Length-weight relationship and reproductive size of silky shark *Carcharhinus falciformis* and scalloped hammerhead shark *Sphyrna lewini* collected in Tanjung Luar fish landing port, East Lombok, Indonesia

[1]Iman Wahyudin, [2]Mohammad M. Kamal, [2]Achmad Fahrudin, [2]Mennofatria Boer

[1] Study Program Marine and Coastal Resource Management, Graduate School, Bogor Agricultural University, Bogor, Indonesia; [2] Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor, Indonesia. Corresponding author: I. Wahyudin, imanwahyudin75@gmail.com

Abstract. This research examines biological aspects of silky shark (*Carcharhinus falciformis*) and scalloped hammerhead shark (*Sphyrna lewini*) caught in Tanjung Luar, Lombok District, Indonesia. The purpose of this research was to know the relationship and condition factor for both types of shark caught in Tanjung luar. Sampling was done in March-May 2018, by using Surface longline and bottom longline. The results showed that *C. falciformis* has a positive allometric growth pattern and *S. lewini* has a negative allometric growth pattern. In addition, the relative weight condition factor showed the figures above 100 (categorized as good waters) and viewed from the sexual maturity aspect, most of the hammerhead shark was included in mature category, while for the silky shark, and most of female shark was included in the immature category.
Key Words: sexual maturity level, clasper, isometrik, condition factor, allometric.

Introduction. Indonesia is a country that is rich in shark resources (White et al 2006; Fahmi 2010). Based on the export data of shark products in Indonesia, in the period of 1992-1995, total exports almost reached 10 thousand tons, with main destination to Japan, Hong Kong, China, Taiwan, South Korea, Singapore and Malaysia (Fahmi & Darmadi 2013). Over the past 20 years, Indonesia has been the top shark fishing nation, reporting average annual elasmobranch landings of 100,000 tons (FAO FishStatJ, 2015 in Jaiteh et al (2018). Meanwhile, based on data from the export recommendation of shark products from the Ministry of Marine Affairs and Fisheries (MMAF) of the Republic of Indonesia in 2018, Japan, Hong Kong, and Singapore remain the main markets for Indonesian sharks.

The silky shark, *Carcharhinus falciformis,* is one of the three most abundant shark species in the world and is widely distributed in tropical and subtropical waters (Compagno 1984). *C. falciformis* is a medium-sized shark that are oceanic and pelagic which is commonly found in offshore waters close to the mainland and in layers near the surface, although sometimes encountered to a depth of 500 m (White et al 2006). The scalloped hammerhead, *Sphyrna lewini*, shark is a coastal and semioceanic hammerhead shark that is circumglobal in coastal warm temperate and tropical seas, from the surface and intertidal to at least 275 m depth (Baum et al 2007). For the reason of commercial benefits, these two sharks have been the most targeted species by fishermen both in the tropic and sub-tropic waters (Compagno 1984; Bonfil 1999). In West Nusa Tenggara Province of Indonesia, particularly at Tanjung Luar fish landing port, it is shown from catch data monitoring that the highest landing was contributed from these two sharks in

2015-2016 (MMAF 2015). For *S. lewini* itself, Fahmi & Darmadi (2015) stated that this species contributed 18% of total catch from longline fisheries in Tanjung Luar.

The biological characteristics of sharks are susceptible to overfishing pressures (Gallucci et al 2006; Musick et al 2000) due to their long life cycle, slow growth and tardive maturation and low fecundity (Castro et al 1999; Compagno 1998; Last & Stevens 1994; Stobutzki et al 2002). The pressure of unsustainable fisheries has resulted in the population of *C. falciformis* being increasingly threatened, and its conservation status is almost threatened (Bonfil 1999). According to Ferretti et al (2008) and Hayes et al (2009) the population of *S. lewini* is suspected to have been under pressure due to intensive fishing and trading (especially the fins). According to IOTC (2014) there has been a decline in population of *S. lewini* worldwide, including the waters of the Indian Ocean.

