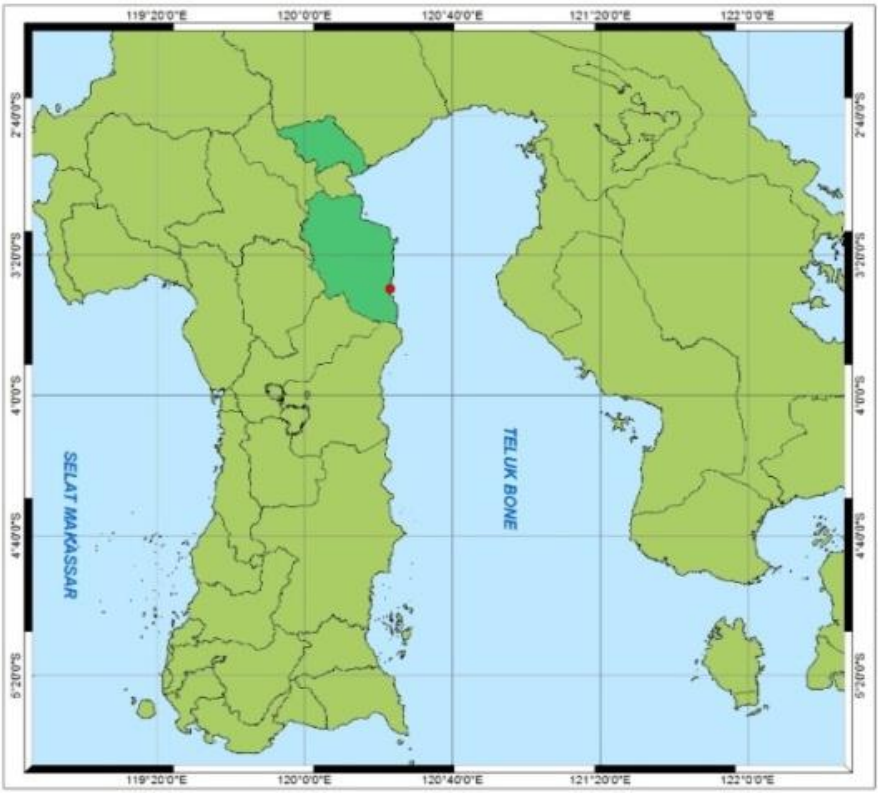

Figure 1. Research area - Bone Bay waters (Mallawa et al 2018).

The fishing mortality rate (F) was estimated by using the equation:

$Z = F + M$, so $F = Z - M$

The exploitation rate (E) was estimated by using the Beverton and Holt equation (Mallawa 2013):

$E = F / Z$ or $E = F/F + M$

Yield per Recruitment (Y/R) was estimated using the Beverton and Holt equation (Mallawa 2013) with the help of FISAT II software:

$(Y/R) = E * U^m \left[1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} + \frac{U^3}{1+3m}\right]$, where $U = 1 - \frac{Lc}{L\infty}$ $m = \frac{1-E}{M/K}$

Where: Lt = fish length at age t (cm);

L = infinity length (cm);

Lc = the length of the smallest fish that has been caught ≥ 50% (cm);

t = age of fish (year);

t_0 = theoretical age at zero length (years);

K = growth rate coefficient (per year);

Z = total mortality rate;

M = natural mortality rate;

F = arrest mortality rate;

E = rate of exploitation;

T = average water temperature (ºC).

The population parameters above are estimated using the Electronic Length Frequency Analysis (ELEFAN), with the help of FISAT II software (Gayanilo et al 2005).

Results and Discussion

Size structure and cohorts. The measurements results for the narrow-barred Spanish mackerel captured show that the minimum FL was 39.5 cm, the maximum was 149.5 cm and most measurements had values in the 59.5–89.5 cm interval (Figure 2).

