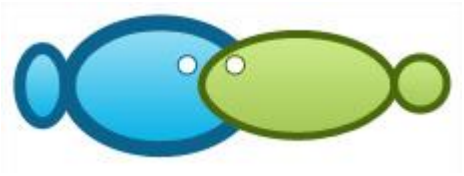

Population dynamics of *Prionace glauca*, using length frequency in the waters of Makassar Strait, Indonesia

Faisal Amir, Achmar Mallawa, Joeharnani Tresnati

Department of Fisheries, Faculty of Marine Science and Fisheries, Hasanuddin University, 90245, Makassar, South Sulawesi, Indonesia. Corresponding author: F. Amir, faisalamir_unhas@yahoo.com

Abstract. The blue shark (*Prionace glauca*) is one of the three dominant species caught in the waters of the Makassar Strait, Indonesia, using drift longlines. The research aims to determine population parameters such as length structure, growth, mortality, exploitation rate, and relative yield per recruitment. Measurement of body length of fish is done once a week; 106 specimens were collected from August to October 2020 with a length range of 72 - 270 cm total length (TL). Sex was determined by the presence of a clasper. The length structures were analyzed graphically and to determine the difference between males and females, a t-test at a 95% confidence level was used. Population growth was analyzed by von Bertalanffy's exponential growth, $L_{\sim}$ and K values were estimated with the ELEFAN method (Pauly & David 1981) and t_0 with Pauly's method (Pauly 1983). Total mortality (Z) expected from the catch curve and natural mortality (M) is obtained from the empirical relationship of Pauly's (Pauly 1980). The length at first capture (L_c) was estimated with the FISAT-II method. Finally, the estimate of the optimal exploitation rate (E_{opt}) was done using the relative yield per-recruitment (Y/R)' model of Beverton and Holt (Sparre et al 1989). The results showed that the value of $L_{\sim}$=378.5 cm TL, K=0.25 year^{-1}, and t_0=-0.32 year. The estimated values for Z=2.63 years^{-1}, M=0.36 years^{-1}, F=2.27 years^{-1}, and Lc=156.1 cm TL. The catch is dominated by juvenile fish. The estimated rate of exploitation was above the optimum rate of exploitation, indicating that the blue shark population in the Makassar Strait waters is being over-exploited.
Key Words: blue shark, growth, mortality.

Introduction. The blue shark (*Prionace glauca*) is one of the three dominant shark species caught in the waters of the Makassar Strait using drift longlines and landed in the Majene Regency, West Sulawesi Province, Indonesia. Sharks and rays caught by Indonesian fishermen in Java, Bali, and Nusa Tenggara amount to 140 species (Fahmi & Dharmadi 2013). The five most dominant shark species found in Indonesia are the silky shark (*Carcharhinus falciformis*), the scalloped hammerhead shark (*Sphyrna lewini*), the blue shark (*Prionace glauca*), the big eye thresher shark (*Alopias pelagicus*), and the thresher shark (*Alopias superciliosus*) (Sembiring et al 2015). The fishing grounds for blue sharks in the Makassar Strait include littoral and offshore waters. The blue shark caught as the main target.

Research on blue sharks has been widely carried out in the world but in Indonesia, it is still very limited (Kurniawan et al 2016; Novianto & Nugraha 2014; Novianto et al 2015; Novianto et al 2014; Pralampita et al 2003; Rapi et al 2020; Sentosa et al 2017). Across the world research presents: a study of the size distribution of blue sharks by Coelho et al (2017); age and growth of blue sharks from the North Atlantic is reported by Coelho et al (2017), Henderson et al (2001), Skomal and Natanson (2003), and Stevens (1975); from the South Pacific Ocean by Joung et al (2018); from the Indian Ocean by Andrade (2017); Coelho et al (2017); from the New Zealand Exclusive Economic Zone by Manning and Francis (2005); aspects of shark fisheries by Carvalho et al (2011); aspects of reproductive biology reported by Castro and Mejuto (1995), Mejuto and García-Cortés (2005), and Megalofonou et al (2009); and a report on the genetic aspects of blue sharks was reported by Veríssimo et al (2017).

Information about the size structure and population parameters of the blue shark in the Makassar Strait has not been reported, even though Majene Regency is the landing center for sharks caught by fishermen in West Sulawesi, especially from Majene Regency. The purpose of this study was to obtain preliminary information on the population of blue sharks captured by fishermen who land their catch in Majene Regency, West Sulawesi Province. We analyzed length frequency data and the size structure was analyzed using the descriptive method as outlined in a bar chart, and population parameters were calculated using FiSat-II (Gayanilo et al 2005) to estimate the value of growth parameters, mortality parameters, length at first capture, and relative yield per recruit.