Length-weight relationship and maturity aspects are important biological information of certain species of which mathematical models may be used to describe fish growth and for stock estimation (Morato et al 2001). While the maturity size parameter describes the cycle of sexual maturity and it is an important element for understanding the reproductive aspects of fish.

The current research results are still limited to studies on the size distribution and sex ratio of *C. falciformis* in the southern waters of West Nusa Tenggara, Chodrijah & Faizah (2015) and Sentosa (2017) dealt with biological characteristics of sharks and rays appendix II CITES landed in Tanjung Luar, East Lombok.

Material and Method

Data collection. Primary data was based on shark fishing landed at Tanjung Luar Fish Landing Port during March-May 2018 (Figure 1). Totally 1,753 *C. falciformis* and 219 *S. lewini* were observed, of which 313 *C. falciformis* and 140 *S. lewini* were taken as a samples. Determination of the number of samples was based on a list of sample determinations proposed by Krejcie & Morgan (1970). Identification and measurement activities were carried out to obtain biological data in the form of total length (TL) data, clasper maturity level data and sex ratio.

Figure 1. Map of research location.

Data analysis

Length-weight relationship and condition factor. Length-weight relationship (LWR) was calculated using the equation $W=aL^b$ (Sarang et al 2015; Keyombe et al 2015). The values of constant *a* and *b* were estimated using the least-square method applied to the log transformed data as $\log W = \log a + b \log L$ (Ricker 1973), where *W* (g) is the body weight of the fish, L (cm) is the total length, *a* is the intercept of the regression curve and *b* is the regression coefficient. Fulton's condition factor (*K*) was estimated from the relationship *K=100W/L3* to assess the fish condition in Tanjung Luar.

Clasper maturity level. Clasper maturity level was a measure of the achievement of maturity in males cartilaginous fish. There are 3 levels of maturity, namely Non-Calcified (NC), Non-Full-Calcified (NFC), and Full-Calcified (FC). NC is characterized by a clasper that is flat and has a soft texture with a vulnerable length of 1-13 cm. The clasper will begin to fill but with a flabby texture indicating the NFC phase. The peak of maturityis when the clasper is fully charged and hardened is in the FC phase (Shadwick et al 2015).

Size capture comparison. To measure the sexual maturity level of males and females was done by comparing the size of the body length of the shark caught compared to the maximum size that can be achieved and the size of sexual maturity (Courturier et al 2012). The maximum size and size of sexual maturity is referred to Compagno (1984).

Results and Discussion. During March-May 2018 period, there were 1,753 *C. falciformis* and 219 *S. lewini* landed at Tanjung Luar. Respectively, length varied between 670 and 2,650 mm and 490–3,040 mm, while weight was between 1,200 and 73,000 g and 500-168,000 g, for *C. falciformis* and *S. lewini*.

For the *C. falciformis*, the estimation value of length-weight coefficient was 3.135. This means that the *C. falciformis* caught at Tanjung Luar show positive allometric growth types, where weight gain is faster than length growth. Based on Figure 2 length-weight relationship has a regression equation y = 3.333x - 14.6667 with the coefficient of determination of 0.957. It is shown that 95.7% of weight is able to explain on length condition (P=0.01). While 4.3% of the fish weight gain may be caused by other factors such as environmental and age factors.
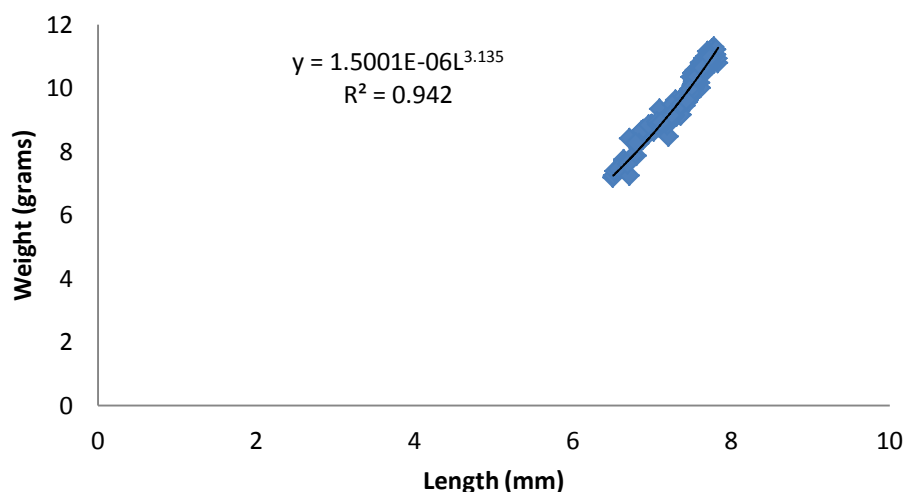