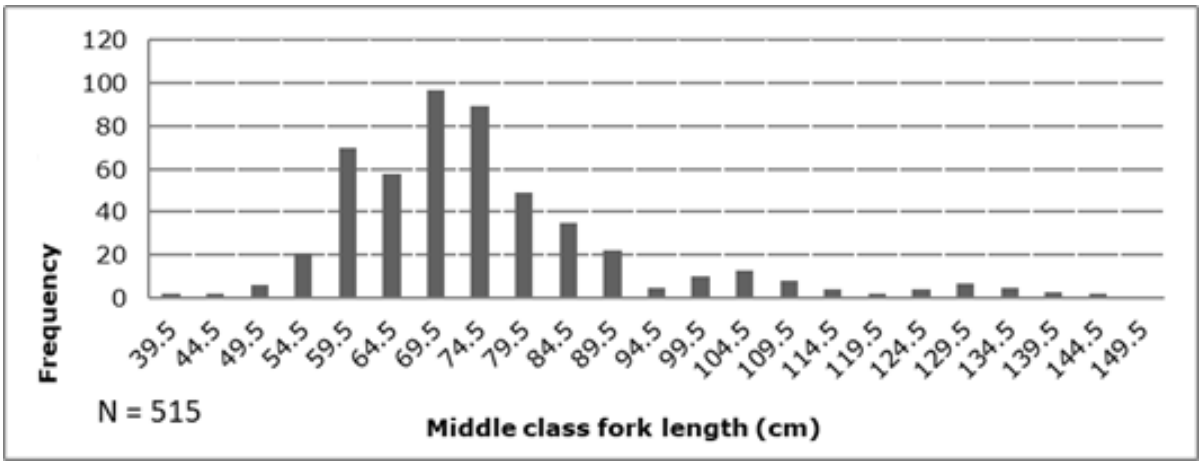

Figure 2. Size structure of narrow-barred Spanish mackerel in Bone Bay waters.

The measurement values can be separated in three cohorts (Figure 3), with an average length of 71.63 cm (SD±9.30) in cohort I, 104.09 cm (SD±8.55) in cohort II and 132.26 cm (SD±9.27) in cohort III.

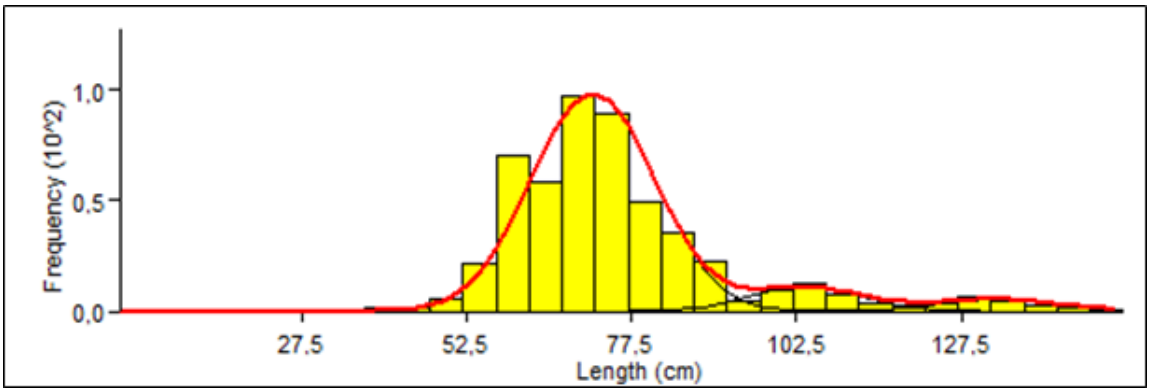

Figure 3. Number of narrow-barred Spanish mackerel captured in Bone Bay waters.

Population growth. The results of the FL data analysis using ELEFAN in FISAT II software (Figures 4 and 5) found that the population growth rate coefficient (K) was 0.55/year and the infinity length (L∞) was 167 cm, t_0 - 0.89 years and Ø - 4.19, so Von Bertalanffy's growth equation can be written as follows:

$$Lt = 167\ (1 + e^{-K(t+0.89)})$$

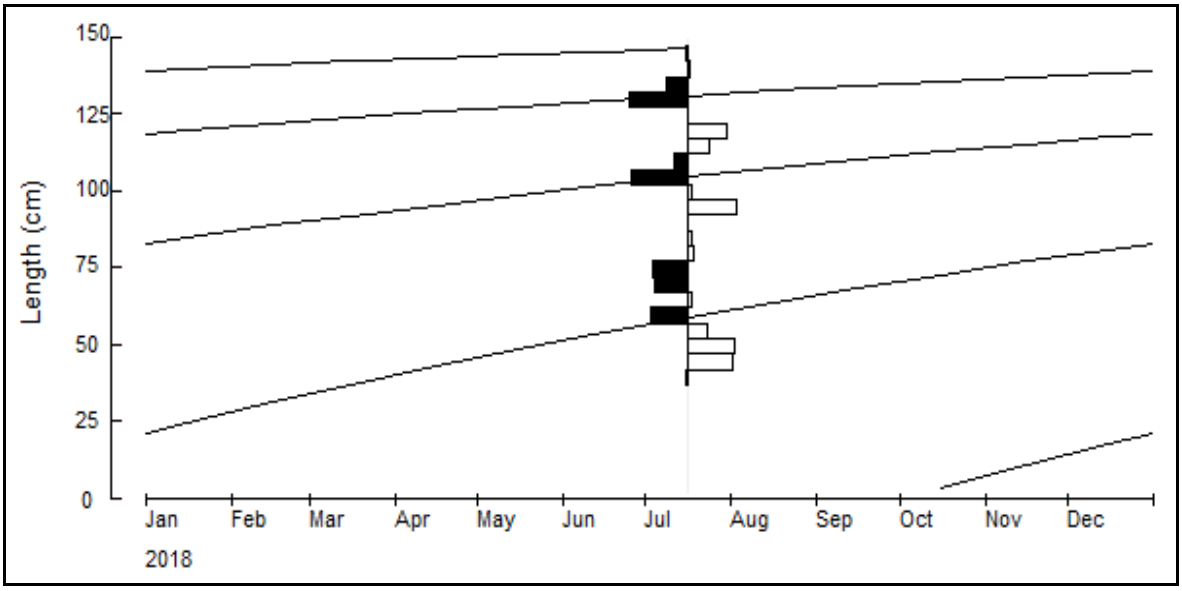

Figure 4. Growth rate of mackerel according to Von Bertalanffy's equation.
(Rn = 0.647, Sample Start = 1, Start Length = 104.5)