Material and Method. The study was conducted in August - October 2020. Body length data for each sex was collected at three large collector locations in Majene Regency, West Sulawesi Province, Indonesia. Determination of fishing grounds was done by plotting all coordinate points of each operating fishing vessel stored in the global position system (GPS) using ArcGis 10.5 software (Figure 1).

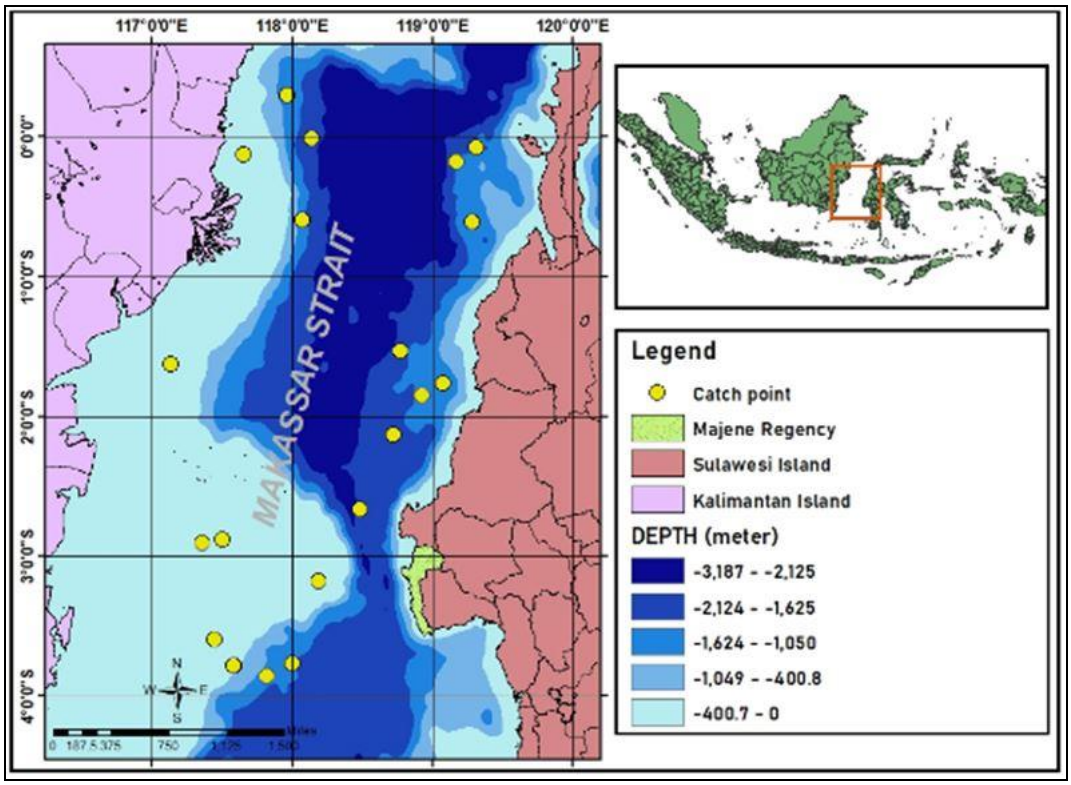

Figure 1. Location of data collection in Majene Regency, West Sulawesi Province, Indonesia.

Total length (cm TL) data for blue sharks was collected once a week from each fishing vessel that lands their catch at the collectors' sites. Determination of sex and body length of sharks caught by fishermen is carried out on the spot. Sex is recognized by the presence of a clasper in male fish. The 3-month length frequency measurement data was tabulated with 10 cm class intervals based on sex. Determination of the size structure of the fish was done using a bar chart. The differences in length measures between the sexes were analyzed using the t-test with the Statistical Package for the Social Sciences (SPSS) ver.16 (Hartono 2008). Significance of differences was defined at $p<0.05$. Estimated values of population parameters were analyzed using FiSat-II (Gayanilo et al 2005). The value of von Bertalanffy's growth parameter was estimated using ELEFAN-I (Pauly & David 1981) on the "Response Surface" routine by projecting several possible combinations of the desired von Bertalanffy growth parameters (L_∞ and K). The main criterion for selecting a von Bertalanffy growth parameter combination that is considered "best" is based on the Explained Sum of Peaks (ESP) / Available Sum of Peaks (ASP) ratio criteria, which ranges from 0.0 to 1.0 (Pauly & David 1981). The ESP/ASP ratio is

analogous to the ratio of Variance/Total Variance, as used in statistical analysis. The ratio is also considered analogous to the determinant coefficient (R^2) as used in regression analysis so that it can be used to measure the "Goodness of Fit" of the obtained von Bertalanffy curve. The estimated value "t_0" (the age of the fish at zero length) is obtained using the following Pauly (1983) empirical formula:

$$Log_{(-t0)} = -0.3922 - 0.2752 (LogL_\infty) - 1.038 (LogK)$$

By substituting the estimated values of L_∞, K, and t_0 into the von Bertalanffy growth model (Sparre et al 1989), a population growth model for blue sharks in the Makassar Strait will be obtained as follows:

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

where,
L_t = length of shark at age t (cm TL),
L_∞ = asymptote length (cm TL),
K = growth coefficient ($year^{-1}$).