Figure 2. Length-weight relationship of *Carcharhinus falciformis* landed at Tanjung Luar Fish Landing Port.

Meanwhile, for *S. lewini*, based on data analysis of length-weight relationship, the estimation value of the length-weight coefficient is 2.8. This means that the growth pattern of the hammerhead shark landed at Tanjung Luar shows a negative allometric growth pattern (Figure 3). Based on Figure 3, length-weight relationship have regression equation y = 2.8x - 11.8 with determination coefficient of 0.982. It is shown that 98.2%

of weight is able to explain on length condition (P=0.01). While 1.8% increases in shark weight is caused by other factors such as environmental factors and age.

The plotted equation reads:
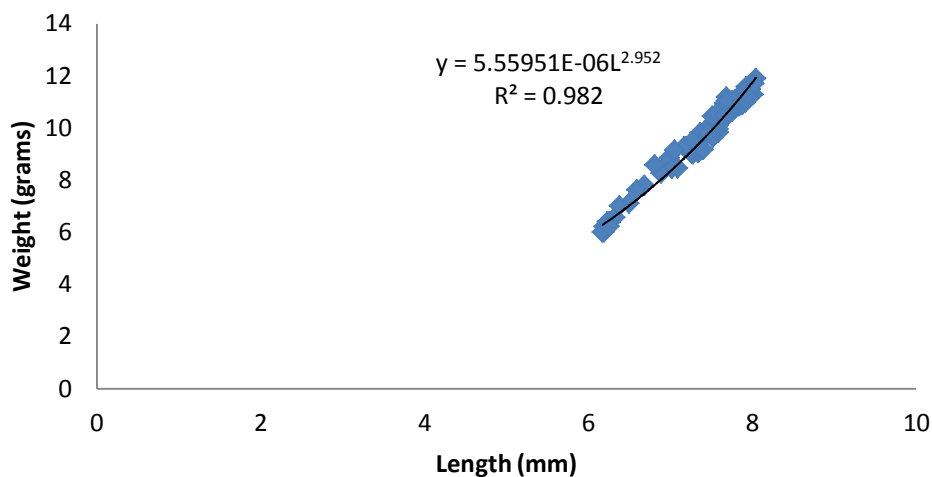$$y = 5.55951\text{E-}06L^{2.952}$$
$$R^2 = 0.982$$

Figure 3. Length-weight relationship of *Sphyrna lewini* landed at Tanjung Luar Fish Landing Port.

In this study, it was found that the *S. lewini* had relatively small *b* values (less than 3). Muchlisin (2010) states that the size of the value of b is also influenced by the behavior of fish, such as fish that swim active (pelagic fish) showed a lower value *b* when compared with passive swim fish (mostly demersal fish). Perhaps this is related to the allocation of energy spent on movement and growth.

The results showed the value of determination (R^2), of *C. falciformis* is 0.957 and of *S. lewini* is 0.982. If the determination (R^2) value is higher, it indicates a close relationship between weight gain and increase in fish length, and conversely (Walpole 1995). In this study, *C. falciformis* have the lowest correlation value compared to *S. lewini* that are close to 1. This indicates that the total length of fish body, the total weight of the fish body will also increase; in accordance with the opinion of Walpole (1995) which states that if the value of R is near 1, accordingly the closer the relationship between the two variants.

The growth rates will increase as the amount of food eaten increases. Growth is closely related to food, because nutrients and energy needed for growth come from food (Pratiwi et al 2011). It further states that growth will occur when there is excess energy once the available energy is already used for standard metabolism, digestion and activity.

