Population parameter, size distribution and sex ratio of the blue shark (*Prionace glauca* Linnaeus, 1758) caught in the southern of Nusa Tenggara

U Chodrijah¹ and R Faizah²

¹ Research Institute for Marine Fisheries
² Center for Fisheries Center

Email: umi_chodriyah@yahoo.co.id

**Abstract.** The blue shark (*Prionace glauca* Linnaeus, 1758) was a targeted shark caught in the artisanal fisheries in Tanjung Luar, West Nusa Tenggara. This species was caught by drifting longline. The study aims to obtain the parameter population, size distribution and sex ratio of the blue shark from these waters. The research was conducted in Tanjung Luar during 2019-2020, and a total of 1676 blue sharks were caught by drift longline. The data were analyzed by using ELEFAN II. The size blue sharks varied from 73 cm to 397 cm total length (TL), with mean length was 266 cm for males and 72-390 cm with mean length 255.61 cm TL for females. Male was dominated sex ratio. The equation growth for blue shark for male was \( Lt = 400 \left(1 - e^{0.28 \times (-6.2921)} \right) \) and female was \( Lt = 390 \left(1 - e^{0.03 \times (0.3307)} \right) \). The first captured (Lc) length for males and females are 267.76 cm and 250.98 cm, respectively. Natural mortality (M) = 0.42/year, the fishing mortality (F) = 0.50/year. The exploitation rate was > 0.55/year it means that utilization rate of blue sharks in Southern of Nusa Tenggara waters was susceptible to overfishing. This condition needs good management actions for this species.

1. **Introduction**

The blue shark (*Prionace glauca* Linnaeus, 1758) or his karet in Indonesia is a shark's members in marine ecosystems as large predators. The species has a gestation period between 9-12 months and an average litter size of 34 pups. Characteristics of reproductive are different between oceans, but females mature between 5-7 years old and males between 4-6 years old. The blue shark is oceanic, epipelagic, highly migratory, and has a wide distribution. In Indonesia, this shark is found in Indian waters, from West Sumatera to West Nusa Tenggara. Sometimes they are found in the South China Sea and Banda Sea [1]; [2].

For the status conservation, the blue shark was given a Near Threatened (UN) status by The IUCN Red List in 2009 [3]. However, related to CITES (Convention on International Trade in Endangered Wild Fauna and Flora Species), the status has not been evaluated whether it is included in the appendix or not. The blue sharks are bycatch in pelagic fisheries' activity, especially in tuna longline fisheries in the Southern Indian Ocean [4][5]. In addition, the type of blue shark is sometimes also caught by gillnet tuna and purse seine [1]. The blue shark is caught by drift longline in Tanjung Luar. Generally, *P. glauca* caught in large numbers (about 20 million/year), mainly as bycatch, but the research related to population biology was limited, and almost the catch for this shark was unreported [3].
The population of the blue shark has unknown; however, the catch of this shark was predicted to decline, especially in Southern Java waters [1]. Studies on the blue shark fisheries in Indonesia are also still limited. Several studies for blue sharks in Indonesia waters are [6][7][8][4][5][9][10]. Related to inadequate information biology of P. glauca in the Indonesia waters, mainly in The Southern of Nusa Tenggara. The study aims to obtain the size distribution, growth, sex ratio and the level calcification this species. The results of this study will be used to support sustainable management.

2. Material and methods

2.1. Data collection
Research of the blue shark was conducted in TPI Tanjung Luar during March 2019-2020. The number of samples was 1676 individuals come from driftnet longline fisheries. The parameters measured in this study are total length, weight, and sex for further analysis. The unit of measurement for length in cm and for weight in kg. Females and males are determined by looking at the clasper organs in males.

2.2. Analysis
The model growth curves for the study was used three-parameter von Bertalanffy growth function (VBGF)[11] following equation (1):

\[ L_t = L_\infty \left(1-e^{-k(t-t_0)}\right) \] (1)

Where:
- \( L_t \) = the length at age \( t \) (years);
- \( L_\infty \) = asymptotic length (cm);
- \( t_0 \) = theoretical age when the length is zero (years), and
- \( k \) = the growth coefficient.