The natural mortality rate (M) was estimated using Pauly's (1980) empirical formula:

$$M = Exp [-0.0152 - 0.279 (LnL_\infty) + 0.6543 (LnK) + 0.4634 (LnT^oC)]$$

where,
T^oC = average water temperature (^oC).

The total mortality coefficient (Z) was calculated using the catch curve method converted to length (Sparre et al 1989) calculated by FiSat-II (Gayanilo et al 2005). The catch mortality rate (F) is obtained by subtracting the value of M against Z (F=Z-M). L_c value was estimated by FiSat-II (Gayanilo et al 2005). The rate of exploitation (E) is obtained from E=F/Z. The relative catch per recruit (Y/R)' is estimated from the Beverton and Holt equations (Sparre et al 1989), that is:

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

where the value mentioned above is obtained from:

$$U = 1 - \frac{Lc}{L\infty}, \quad m = \frac{1-E}{M/K} = K/Z, \text{ and } E=F/Z$$

where,
E = rate of exploitation
K = coefficient of growth rate ($year^{-1}$)
L_∞ = length of fish asymptote (cm TL)
L_c = length of first time caught by a fishing gear (cm TL)
M = natural mortality rate ($year^{-1}$).

Results

Length size structure. The total specimens measured were 106 (48 males and 58 females) blue sharks. The total length intervals and mean total length was 72.0–265.0 cm TL (174.8±62.7 cm TL), 72.0-270.0 cm TL (172.1±64.1 cm TL), and 72.0–270.0 cm TL (172.2±64.5 cm TL) for male, female, and combined male and female blue sharks

respectively (Figure 2). The average length (mean±SD) of male samples of blue sharks was not significantly different from that of females at p=0.717 (p>0.05).

Growth. The t-test results showed that the length of male blue sharks was not different from that of females (p>0.05), so the population parameter analysis used a combination of male and female data. The estimated values for von Bertalanffy's growth equation parameters for blue sharks obtained were L_∞=378.5 cm TL and K=0.25 $year^{-1}$ at Rn=0.856 with Starting Sample (SS)=1 and Starting Length (SL)=105.0. The estimated age at zero length (t_0) is -0.32 years. Based on the values for L_∞, K, and t_0 obtained, the von Bertanlanffy growth equation can be written as follows:

$$L_t = 378.5\ [1 - \exp^{-0.25\ (t+0.32)}]$$

By using the growth equation obtained, the lifespan of each fish length can be predicted (Figure 3). Using the longevity relationship from the von Bertlanffy growth equation (Figure 3), the observed age range of blue sharks caught by Majene fishermen is 0.542 years to 4.677 years for minimum and maximum age, L_c age caught was 1.81 years, and the average age caught was 2.11 years.