The value of the condition factor is calculated based on the average of the relative weights. The results showed that the average value of the relative weights (Wr) for the silky sharks was 102.82, while for the average *S. lewini*, the value of Wr was 102.55. From the analysis it can be seen that the condition of the two shark species caught in Tanjung Luar Regency of East Lombok is above 100. According to Anderson & Neuman (1996) if the Wr value is below 100 then the fish population in the waters is in bad condition, if the value is above 100 then fish population in the waters is still in very good condition and very suitable to support its growth. This is in accordance with the opinion of Muchlisin (2010) that if the condition factor is in the range of 100 then the inhabitants are still in a balanced state.

Aquatic quality parameters are also major indicators in fish growth. If the water quality is good then the fish can live, grow and develop well. Based on water quality data in the waters in the elasmobranch fishing area there is no pollution occurrence. This can be seen from several indicators of water quality such as pH average sea waters ranged from 7.4 to 8.6, salinity is in the range of 34-37 ppt, while sea surface temperature ranges from 26.6 to 30.2°C. In addition, the dissolved oxygen content in the waters

ranges from 2.9-11 mg/L. All these parameters are still below the sea water quality standard for marine biota (Ministerial Decree No. 51 of 2004).

Clasper maturity level. *C. falciformis* landed in Tanjung Luar, in terms of the Clasper maturity level, are dominated by sexually mature species. In Figure 4, it can be seen that out of 157 male sharks landed, 51% were in the full-calcified (FC) maturity level of clasper, 38% were in the non-calcified (NC) phase and only 11% of the individuals were classified in the non-fully calcified (NFC) category.
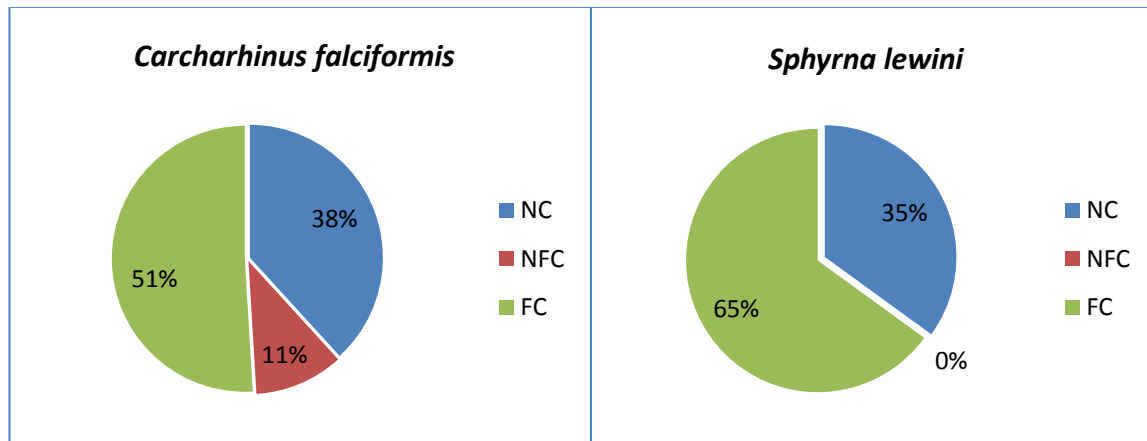

Figure 4. Clasper maturity level of *Carcharhinus falciformis* and scalloped hammerhead sharks *Sphyrna lewini*.