The value of \( t_0 \) was estimated using the empirical equation [12]

\[ \log(-t_0) = -0.392 - 0.275 \times \log L_\infty - 1.038 \times \log K \] (2)

The total mortality (Z) was calculated by:

\[ Z = M + F \ldots. \] (3)

The natural mortality rate (M) was estimated by apply empirical model from [12]:

![Figure 1. Sampling location in Tanjung Luar](image-url)
\[
\log M = -0.0066 \cdot 0.279 \log L + 0.6543 \log K + 0.4634 \log T \ldots
\]

T (°C) = average temperature of the aquatic environment. The fishing mortality was calculated from the formula:

\[
F = (Z - M)
\]

Exploitation rate (E) was calculated by the relationship:

\[
E = \frac{F}{Z}
\]

The sex ratio was analysed by formula [13]:

\[
NK = \frac{N_{FM}}{N} \times 100%.
\]

Where NK = sex ratio; NFM = number of females/male; N = total number of the blue shark observed. The balance of the sex ratio was carried out by the Chi-Square test [14]

3. Results and discussion

3.1. Distribution of size

The total length of females varied from 72 to 390 cm total length (TL) with mean = 255.61 cm and modus 270 cm, for males from 73 - 397 cm TL, mean 266 cm and modus was 290 cm (Figure 2). The maximum size was reported by [14] for blue sharks in the Atlantic Ocean is very close to our estimation (400 cm). However, the maximum length in this study is larger than the length was recorded by [10] in the same waters (L max = 383cm) and by [16] in the Mediterranean Sea (Lmax =349 cm). A similar result was reported by [17] in the Indian Ocean that the maximum length was 394 cm. The blue sharks are oceanic species, so that there are many adult sharks offshore or in oceans [18][19]. The size of the blue shark was variety depends on the fishing ground.[19] mentioned that *P. glauca* has a maximum total length was 380 m and is often caught below 335 cm. Meanwhile [20] recorded sizes up to 383 cm.

![Figure 2a. Size distribution of the blue shark (Prionace glauca) female](image)

![Figure 2b. Size distribution of the blue shark (Prionace glauca) male](image)

3.2 Length and weight relationship

The blue shark, *Prionace glauca* has a length and weight relationship as follows W= 1E-05L^{2.728}, r = 0.93 for female and W= 1E-05L^{2.756} with r = 0.92 for male with growth pattern were negative allometric for both sexes (t-test ; P < 0.05) (Figure 3 ). These conditions indicate that the blue shark has elongated growth.
The result of this study was similar with [6]; they found the b value less than 3 in Palabuhan Ratu, Cilacap, and Tanjungluar, b value was more than 3. [21] and from [22] found b value of the blue shark from North-western and Atlantic South Western Indian Ocean were more than 3 (b =3.178 and b = 3.204, respectively). The difference in the value of b could be caused by different habitats and the number of samples used in relationship analysis length-weight. Information regarding the length-weight relationship is essential for estimating the weight of a shark to evaluate the biomass if only length data is available [23].

3.3. Growth parameter estimation ($L_\infty$, $K$, $t_0$)

The growth parameters estimation of the blue shark, *Prionace glauca*, for both sexes were asymptotic length ($L_\infty$) was 400 cm TL, the growth coefficient ($k$) was 0.20/year, and the theoretical age at zero-length ($t_0$) was −0.29 years for male and then for female, $L_\infty = 390.5$ cm TL, $k= 0.25$/year, and $t_0 = 0.33$ years (Figure 4). These results suggest that males have slower growth than females. These values are substantially greater than 333.02-385.59 cm at asymptotic length described by [10] In the same waters, and that was described by [24] (330.4-376.6 cm). The value of $L_\infty$ in the present study was similar to that reported by [16] in the Mediterranean Sea ($L_\infty = 401$ cm) and by [25] and [26] were estimated that asymptotic lengths values of 395 and 423 cmTL, respectively. The observed maximum age of blue shark specimens was 13 years for females and 15 years for males. For males, the age was similar to the blue shark in the Central South Pacific Ocean [24]. However, [27] reported that the maximum observed age of 22 and 19 years for males and females, respectively.

$k$ value of blue sharks more than 0.1 for a year in the Southern of Nusa Tenggara. This value, similar to several studies about the blue shark’s growth parameter, was found $k$ value >1. [24] stated this condition showed that this species has faster grow than most other large pelagic sharks. [28] said this difference may be due to water temperature as the temperature is very influential in shark growth.
3.4. The length at first captured ($L_c$)

The length in first capture for the blue shark (*Prionace glauca*) was calculated to be $L_c = 250.98$ cm for female and $267.76$ cm for male (Figure 5a&b).