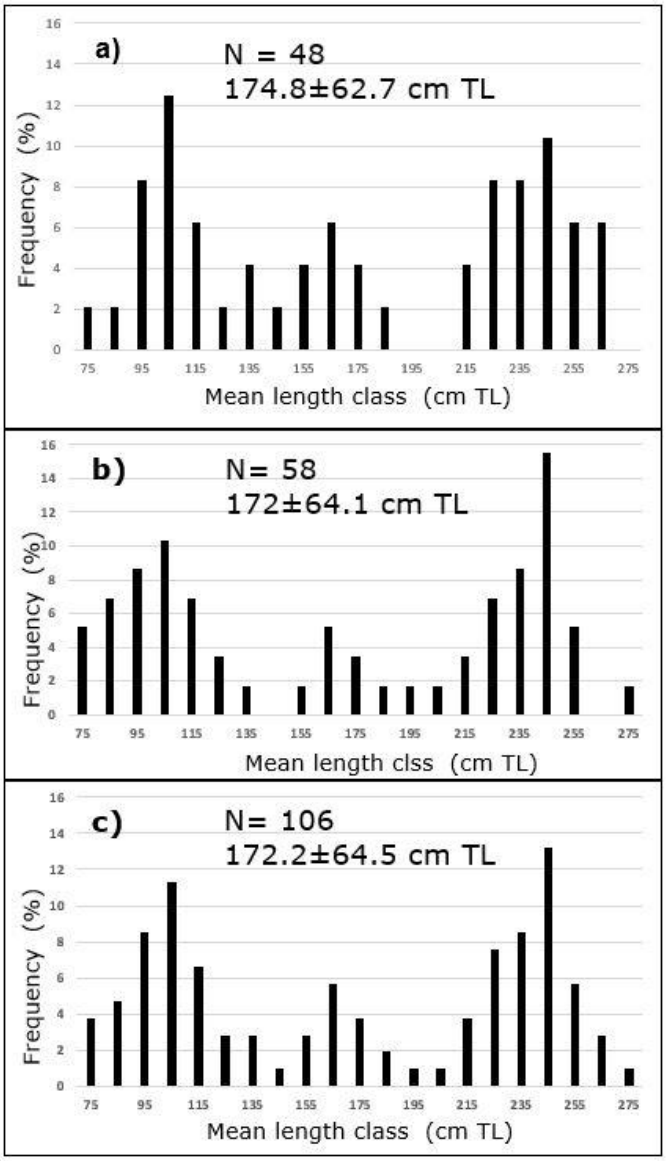

Figure 2. The length structure of the blue shark *Prionace glauca* in Makassar Strait waters: a) male, b) female, c) male and female combined.

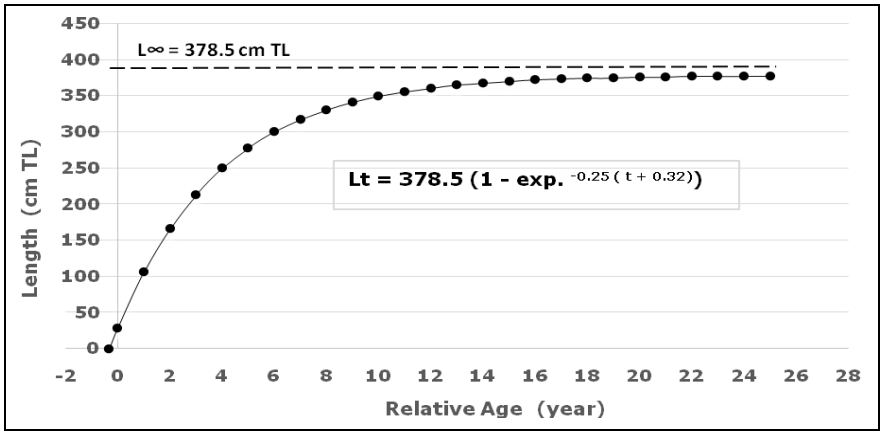

Figure 3. Growth curve for blue shark (*Prionace glauca*) in Makassar Strait.

Mortality and exploitation rates. Estimation of the total mortality rate (Z) using a long-converted catch curve (Figure 4) gives a value of Z=2.63 year^{-1}. By inputting the estimated value of L_∞=378.5 cm TL, K=0.25 year^{-1}, and the average temperature of the waters in the Makassar Strait (28^{0}C), Pauly's (1980) empirical relationship gives an estimated value of natural mortality of M=0.36 year^{-1}. Since Z=M+F, then F=Z-M=2.63-0.36=2.27 year^{-1} and the rate of exploitation (E=F/Z) is 2.27/2.63=0.86.

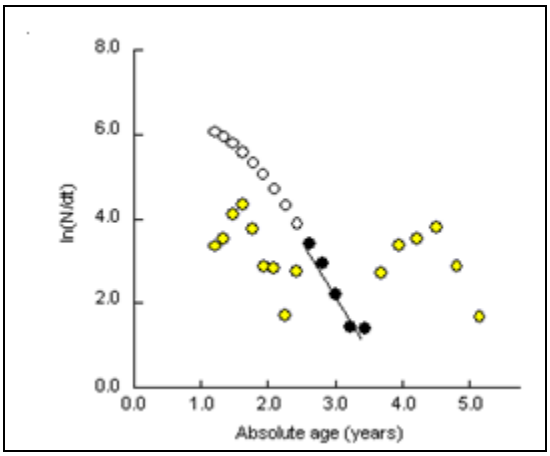

Figure 4. Length-based catch curve of the blue shark *Prionace glauca*. Input L∞=378.5 cm TL, K=0.25 year^{-1}, and M=0.36 year^{-1}.

Relative yield per recruitment. Relative yield per recruitment was determined as a function of exploitation rate assuming Lc/L∞ and M/K were 0.4123 and 1.44, respectively. The relative yield per recruitment (Y/R)' plot against E is shown in Figure 5, where the $(Y/R_{max.})'$=0.0577 is obtained at E_{max}=0.80 and as the rate of exploitation increases over this value the relative yields per recruitment decreased. In this study, the actual (Y/R)' value obtained was 0.0573 at E=0.86 which had passed the (Y/R)' optimal point of 0.0577 at E=0.80 (Figure 5), which indicates that the fish population blue sharks in the Makassar Strait is being overfished.