Size captured and size of sexual maturity. Based on data comparison of captured size, maximum size and size of sexual maturity, described by Compagno (1984), male and female shark species caught in Tanjung Luar have different proportion sizes of sexual maturity (Figure 5).
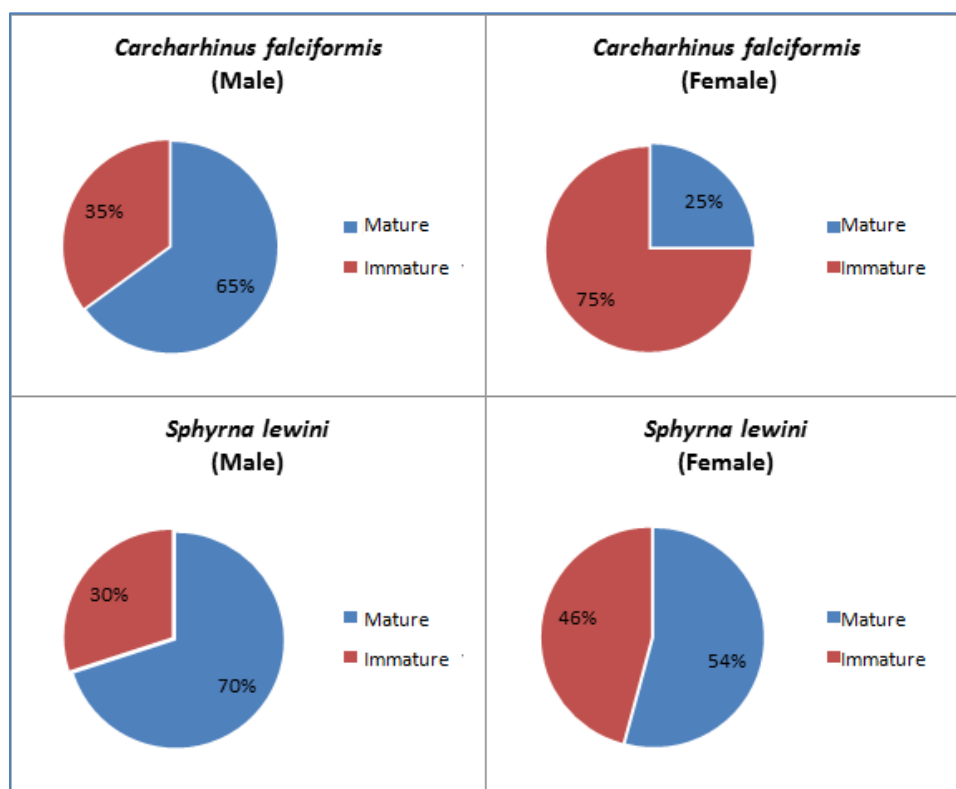

Figure 5. The sexual maturity level of *Carcharhinus falciformis* and *Sphyrna lewini* according sexes.

For *C. falciformis*, out of 157 male shark samples measured during March-May 2018, around 65% belong to the sexually mature category. While for female sharks about 75% are in the immature category.

As for *S. lewini*, out of 140 shark samples measured during March-May 2018, more than 50% belong to the sexually mature category. For male *S. lewini* from 20 sharks measured, around 70% belong to the sexually mature category. As for the female sharks from 140 samples measured, around 54% were included in the sexually mature category. The level of sexual maturity of *S. lewini* can be seen in Figure 5.

Conclusions. The growth pattern of *C. falciformis* is positive allometric (b>3) indicated that gain in weight was faster compared to length growth, on the contrary, *S. lewini* showed, negative allometric growth (b<3), where the increase in length is faster than that of weight. The average value of the relative weight (Wr) were >100 for both species, which mean that aquatic environment is in good condition and support its fauna growth. The maturity level of shark claspers (*C. falciformis* and *S. lewini*), showed that >50% are in the full-calcified (FC) category, meaning that the species has reached the peak of sexual maturity. Based on data comparison between caught size, maximum size and size of sexual maturity, of male sharks landed in Tanjung Luar, 65% are included in the sexually mature category. While for female sharks about 75% are in the immature category.

References

Anderson R. O., Newmann R. M., 1996 Length weight and associated structural indices. In: Fisheries techniques. 2nd edition, Murphy B. R., Willis D. W. (eds), pp. 447-481, American Fischeries Society, Bethesda, Maryland.

Baum J., Clarke S., Domingo A., Ducrocq M., Lamónaca A. F., Gaibor N., Graham R., Jorgensen S., Kotas J. E., Medina E., Martinez-Ortiz J., Monzini Taccone di Sitizano J., Morales M. R., Navarro S. S., Pérez-Jiménez J. C., Ruiz C., Smith W., Valenti S. V., Vooren C. M., 2007 *Sphyrna lewini*. In: IUCN 2018. IUCN Red List of Threatened Species 2018.