3.5. The mortality and exploitation rate

From the catch curve based on length, the natural mortality rate ($M$) is $0.38$/year, and the fishing mortality was $1.07$/year (Figure 6). Thus, the total mortality rate ($Z$) becomes $0.87$/year. The exploitation rate ($E$) was estimated as $0.56$/year.

The $F$ value > $M$ value, this condition indicates that exploitation for the blue shark in these waters is not optimum. As [29] suggested that fish stock would be optimum when the fishing mortality is equal with its natural mortality. In the present study, the exploitation rate value was $0.56$ / year, so it can be said that the blue shark caught in the Southern of Nusa Tenggara has fully exploited.
3.6. **Sex ratio**  
The sex ratio of the blue shark (*Prionace glauca*) in this research was 1: 0.58 (Figure 7), and it is significantly different from ideal condition ratio 1:1 ($\chi^2 = 3.814$, $P<0.05$), which means that the sex ratio of the blue shark was not balanced.

**Figure 6.** The catch curve of the blue shark (*Prionace glauca*)

**Figure 7.** Sex Ratio of the blue shark (*Prionace glauca*)

Monthly, sex ratio was dominated by females in June, July, and November 2019, but in 2020, the female shark was dominated only in May. In general, the number of males is more than females. This condition showed that the number of blue sharks from the Southern of Nusa Tenggara was dominated by males (Figure 8).
Figure 8. The monthly sex ratio of the blue shark (*Prionace glauca*)

[23] stated that sex ratio describes the proportion ratio of males to females of population. The present result was similar to [10], where the sex ratio of the blue shark in the Indian Ocean was unbalanced where the sex ratio is dominated by the male by (75.76%). Some result studies showed the same condition where the blue shark was dominated by a male [30] [6] [31], [16] [32][33][34][8], and [35], [31] [36] and [37] also stated that the sex ratio of *P. glauca* was significantly dominated by male species at several landing sites in Indonesia. In contrast, [17] found that the blue shark from the Indian Ocean was dominated by the female [6]; [38] revealed that an unequal sex ratio could be caused by differences in fish behavior according to gender, environmental conditions, reproductive processes, feeding habits, migration, and fishing factors. The other opinion, expressed by [16] that differences in the sex composition of catches reflect differences in the natural distribution of sex and size, possibly derived from sexual differences in reproductive behavior. [39]; [40], [33] argued that the sex ratio is not balance can potentially improve the vulnerability of the blue sharks to overfishing.

3.7. The level of calcification

Observations on the level of calcification of clasper the male shark indicate the maturity level of the blue shark male was dominated by the Fully Calcified category (FC). It means that the sharks caught are dominated by adult sharks with matured sex. This condition was similar with the [10] study that the level of maturity was dominated by FC between 2014-2016. [30] expressed that the clasper phenomenon is commonly used to determine the sexual maturity of males.
4. Conclusions
The growth pattern of the blue shark Prionace glauca was negative allometric for both sexes. The mature males dominate the sex ratio. The population parameter of this species has the growth equation von Bertalanffy \( Lt=400 \left(1-e^{-0.28(t+0.29)}\right) \) for males and \( Lt=390.5\left(1-e^{-0.25(t+0.33)}\right) \) for females. Length at first caught \( L_c = 267.76 \) cm for males and 250.98 cm for females. The exploitation rate \( (E) = 0.56/\text{year} \) indicates that the exploitation of blue sharks is not optimum; therefore, it is necessary to have a good fisheries management strategy for the sustainability of blue shark fisheries in the Southern Nusa Tenggara.

Acknowledgments
The authors would like to thank shark enumerators at Tanjung Luar, East Lombok. This study was funded by Research Institute for Marine Fisheries (RIMF) Jakarta, Indonesia.