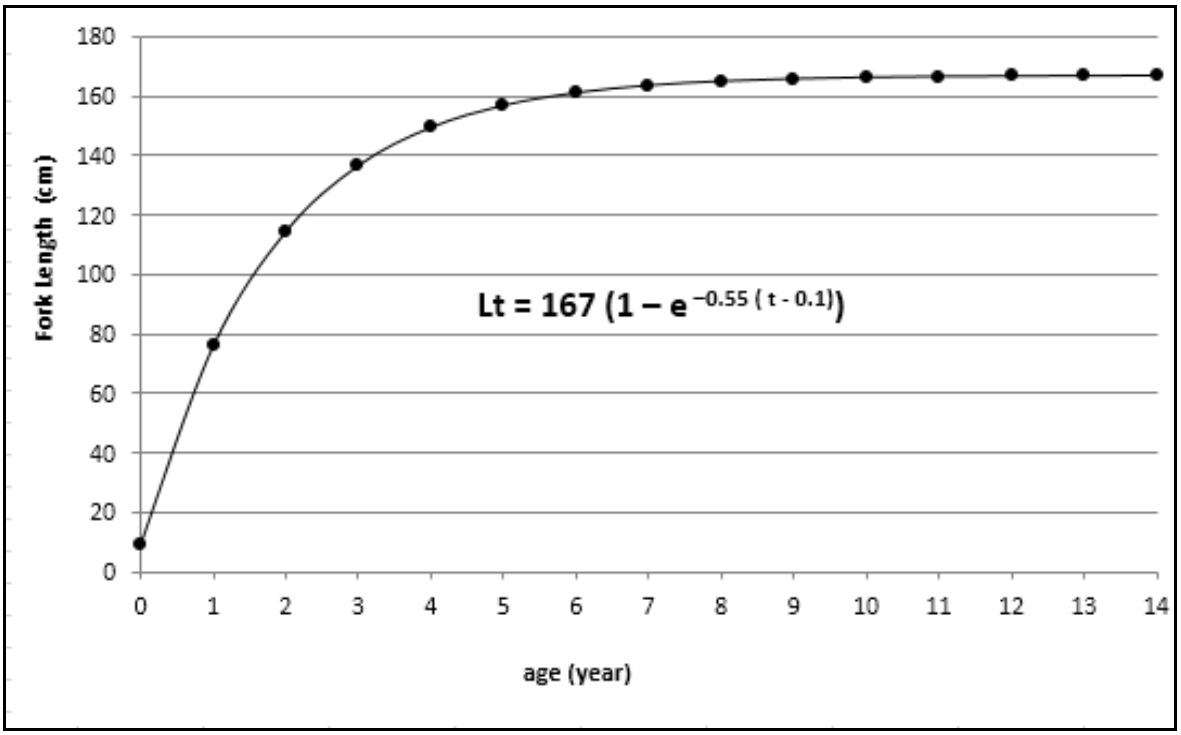

Figure 5. Von Bertalanffy's growth curve for narrow-barred Spanish mackerel in Bone Bay waters.

Mortality Rate. The value of total mortality (Z) was 1.84/year (Figure 6). The natural mortality rate (M) was 0.76/year. The fishing mortality rate (F) was 1.08/year.
Exploitation Rate. The exploitation rate (E) was 0.59 per year. The high value shows a high rate of exploitation of narrow-barred Spanish mackerel in Bone Bay waters.

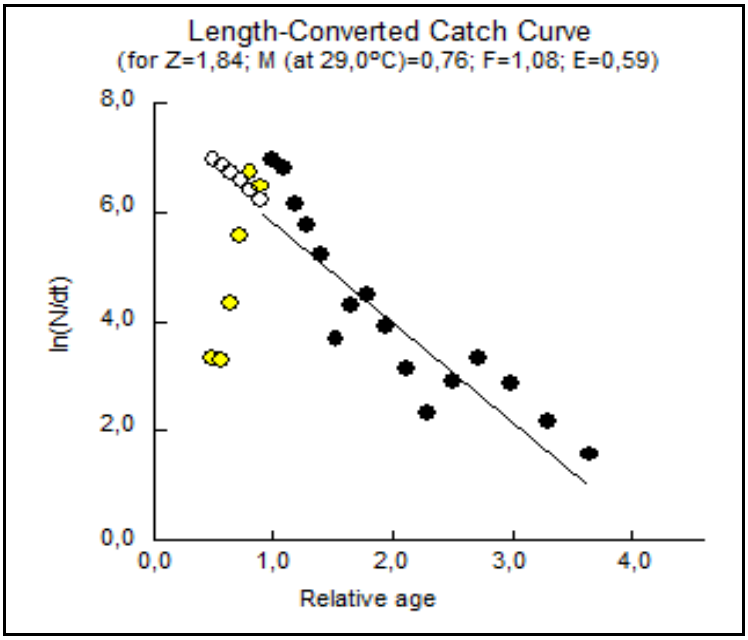

Figure 6. Length-converted catch curve (Beverton and Holt) for narrow barred Spanish mackerel in the Bone Bay waters. N – the number of fish in each age group (cohort); dt - the age difference between two age groups; Z - total mortality; M - natural mortality; F - fishing mortality; E - exploitation rate.

Yield per recruitment. The exploitation rate of 0.59 per year results in the current Y/R value of 0.04537 grams per recruit. This value is lower than the maximum Y/R value of 0.04558 grams per recruit. Furthermore, the maximum Y/R value can be reached at an E value of 0.53 per year, so in the case of narrow-barred Spanish mackerel at Bone Bay waters the current E value must be lowered (Figure 7).