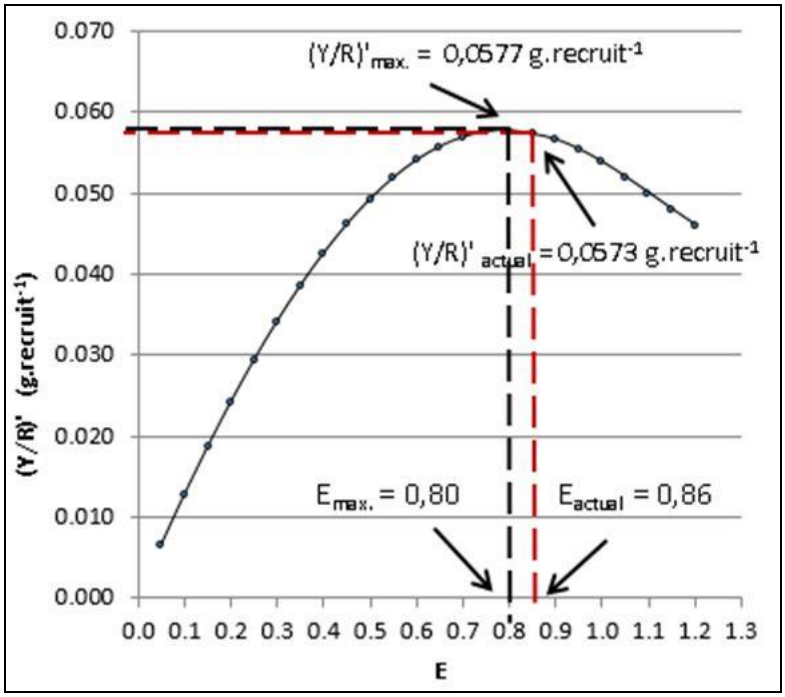

Figure 5. Relative yield per recruitment of blue sharks (*Prionace glauca*) in Makassar Strait waters.

Discussion. The range of length and mean length of the blue sharks in this study was 72.0–270.0 cm TL (172.2±64.5 cm TL), this size range is smaller than that reported by Coelho et al (2017), Joung et al (2017; 2018), Pralampita et al (2003), and Sentosa et al (2017). Sentosa et al (2017) reported that male blue sharks caught from the southern waters of Nusa Tenggara, Indonesia, were dominated by the size class of 250-290 cm TL and females were relatively dominated by two size classes, namely 210-250 cm TL and 250-290 cm TL with a combined average size of 254.02 cm TL. The low average size and maximum size of blue sharks caught in the Makassar Strait waters are suspected to be because fishermen who carry out fishing activities with a trip duration of 10-14 days, and their fishing ranges are limited to littoral and oceanic waters. This condition suggests that blue sharks that migrate from the western Pacific Ocean through the Sulawesi Sea to enter the Makassar Strait from the north are likely to be dominated by juvenile blue sharks. Nakano and Stevens (2008) state that blue sharks are classified as oceanic and epipelagic species and are found in all tropical to subtropical waters to continental shelf waters with the highest abundance found in the South Atlantic. This difference in size can also be influenced, among others, by differences in environmental conditions, stock conditions, fishing season, and the type of fishing gear used. Referring to Pratt (1979), who classified the size of maturity of blue sharks from the western Atlantic Ocean, namely 218 cm TL for adult males and 173 to 221 cm TL for adult females, the blue sharks caught in the Makassar Strait landed in Majene Regency are between 72.0-265 cm TL and 72.0-270 cm TL, respectively for males. and females. Then they can be grouped into juvenile males, adult males, and juvenile females, pre-adult females, and adult females, with the following percentages 60.4%, 39.6, and 50.0%, 12.1%, 37.9%. This percentages shows that the blue sharks caught are dominated by juveniles with a ratio of 3:2 between juveniles and adults.