References
[1] Fahmi and Dharmadi 2013 Tinjauan Status Perikanan Hiu dan Upaya Konservasinya di Indonesia (p. 179). Jakarta: Direktorat Konservasi Kawasan dan Jenis Ikan Direktorat Jenderal Kelautan, Pesisir dan Pulau-Pulau Kecil
[2] Froese R and Pauly D. (Eds.) 2017 FishBase World Wide Web electronic publication. www.fishbase.org, version 10/2016
[3] Stevens J 2009 Prionace glauca The IUCN Red List of Threatened Species 2009: e.T39381A10222811., 1–11. http://doi.org/http://dx.doi.org /10.2305/IUCN.UK.2009-2.RLTS.T39381A10222811.en
[4] Novianto D Rochman, F Bahtiar A Nugraha B and 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
[5] Novianto D Rochman, F and Nugraha B 2014 Species composition, CPUE and length frequency of oceanic sharks based on observer data from the Indonesian longline fishery in the Indian Ocean. IOTC–2014–WPEB10–13 Rev_1, 1–12.10.1016/j.fishres.2015.07.016
[6] Pralampita W A Chodriyah U and Widodo J 2003 Panjang, Bobot, dan Nisbah Kelamin Cucut Lanjam dari Genus Carcharhinus dan Cucut Selendang, Prionace glauca (Famili
Carcharhinidae) yang Didaratkan dari Perairan Samudera Hindia Selatan Jawa, Bali, dan Nusa Tenggara J Lit Perikan Ind. Edisi Sumber Daya Dan Penangkapan, 9(3) 35–47

[7] Kurniawani R Barata and Nugroho S C 2016 Laju pancing (hook rate), panjang hiu aer (Prionace glauca) dan daerah penangkapannya di Samudera Hindia. In Dharmadi & Fahmi (Eds.) Prosiding Simposium Hiu dan Pari di Indonesia (pp. 63–68) Jakarta Kementerian Kelautan dan Perikanan.

[8] Novianto D Rochman F and Nugraha B 2014 Species composition, CPUE and length frequency of oceanic sharks based on observer data from the Indonesian longline fishery in the Indian Ocean.IOTC–2014–WPEB10–13 Rev_1 1–12

[9] Sentosa A A Widarmanto N Wiadnyana N N and Satria F 2016 Perbedaan hasil tangkapan hiu dari rawai hanyut dan dasar yang berbasis diTanjung Luar Lombok J Lit Perikan Ind 22(2),105–114

[10] Sentosa A A U Chodrijah and I Jatmiko 2017 Size Distribution and Some Population Parameters of Blue Shark (Prionace glauca Linnaeus, 1758) Caught In Southern Nusa Tenggara J Lit Perikan Ind 23 (2) 67-76

[11] Sparre P and Venema S C 1998 Introduction to Tropical Fish Stock Assessment Part 1 Manual FAO Fisheries Technical Paper 306 p 376

[12] D Pauly 1983 Some simple methods for the assessment of tropical fish stocks FAO Fish Tech. Pap

[13] Khouw A S 2016 Methods and Quantitative Analysis in Bioecology (Bandung: Alfabet) [in Indonesia].

[14] Gay L R 1996 Educational Research: Competencies for Analysis and Application (New Jersey: Prentice-Hall Inc) p 662

[15] Froese R and Pauly D (eds) 2005 FishBase World Wide Web electronic publication Available at http://www.fishbase.org /

[16] Megalofonou P D damalas and G de metrio 2009 Biological characteristics of blue shark Prionace glauca in the Mediterranean Sea Journal of the Marine Biological Association of the United Kingdom, 2009 89(6), 1233–1242. https://doi:10.1017/S0025315409000216.

[17] Coelho R Mejuto J Domingo A et.al. 2017 Distribution patterns and population structure of the blue shark (Prionace glauca) in the Atlantic and Indian Oceans Fish Fisheries 19 (2):1–17 https://doi.org/10.1111/faf.12238

[18] Compagno L Dando M and Fowler S 2005 A Field Guide to the Sharks of the World (p. 496) Princeton NJ Princeton University Press

[19] Compagno L J V 1998 Sharks In K. E Carpenter and V H Niem (Eds.) FAO Identification Guide for Fishery Purposes The Living Marine Resources of the Western Central Pacific Vol. 2 Cephalopods Crustaceans Holothurians and Sharks (pp. 1193–1366) Rome, Italy Food and Agriculture Organization

[20] White W T Last P R Stevens J D Yearsley G K Fahmi and Dharma 2006 Economically Important Sharks and Rays of Indonesia National Library of Australia Cataloging-in-Publication entry Australia 329