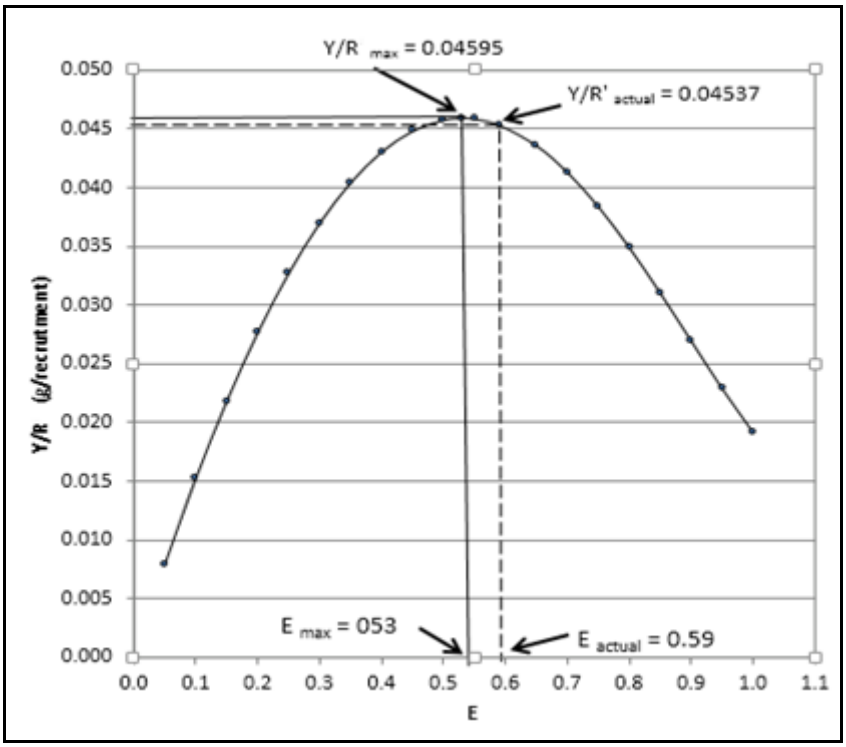

Figure 7. Relationship between Yield per Recruitment (Y/R) and the rate of exploitation (E) of narrow-barred Spanish mackerel in Bone Bay waters.

The number of age groups of narrow barred Spanish mackerel in Bone Bay waters was less than five, indicating that this population is scarce or has been under pressure (Mallawa et al 2017). This is in line with the information issued by the DGFC-RI (2014); the level of exploitation of large pelagic fish, including narrow-barred Spanish mackerel in the WPP RI 713 waters, was fully exploited and even over exploited. This is confirmed by other organizations, the IOTC (2017) also reporting that in the Western Indian Ocean (FAO Major Fishing Area 51) and the Eastern Indian Ocean (FAO Major Fishing Area 57), including Indonesian waters (Large Marine Ecosystem Area 38), narrow barred Spanish mackerel stocks are fully exploited.

K is a curvature parameter that determines how fast the fish approach L∞ (Sparre et al 1989). The K value of narrow-barred Spanish mackerel in Bone Bay waters of 0.55 per year is categorized as high (>0.5 per year), which means that the fish quickly reaches its L∞. A high K value (0.55 per year) or a rapid L∞ achievement also occurs in narrow-barred Spanish mackerel in Kwandang Bay, Sulawesi Sea (Nugroho & Hidayat 2014). The same phenomenon occurs in male narrow-barred Spanish mackerel, in the Arabian Sea (Claereboudt et al 2005), and male and female mackerel in Tanzanian waters, near Dar Es Salaam (Johnson et al 2014). Different results also exist (Table 1), some researchers reporting low K values (K<0.5 per year), or slow L∞ achievement for narrow-barred Spanish mackerel (Grandcourt et al 2005; Shojaei et al 2007; Darvishi et al 2012).