Bonfil R., 1999 The dogfish (*Squalus acanthias*) fishery of British Columbia, Canada and its management. In: Case studies of the management of elasmobranch fisheries. Shotton R. (ed), pp. 608-655. FAO Fish, Technical Paper 378, FAO, Rome.

Castro J. L., Woodley C. M., Brudek L. L., 1999 A preliminary evaluation of the status of shark species. FAO Fisheries, Technical Paper 380, 72 p.

Chodrijah U., Faizah R., 2015 Struktur Ukuran dan Nisbah Kelamin Ikan Cucut Kejen (*Carcharhinus falciformis*) di Perairan Selatan Nusa Tenggara Barat. Di Dalam: Prosiding Simposium Hiu Dan Pari Di Indonesia 2015.

Compagno L. J. V., 1998 Sharks. In: FAO Identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 2., Cephalopods, Crustaceans, Holuthurians and Sharks. Carpenter K. E., Niem V. H. H. (eds), pp. 1193-1366, Rome, Italy: Food and Agriculture Organization.

Compagno L. J. V., 1984 Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1- Hexanchiformes to Lamniformes: viii, 1-250. Part 2-Carcharhiniformes: x, 251-655. FAO Fisheries Synopsis 125:1-655.

Courturier L. I. E., Marshall A. D., Jaine F. R. A., Kashiwagi T., Pierce S. J., Townsend K. A., Weeks S. J., Bennett M. B., Richardson A. J., 2012 Biology, ecology, and Conservation of the Mobulidae. Journal of Fish Biology 80:1075–1119.

Fahmi, 2010 Sharks and rays in Indonesia. Research Center for Oceanography - Indonesian Institute of Sciences. Marine Research in Indonesia 35(1):43-54.

Fahmi, Dharmadi, 2013 Tinjauan Status Perikanan Hiu dan Upaya Konservasinya di Indonesia. Direktorat Konservasi dan Jenis Ikan, Direktorat Jenderal Kelautan, Pesisir dan Pulau-Pulau Kecil, Kementerian Kelautan dan Perikanan.

Fahmi, Dharmadi, 2015 Pelagic shark fisheries of Indonesia's Eastern Indian Ocean Fisheries Management Region. African Journal of Marine Science 37(2):259-265.

Ferretti F., Myers R. A., Serena F., Lotze H. K., 2008 Loss of large predatory sharks from the Mediterranean Sea. Conservation Biology 22:952-964.

Galluccci V. F., Taylor I. G., Erzini K., 2006 Conservation and management of exploited shark populations based in reproductive value. Canadian Journal of Fisheries and Aquatic Sciences 63:931–942.

Hayes C. G., Jiao Y., Cortes E., 2009 Stock assessment of scalloped hammerheads in the western North American Journal of Fisheries Management 29:1406-1417.

Jaiteh V. F., Hordyk A. R., Braccini M., Warren C., Loneragan N. R., 2017 Shark finning in eastern Indonesia: assessing the sustainability of a data-poor fisher. ICES Journal of Marine Science 74:242–253.

Keyombe J. L., Waithaka E., Obegi B., 2015 Length–weight relationship and condition factor of *Clarias gariepinus* in Lake Naivasha, Kenya. International Journal of Fisheries and Aquatic Studies 2(6):382-385.

Krejcie R. V., Morgan D. W., 1970 Determining sample size for research activities. Educational and Psychological Measurement 30:607-612.

Last P. R., Stevens J. D., 1994 Sharks and rays of Australia. CSIRO, Australia, 513 p.

Morato T. P., Afonso P., Lourinho P., Barreiros J., Santos R. S., Nash R. D. M., 2001 Length-weight relationship for 21 coastal fish species of the Azores, north-eastern Atlantic. Fisheries Research 50(3):297-303.