[21] Campana S E L Marks W Joyce and N Kohler 2005 Catch bycatch and indices of population status of blue shark (Prionace glauca) in the Canadian Atlantic ICCAT, Col. Vol. Sci. Pap., 58 (3) 891-934

[22] Ariz J A D de Molina M L Ramos J C Santana 2007 Length-weight relationships conversion factors and analyses of sex-ratio, by length-range, for several species of pelagic sharks caught in experimental cruises onboard Spanish longliners in the South Western Indian Ocean during 2005 by IOTC-2007-WPEB-04
[23] Effendie M I 2002 Biologi Perikanan (p. 163). Yogyakarta: Yayasan Pustaka Nusantara.
[24] Joung S J, G T Lyua Hsu, H H Liu K M and S B Wang 2018 Age and growth estimates of the blue shark Prionace glauca in the central South Pacific Ocean. Marine and Freshwater Research. https://doi.org/10.1071/MF17098.
[25] 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 United Kingdom 55 657–665. https://doi.org/10.1017/S0025315400017318.
[26] Aasen O 1966 Blahaien Prionace glauca (Linnaeus, 1758). Fisken og Havet 1 1–15.
[27] Manning M J and 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, Ministry of Fisheries Wellington New Zealand.
[28] Simpfendorfer C A, McAuley R B, Chidlow J and Unsworth P 2002 Validated age and growth of the dusky shark, Carcharinus obscurus from western Australian waters. Marine and Freshwater Research 53 567–573. http://doi:10.1071/MF011131.
[29] Gulland J A 1983 Fish stock assessment: a manual of basic methods. Chichester: U K Wiley Interscience. FAO/Wiley series on Food and Agriculture.
[30] White W T 2003 Aspects of the biology of elasmobranchs in a subtropical embayment in Western Australia and of chondrichthyans fisheries in Indonesia. PhD Thesis. Murdoch University Western Australia.
[31] White W T 2007 Catch composition and reproductive biology of whaler sharks (Carcharhiniformes: Carcharhinidae) caught by fisheries in Indonesia. Journal of Fish Biology 71(5), 1512–1540. http://doi.org/10.1111/j.10958649.2007.01623.x.
[32] Montealegre-Quijano S and Vooren C M 2010 Distribution and abundance of the life stages of the blue shark Prionace glauca in the Southwest Atlantic. Fisheries Research 101(3), 168–179. http://doi.org/10.1016/j.fishres.2009.10.001.
[33] Zhu J, Dai X, Xu L, Chen X and Chen Y 2011 Reproductive biology of female blue shark Prionace glauca in the southeastern Pacific Ocean. Environmental Biology of Fishes 91(1), 95–102. http://doi.org/10.1007/s10641-010-9763-1.
[34] Tavares R, Ortiz M and Arrocha F 2012 Population structure, distribution and relative abundance of the blue shark (Prionace glauca) in the Caribbean Sea and adjacent waters of the North Atlantic. Fisheries Research 129-130 137–152. http://doi.org/10.1016/j.fishres.2012.06.018.
[35] Nurcahyo H, Sangadji I M and Yudiarso P 2016 Komposisi spesies distribusi panjang dan rasio kelamin hiu yang didaratkan di Jawa Timur Bali NTB dan NTT. In Dharmadi and Fahmi (Eds.), Prosiding Simposium Hiu dan Pari di Indonesia (pp. 33-41). Jakarta: Kementerian Kelautan dan Perikanan.
[36] Stevens J D 1984 Biological observations on sharks caught by sport ûshermen off New South Wales. Australian Journal of Marine and Freshwater Research 35 573–590.
[37] Skomal G B and Natanson L J 2003 Age and growth of the blue shark (Prionace glauca) in the North Atlantic Ocean Fishery Bulletin 101 627–639.
[38] Rahardjo P 2007 Pemanfaatan dan Pengelolaan Perikanan Cucut dan Pari (Elasmobranchii) di Laut Jawa. Sekolah Pascasarjana Institut Pertanian Bogor Bogor.
[39] Bal D V and K V Rao 1984 Marine Fisheries. Ata Mc Graw-Hill Publ Co Ltd New Delhi. 470.
[40] Klimley A P 2013 The Biology of Sharks and Rays (p. 512). Chicago: The University of Chicago Press, Ltd.