Growth parameters for blue sharks from various locations in the Pacific Ocean have been reported by several researchers (Table 1). The L_∞ parameter estimates for blue sharks in our study in the Makassar Strait are relatively the same as for blue sharks obtained from other waters reported by Nakano (1994) from the North Pacific for male blue sharks, Tanaka et al (1990) western North Pacific, Joung et al (2018) from the western South Pacific, Henderson (2001) from the Northeast Atlantic, Skomal and Natanson (2003) for female blue sharks from the central South Pacific, but larger than that reported by Cailliet et al (1983) from the Pacific North eastern, Blanco-Parra et al (2008) from the western South Pacific, Skomal and Natanson (2003) from the central

South Pacific, Lessa et al (2004) and Joung et al (2017) from the eastern South Atlantic. The estimated K values obtained were similar to those reported by Cailliet et al (1983) from the eastern North Pacific for female blue sharks, but greater than the K values reported by other researchers from different locations (see Table 1). The recorded low maximum sample size of this study (270 cm TL) with an estimated age of 4.68 years is very small compared to the estimated age of blue sharks caught from other ocean waters, which is >10 years. Information on age and growth is needed in the management of an exploited resource (Sparre et al 1989). This study provides preliminary information on population parameters, namely age and growth of blue sharks in the Makassar Strait waters based on samples collected from the catch of traditional fishermen using drift longlines landed in Majene Regency. The low catch size range of blue sharks recorded in this study compared to that reported by other researchers at different locations is due to the location of the fishing grounds and the fishing gear technology used.

Based on the analysis of relative yield per recruitment from Beverton and Holt model (Sparre et al 1989) the exploitation rate of blue sharks obtained during the study was E=0.86, greater than E_{MSY}=0.8. This condition indicates that the status of the blue shark population in the Makassar Strait is labeled as over-exploited. If you want to keep the blue shark population in equilibrium (Y'/R), then the current exploitation rate must be reduced by 7.5% to reach E_{max}. There is no recorded information about the mortality coefficient values of blue sharks from various waters, so it is hoped that the results of our research assumptions can become a basis for reference in managing blue sharks in the Makassar Strait waters so that the blue shark population can provide optimal benefits for fishermen in Majene Regency, especially while maintaining the sustainability of its natural population.

Table 1

Estimated values of growth parameters (L_∞, K, t_o) and maximum observed age (t_{max}) of blue sharks from other oceans

References	*Research sites*	*Sex*	*N*	L_∞ *(cm TL)*	*K* *(year^{-1})*	t_0 *(year)*	t_{max} *(year)*
This study	Makassar Strait	Combined	106	378.5	0.25	-0.32	4.68
Cailliet et al (1983)	Eastern North Pacific	Male	38	295.3	0.18	-1.11	9
		Female	83	241.9	0.25	-0.80	9
Tanaka et al (1990)	Western North Pacific	Male	43	369.0	0.1	-1.38	7
		Female	152	304.0	0.16	1.01	8
Nakano (1994)	North Pacific	Male	148	378.8	0.13	-0.76	10
		Female	123	318.5	0.14	-0.85	10
Manning and Francis (2005)	South Pacific	Male	140	411.1	0.088	-1.26	22
		Female	288	321.1	0.126	-1.05	19
Blanco-Parra et al (2008)	Eastern North Pacific	Male	593	299.9	0.10	-2.44	16
		Female	324	237.5	0.15	-2.15	12
Joung et al (2018)	Central South Pacific	Male	173	376.6	0.128	-1.48	15
		Female	86	330.4	0.164	-1.29	11

Conclusion. This study succeeded in collecting preliminary information on the population of blue sharks (*Prionace glauca*) caught by fishermen from the Makassar Strait waters, namely that the average catch sizes of male and female blue sharks are not different, and they are dominated by relatively juvenile sharks. The growth parameters of blue sharks in the Makassar Strait are higher than in several other waters, population mortality is dominated by fishing mortality, and blue shark populations are over-

exploited. It is necessary to collect data on the catches of blue sharks in the Makassar Strait as a whole, at least yearly, to obtain accurate data that can be used as the basis for sustainable blue shark population management in the Makassar Strait waters.

Acknowledgements. The author would like to thank the leaders of Hasanuddin University Makassar, Indonesia, and the leaders of the Institute for Research and Community Service (LP2M), Hasanuddin University. This research was funded in the Hasanuddin University Basic Research Grant with contract number No.1585/UN4.22/PT.01.03/2020 dated 27 May 2020.

Conflict of Interest. The authors declare no conflict of interest.

References

Andrade I., Rosa D., Muñoz-Lechuga R., Coelho R., 2017 Age and growth of the blue shark (*Prionace glauca)* in the Indian Ocean. IOTC–2017–WPEB13–20.

Blanco-Parra M. P., Galván-Magaña F., Márquez-Farías F., 2008 Age and growth of the blue shark, *Prionace glauca* Linnaeus, 1758, in the northwest coast off Mexico. Reviews in Marine Biology and Oceanography 43:513–520.