Table 1

Estimated growth parameters of Von Bertalanffy of narrow barred Spanish mackerel

Area	*V. Bertalanffy growth parameter*				*N*	*Analysis method*	*Reference*
	L∞ (cm)	*K year^{-1}*	*to (year)*	*Ø*			
Persian Gulf and Oman Sea	175.26	0.45	-	4.1	1995	ELEFAN	Darvishiet al 2012
West coast Australia	183.3 (F)	0.10	-1.47	8.12	-	Annual increment	Newman et al 2012
	122.9 (M)	0.33	-1.83	8.51			
Pilbara Australia	133.4 (F)	0.38	-1.49	8.77	-	Annual increment	Newman et al 2012
	119.8 (M)	0.42	-1.31	8.70			
Kimberly Australia	130.4 (f)	0.38	-1.52	8.72		Annual increment	Newman et al 2012
	113.8 (M)	0.37	-2.19	8.47			
Persian Gulf and Oman Sea	151	0.46	-	-	475	ELEFAN	Kaymaran et al 2013
Dar es Salam, Tanzania	122	0.68	0.17	-	-	ELEFAN	Johnson et al 2014
Kwandang Bay & Sulawesi Sea, Indonesia	142.3	0.81	-0.105	4.20	-	ELEFAN	Nugroho & Hidayat 2014
Northern Persian Gulf, Iran	148	0,5	-	-	38931	ELEFAN	Niamaimandi et al 2015
Southern Mozambique and Kwa Zulu Natal, South Africa	130.85 (F)	0.31	-1.35	8.57	-	Annual increment	Lee & Mann 2017
	119.22 (M)	0.28	-1.85	8.28			
Karimunjawa, Java Sea, Indonesia	97.65	0,45	-0,26	-	314	ELEFAN	Yuliana & Nurhasanah 2017
Bone Bay, Indonesia	167	0.55	-0.89	4.19	515	ELEFAN	The present study

L∞ - infinity length; K - growth rate coefficient; to - theoretical age at zero length; Ø - growth performance index; N - number of fish samples.

The phi prime (Ø) value obtained from this study was 4.19, similar to the value of prime phi (Ø) from Kwandang Bay, Sulawesi Sea (Nougroho & Hidayat 2014) and to the values

from the Persian Gulf and Oman Sea (Darvishi et al 2012). However, it is lower compared with the values from west coast waters, Pilbara, Kimberly, Australia (Newman et al 2012), southern Mozambique and Kawa Zulu, South Africa (Lee & Mann 2017). Thus, narrow-barred Spanish mackerel has a similar growth pattern in the same geographical area, but different in farther regions. Based on the range of the prime phi values obtained in this study, it can be stated that the growth rhythm of mackerel in Bone Bay is high. Rapid growth also occurs in other large pelagic fish, in Bone Bay, like skipjack, because of prey abundance (Mallawa et al 2017).

The values for Z, M and F are high. The high value of the total mortality and fishing mortality rates can lead to a high rate of exploitation. Furthermore, the high rates of exploitation represent conditions for the decrease of narrow-barred Spanish mackerel populations. The high Z, F and E rates also occur in narrow-barred Spanish mackerel populations in the Persian Gulf and Oman Sea (Motlagh & Shojaei 2009; Darvishi et al 2012; Kaymaran et al 2013). These values are also reported to occur in Indonesian waters, in the Java Sea (Yuliana & Nurhasanah 2017) and in the Kwandang Bay of Sulawesi Sea (Nougroho & Hidayat 2014). The Z, M, F and E for narrow barred Spanish mackerel in different waters are presented in Table 2.

Table 2

Total, natural, and fishing mortality and rate of exploitation of narrow barred Spanish mackerel in various locations of the Indian Ocean

Fishing Area	*Total mortality year^{-1}*	*Natural mortality year^{-1}*	*Fishing mortality F year^{-1}*	*Exploitation rate*	*Reference*
Persian Gulf and Oman Sea	1.98	0.50	1.48	0.74	Darvishi et al 2012
Northern Persian Gulf & Oman Sea	1.93	0.54	1.39	0.72	Kaymaram et al 2013
Persian Gulf & Oman Sea	1.13	0.43	0.70	0.62	Kaymaram et al 2013
Dar es Salam, Tanzania	1.44	0.43	1.01	0.70	Johnson et al 2014
Kwandang Bay, Sulawesi Sea, Indonesia	1.19	0.66	0.53	0.39	Nugroho & Hidayat 2014
Northern Persian Gulf, Iran	0.97	0.56	0.41	0.42	Niamaimandi et al 2015
Karimunjawa, Java Sea, Indonesia	1.12	0.79	0.33	0.29	Yuliana & Nurhasanah 2017
Bone Bay, Indonesia	1.84	0.76	1.08	0.59	The present study