Muchlisin Z. A., 2010 Diversity of freshwater fishes in Aceh Province, Indonesia with emphasis on several biological aspects of the Depik (*Rasbora tawarensis*) an endemic species in Lake Laut Tawar. n PhD Dissertation, Sains Malaysia University, Penang.

Musick J. A., Burgess G., Cailliet G. M., Camhi, Fordham S., 2000 Management of sharks and their relatives (Elasmobranchii). Fisheries 25:9–13.

Pratiwi, Rostika R., Dhahihay Y., 2011 Pengaruh tingkat pemberian pakan terhadap laju pertumbuhan dan deposisi logam berat pada ikan nilem di KJA Waduk Ir. H Djuanda. Jurnal Akuatika 2(2):1-11.

Ricker W. E., 1973 Linear regressions in fishery research. Fisheries Research Board of Canada Bulletin 30:309-434.

Sarang N., Shrivas A. K., Sao S., Vardia H. K., 2015 Length-weight relationship and condition factor of *Catla catla* in Chhirpani Reservoir, Chhattisgarh, India.

Sentosa A. A., 2017 Karakteristik Biologi Hiu dan Pari Appendiks II CITES Yang Didaratkan di Tanjung Luar, Lombok Timur. Balai Riset Pemulihan Sumberdaya Ikan. Seminar Tahunan XIV Hasil Penelitian Kelautan dan Perikanan.

Stobutzki I. C., Miller M. J., Heales D. S., Brewer D. T., 2002 Sustainability of elasmobranchs caught as bycatch in a tropical prawn (shrimp) trawl fishery. Fisheries Bulletin 100:800-821.

Shadwick R. E., Farell A. P., Brauner C. J., 2015 Physiology of Elasmobranch Fishes: Structure and interaction with environment. Massachusetts (US): Academic Press.

Walpole R. E., 1995 Pengantar Statiska. Edisi ke-3. PT Gramedia Pustaka Utama, Jakarta.

White W. T., Last P. R., Stevens J. D., Yearsley G. K., Fahmi, Dharmadi, 2006 Economically important shark and rays of Indonesia. Australian Centre for International Agricultural Research, 2006 GPO Box 1571, Canberra, Australia 2601.

*** IOTC (International Ocean Tuna Commission), 2014 Status of the Indian Ocean Scalloped Hammerhead Shark (SPL: Sphyrna lewini) CITES APPENDIX II species. DRAFT: EXECUTIVE SUMMARY: SCALLOPED HAMMERHEAD SHARK.

*** ME (Ministry of Environment), 2004 Ministerial Decree No. 51. The criteria for seawater quality standards. Jakarta.

*** MMAF (Ministry of Maritime Affairs and Fisheries), 2015 Profile of landed shark surveys in East Java, Bali, West Nusa Tenggara and East Nusa Tenggara. Coastal and Marine Resources Management Center, Directorate General of Sea Space Management.

Authors:
Iman Wahyudin, Ministry of Marine Affairs and Fisheries, Directorate General of Sea Space Management, Indonesia, 16680 Jakarta, e-mail:imanwahyudin75@gmail.com
Mohammad Mukhlis Kamal, Bogor Agricultural University, Faculty of Fisheries and Marine Science, Department of Aquatic Resource Management, Indonesia, 16680 Bogor,Campus IPB Dramaga, e-mail: m_mukhliskamal@yahoo.com
Achmad Fahrudin, Bogor Agricultural University, Faculty of Fisheries and Marine Science, Department of Aquatic Resource Management, Indonesia, 16680 Bogor,Campus IPB Dramaga, e-mail: fahrudina@yahoo.com
Mennofatria Boer, Bogor Agricultural University, Faculty of Fisheries and Marine Science, Department of Aquatic Resource Management, Indonesia, 16680 Bogor,Campus IPB Dramaga, e-mail: mboer@ymail.com
How to cite this article:
Wahyudin I., Kamal M. M., Fahrudin A., Boer M., 2019 Length-weight relationship and reproductive size of silky shark *Carcharhinus falciformis* and scalloped hammerhead shark *Sphyrna lewini* collected in Tanjung Luar fish landing port, East Lombok, Indonesia. AACL Bioflux 12(1):355-362.