Cailliet G. M., Martin L. K., Harvey J. T., Kusher D., Welden B. A., 1983 Preliminary studies on the age and growth of blue, *Prionace glauca*, common thresher, *Alopias vulpinus*, and shortfin mako, *Isurus oxyrinchus*, sharks from California waters. NOAA Technical Report NMFS-8. Proceedings of the International Workshop on Age Determination of Oceanic Pelagic Fishes: Tunas, Billfishes, and Sharks. NOAA Technical Report NMFS, 8:179–188.

Carvalho F. C., Murie D. J., Hazin F. H. V., Hazin H. G., Leite-Mourato B., Burgess G. H., 2011 Spatial predictions of blue shark (*Prionace glauca*) catch rate and catch probability of juveniles in the Southwest Atlantic. – ICES Journal of Marine Science, 68:890–900.

Castro J. A., Mejuto J., 1995 Reproductive parameters of blue shark, *Prionace glauca*, and other sharks in the Gulf of Guinea. Marine and Freshwater Research 46(6):967-973.

Coelho R., Mejuto J., Domingo A., Yokawa K., Liu K., Cortes E., Romanov E. V., da Silva C., Hazin F., Arocha F., Mwilima A. M., Bach P., de Zárate V. O., Roche W., Lino P. G., García-Cortés B., Ramos-Cartelle A. M., Forselledo R., Mas F., Ohshimo S., Courtney D., Sabarros P. S., Perez B., Wogerbauer C., Tsai W., Carvalho F., Santos M. N., 2017 Distribution patterns and population structure of the blue shark (*Prionace glauca*) in the Atlantic and Indian Oceans. Fish and Fisheries 19(1):90–106.

Fahmi, Dharmadi 2013 [Status of shark fisheries and aspects of management]. Oseana, Volume XXX, Number 1, 2005:1-8 [in Indonesian].

Gayanilo F. C. J., Sparre P., Pauly D., 2005 FAO ICLARM Stock Assessment ToolsII (FiSAT II). Revised version (p. 168). User's Guide. FAO Computerized Information Series (Fisheries). No.8, Revised version. Rome, Italy: Food and Agriculture Organization.

Hartono J., 2008 [Information systems research methodology]. Yogyakarta: CV Andi Offset. 312p [in Indonesian].

Henderson A. C., Flannery K., Dunne J., 2001 Observations on the biology and ecology of the blue shark in the northeast Atlantic. Journal of Fish Biology 58:1347–1358.

Joung S., Lyu G., Su K., Hsu H., Liu K., 2017 Distribution pattern, age, and growth of blue sharks in the South Atlantic Ocean. Marine and Coastal Fisheries, 9(1):38-49.

Joung S., Lyu G., Hsu H., Liu K., Wang S., 2018 Age and growth estimates of the blue shark *Prionace glauca* in the central South Pacific Ocean. Marine and Freshwater Research 69(9). https://doi.org/10.1071/MF17098

Kurniawan R., Barata A., Nugroho S. C., 2016 Hook rate, length of blue sharks (*Prionace glauca*) and their fishing grounds in the Indian Ocean. In Dharmadi & Fahmi (Eds.), Proceedings of the Symposium on Sharks and Rays in Indonesia (pp. 63–68). Jakarta: Ministry of Maritime Affairs and Fisheries.