Based on the information presented in Table 2, the rate of exploitation of narrow-barred Spanish mackerel was high in all locations in the waters of the Indian Ocean, except Karimunjawa, Java Sea. According to the results of the analysis (Figure 5), it can be explained that the value of actual Y/R was lower than the maximum Y/R value that can be reached by the population. This indicates that the narrow-barred Spanish mackerel recruitment process is not optimal, due to a high rate of exploitation. The use of environmental non-friendly fishing technology is one of the causes of the decline of large pelagic fish stocks in Bone Bay (Mallawa et al 2018).

Conclusions. The growth of narrow-barred Spanish mackerel in Bone Bay waters is relatively fast, with a Growth Rate Index of 4.19 per year. However, it is lower compared with the growth of narrow-barred Spanish mackerel in Australian waters. Narrow-barred Spanish mackerel in Bone Bay presents a fast growth in the first two to three years. The

infinity length is reached in the 10th to 12th years. The high value of the exploitation rate of narrow-barred Spanish mackerel is a result of the high fishing mortality rates and the natural mortality rate. The recruitment process of narrow-barred Spanish mackerel in Bone Bay waters is not optimal due to the high rate of exploitation.

Acknowledgments. The research was funded by the Research and Community Service Institute of Hasanuddin University. Our thanks go to the Palopo City Fisheries Service, fishermen and fish collectors for their assistance in carrying out the research. We would also like to thank our colleagues from the Faculty of Marine and Fisheries Science for the collaborative help.

References

Claereboudt M. R., Macllwain J. L., Al-Qufi H. S., Abu Ali A. A., 2005 Patterns of reproduction and spawning of the kingfish (*Scomberomorus commerson*) in the coastal waters of the Soltane of Oman. Fisheries Research 73:273-282.

Darvhisi M., Kaymaran F., Paroki P., Ali S., 2012 Estimating growth and mortality parameter of narrow barred Spanish mackerel in the Iranian waters of the Persian Gulf and Oman Sea. Journal of the Persian Gulf-Marine Sciences 3(10):57–62.

Gayanilo F. C. Jr., Sparre P., Pauly D., 2005 FAO-ICLARM stock assessment tools II (FISAT II). Revised version, User's guide, FAO computerized information series (Fisheries), no. 8, FAO Rome, 168 p.

Grandcout E. M., Al Abdelsalam T. Z., Francis F., Al Samsi A. T., 2005 Preliminary assessment of biology and fishery for the narrow barred Spanish mackerel, *Scomberomorus commerson* (Lacepede, 1800), in the southern Arabian Gulf. Fisheries Research 76:277-290.

Johnson M. G., Mgaya Y. D., Shaghude Y. W., 2014 Growth, mortality and reproductive biology of narrow-barred Spanish mackerel, *Scomberomoruscommerson* (Lacepede 1800) along the northern Tanzanian coastal waters. IOTC-2014-WPNT02-29 Rev. 1:1–17.

Kaymaram F., Gashemi S. H., Vahabnezhab A., Darvishi M., 2013 Growth, mortality and exploitation rate of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Persian Gulf and Oman Sea, Iran, Hormozgan's waters. Third Working Party on neritic tuna in Bali Indonesia, IOTC-2013-WPNT03-29 Rev. 1:1–7.

Lee B., Mann B. Q., 2017 Age and growth of narrow-barred Spanish mackerel *Scomberomorus commerson* in the coastal waters of southern Mozambique and Kwa Zulu Natal South Africa. African Journal of Marine Sciences 39(4):397–407.