Lessa R., Santana F. M., Hazin F. H., 2004 Age and growth of the blue shark, *Prionace glauca* (Linnaeus, 1758), off northeastern Brazil. Fisheries Research 66:19–30.
Manning M. J., Francis M. P., 2005 Age and growth of blue shark (*Prionace glauca*) from the New Zealand Exclusive Economic Zone. New Zealand Fisheries Assessment Report 2005/26. 52 p.
Megalofono P., Damalas D., Demetrio G., 2009 Biological characteristics of blue shark, *Prionace glauca*, in the Mediterranean Sea. Journal of the Marine Biological Association of the United Kingdom, 89(6):1233–1242.
Mejuto J., García-Cortés B., 2005 Reproductive and distribution parameters of the blue shark, *Prionace glauca*, on the basis of on-board observations at sea in Atlantic Indian and Pacific Oceans. SCRS/2004/103. Col. Vol. Sci. Pap. ICCAT, 58(3):951-973.
Nakano H., 1994 Age, reproduction and migration of blue shark in the North Pacific Ocean. Bulletin of the National Research Institute of Far Seas Fisheries 31:141–219.
Nakano H., Stevens J. D., 2008 The biology and ecology of the blue shark, *Prionace glauca*. In sharks of the open ocean: biology, fisheries and conservation. Edited by Camhi M. D., Pikitch E. K. and Babcock E. A. Blackwell Publishing Ltd. 502p.
Novianto D., Nugraha B., 2014 [Catch composition of by-catch and target species on tuna longline fisheries in Eastern Indian Ocean]. Marine Fisheries, 5(2):119–127 [in Indonesian].
Novianto D., Rochman F., Bahtiar A., Nugraha B., Jatmiko I., 2015 Blue shark (*Prionace glauca*) length composition from Indonesian longline fleet in the Indian Ocean: period 2005 – 2014. IOTC–2015–WPEB11–23, 1–12.
Novianto D., Rochman F., Nugraha B., 2014 Species composition, CPUE and length frequency of oceanic sharks based on observer data from the Indonesian longline fishery in the IndianOcean. IOTC–2014–WPEB10–13 Rev_1, 1–12.
Pauly D., 1980 On the inter-relationships between natural mortality, growth performance and mean environmental temperature in 175 fish stock. Journal du Conseil 39(3): 175-192.
Pauly D., David N., 1981 ELEFAN-I a basic program for the objective extraction of growth parameters from Length frequency data. Meeresforschung/Rep. Mar. Res. 28(4):205-211.
Pauly D., 1983 Some simple methods for the assessment of tropical fish stock. FAO Fish. Tech. Pap., (234):52p.
Pralampita W. A., Chodriya U., Widodo J., 2003 [Length, weight, and sex ratio of genus Carcharhinus and *Prionace glauca* family Carcharhinidae landed from Indian ocean waters south of Java, Bali, and Nusa Tenggara]. JPPI Resources and Capture Edition vol. 9 No.3:35-47 [in Indonesia].
Pratt H., 1979 Reproduction in the blue shark, *Prionace glauca*. Fishery Bulletin- National Oceanic and Atmospheric Administration 77(2):445-470.
Rapi N. L., Mallawa A., Tresnati J., Amir F., 2020 Growth pattern, condition factor and sex ratio of grey reef shark *Carcharhinus amblyrhynchos* (Bleeker, 1856) in Makassar Strait. IOP Conf. Series: Earth and Environmental Science 564 012016 IOP Publishing. doi:10.1088/1755-1315/564/1/012016
Sembiring A., Pertiwi N. P. D., Mahardini A., Wulandari R., Kurniasih E. M., Kuncoro A. W., Cahyani N. K. D., Anggoro A. W., Ulfa M., Madduppa H., Carpenter K. E., Barber P. H., Mahardika G. N., 2015 DNA barcoding reveals targeted fisheries for endangered sharks in Indonesia. Fisheries Research 164:130–134.
Sentosa A. A., Chodrijah U., Jatmiko I., 2017 [Size distribution and some population parameters of blue shark (*Prionace glauca* Linnaeus, 1758) caught in Southern Nusa Tenggara]. Indonesian Fisheries Research Journal vol.23 (2):67-76 [in Indonesia].
Skomal G. B., Natanson L. J., 2003 Age and growth of the blue shark (*Prionace glauca*) in the North Atlantic Ocean. Fishery Bulletin, 101:627–639.
Sparre P., Ursine E., Venema S. C., 1989 Introduction to tropical fish stock assessment. Part I Manual. FAO. Fisheries Technical 306/1. Rome. 337 p.

Stevens J. D., 1975 Vertebral rings as a means of age determination in the Blue Shark (*Prionace glauca*, L.). Journal of the Marine Biological Association of the UK 55:657–665.
Tanaka, S., Cailliet G. M., Yudin K. G., 1990 Differences in growth of the blue shark, *Prionace glauca*: technique or population? NOAA Technical Report 90:177–187.
Veríssimo A., Sampaio I., McDowell J. R., Alexandrino P., Mucientes G., Queiroz N., da Silva C., Jones C. S., Noble L. R., 2017 World without borders—genetic population structure of a highly migratory marine predator, the blue shark (*Prionace glauca*). Ecol Evol. 2017 Jul; 7(13):4768–4781.

Received: 17 November 2020. Accepted: 05 January 2021. Published online: 23 April 2022.
Authors:
Faisal Amir, Faculty of Marine Science and Fishery, Hasanuddin University, 90245 Makassar, South Sulawesi, Indonesia, e-mail: faisalamir_unhas@yahoo.com
Achmar Mallawa, Faculty of Marine Science and Fishery, Hasanuddin University, 90245 Makassar, South Sulawesi, Indonesia, e-mail: achmar_mallawa@yahoo.co.id
Joeharnani Tresnati , Faculty of Marine Science and Fishery, Hasanuddin University, 90245 Makassar, South Sulawesi, Indonesia, e-mail: jtresnati@yahoo.yahoo.com

How to cite this article:
Amir F., Mallawa A., Tresnati J., 2022 Population dynamics of *Prionace glauca*, using length frequency in the waters of Makassar Strait, Indonesia. AACL Bioflux 15(2):978-987.