Mallawa A., 2013 [Population dynamic and stock assessment Part I. Population dynamic], Hasanuddin University, Makassar, 208 p. [in Indonesian]

Mallawa A., Amir F., Farida G. S., 2017 [Study on stock condition of skipjack (*Katsuwonus pelamis*) in Bone Bay waters, South Sulawesi]. Science Technology of Fishery Resources Utilization 4(2):572–588. [in Indonesian]

Mallawa A., Amir F., Safruddin, Mallawa E., 2018 [The sustainability of fishing technology of skipjack tuna (*Katsuwonuspelamis*) in Bone Bay waters]. Journal of Technology and Management for Fishing 9(1):93–106. [in Indonesian]

Motlagh T. S. A., Shojaei M. G., 2009 Population dynamic of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Persian Gulf , Busherh Province Iran. Indian Journal of Fisheries 56(1):7-11.

Motlagh T. S. A., Shyfabadi S. J., Ghodrata S. M., Abathi B., Taheri M. A., 2008 Population dynamic of the Spanish mackerel (*Scomberomorus commerson*) in coastal waters of Oman Sea. Iranian Journal of Fisheries Sciences 7(2s):257–270.

Newmann S. J., Mackie M. C., Lewis P. D., 2012 Age-based demography and relative fisheries productivity of Spanish mackerel *Scomberomorus commerson* (Lacepede 1800) in Western Australia. Fisheries Research 120-130:46–60.

Niamaimandi N., Kaymaram F., Hoolihan J. P., Mohammadi G. H., Fatemi S. M. R., 2015 Population dynamicparameters of narrow-barred Spanish mackerel

(*Scomberomorus commerson*) from commercial catch in the Northern Persian Gulf. Global Ecology and Conservation 4:666–672.
Nugroho T., Hidayat T., 2014 [Population dynamic of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in Kwandang Gulf of Sulawesi Sea]. Indonesian Journal of Fishery Research 20(4):251–258. [In Indonesian]
Pauly D., 1980 On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil International pour l'Exploration de la mer 39:175–192.
Pauly D., 1984 Length-converted catch curves. A powerfull tool for fisheries research in the tropics. Part II. ICLARM Fishbyte 2(1):17-19.
Shojaei M. G., Motlag S. A. T., Seyfabadi J., Abtahi B., Dehghani R., 2007 Age, growth, and mortality rate of the narrow barred Spanish Mackerel (*Scomberomorus commerson* Lacepede, 1800) in coastal waters of Iran from length frequency data. Turkish Journal of Fisheries and Aquatic Sciences 7:115–121.
Sparre P., Venema S. C., Urchin P., 1989 Introduction to tropical fish stock assessment, Part I, Manual, Rome, Italy, 399 p.
Yuliana E., Nurhasanah, 2017 [The King mackerel and frigate tuna rate exploitation in Karimunjawa Java Sea]. Journal of Mathematics, Sciences and Technology 18(1):44–55. [in Indonesian]
***DGFC-RI (General Directorate for Capture Fisheries of the Republic of Indonesia), 2014 [Performance Map of Indonesian Capture Fisheries Resources]. Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia, Jakarta, 110 p. [in Indonesian]
***FAO, 1995 Code of Conduct for Responsible Fisheries. Rome, Italy, 41 p.
***IOTC Secretariat, 2017 Assessment of Indian Ocean narrow-barred Spanish mackerel (*Scomberomorus commerson*) using data limited catch-based methods. IOTC-2017-WPNT07-17 Rev. 1:1-24.

Received: 20 January 2019. Accepted: 16 April 2019. Published online: 30 June 2019.
Authors:
Achmar Mallawa, Department of Fishery, Faculty of Marine Science and Fishery, Hasanuddin University, Jln Printis Kemerdekaan KM. 10, Tamalanrea, 24095 Makassar, South Sulawesi, Indonesia; e-mail: achmar_mallawa@yahoo.co.id
Faisal Amir, Department of Fishery, Faculty of Marine Science and Fishery, Hasanuddin University, Jln Printis Kemerdekaan KM. 10, Tamalanrea, 24905 Makassar, South Sulawesi, Indonesia; e-mail: faisalamir_unhas@yahoo.com

How to cite this article:
Mallawa A., Amir F., 2019 Population dynamics of narrow-barred Spanish mackerel Scomberomorus commerson (Lacepede, 1800) in Bone Bay waters, South Sulawesi, Indonesia. AACL Bioflux 12(3):908-917.