Available online at: http://ejournal-balitbang.kkp.go.id/index.php/ifrj
e-mail:ifrj.puslitbangkan@gmail.com
INDONESIAN FISHERIES RESEARCH JOURNAL
Volume 26 Nomor 1 June 2020
p-ISSN: 0853-8980
e-ISSN: 2502-6569
Accreditation Number RISTEKDIKTI: 21/E/KPT/2018

SOME REPRODUCTIVE BIOLOGY OF SKIPJACK TUNA (*Katsuwonus pelamis* LINNAEUS, 1758) IN TOLI-TOLI WATERS, CENTRAL SULAWESI

Umi Chodrijah*[1], Thomas Hidayat[1] and Karsono Wagiyo[1]
[1]Researcher in Research Institute for Marine Fisheries, Jl. Raya Bogor No.507, Nanggewer Mekar, Cibinong, Bogor, West Java
Received; February 02-2018 Received in revised from October 22-2018; Accepted January 07-2019

ABSTRACT

Skipjack tuna (*Katsuwonus pelamis*) was one of the export commodities, where the demand and exploitation tend to increase, so sustainable fisheries management is needed based on biological data. The objective of the research was to study the several aspects of biology including of length of weight relationship, sex ratio maturity stage, gonada somatic index (GSI), length at first capture, and length at first maturity. The research was conducted in February - December 2015 in Toli-toli, Central Sulawesi. The results showed that the skipjack tuna growth pattern was allometrically positive (b= 3,318 for male and b = 3.3049 for female), where growth weight was faster than the increased length. The length of the first time capture skipjack tuna of pole and line (43.49 cmFL) was bigger than length at first maturity (41,007 cmFL). It means the mostly skipjack tuna caught have already spawned. The spawning season occurred throughout the year with spawning peaks are in April and September, with fecundity ranging from 450,570 to 1,707,390 eggs.

Keywords: Biological aspect; Skipjack tuna; spawning season; Toli-toli

INTRODUCTION

Indonesia has an important role in the world's tuna fisheries (Marcille *et al*., 1984; Suhana *et al.,* 2016; Tadjuddah *et al*., 2017& Khan *et al.,* 2019), covering 16% of the world tuna production (Buana *et al.,* 2018). Skipjack tuna catch in Indonesia is the largest among the other tuna groups (64.07%) (Majkowski, 2007; Suhana *et al.,* 2016). Skipjack tuna production of Indonesia in 1999 was 205,670 tons (Majkowski, 2007; FAO, 2015; Tridge, 2019) and tended to increase towards 2014 that reached 496,682 tons (DJPT, 2015) then slightly decreased in 2017 with 467,548 ton (https://satudata.kkp.go.id/dashboard_produksi).

Toli-Toli is one of the important fish landing bases in contributing to the skipjack tuna production of Indonesia. Based on Toli-Toli Regency Statistics 2014, total catch of this fish was 60,673 ton, comprising 69,81% tuna fish group and 30.19% of other fish species (pelagic small, demersal, and shrimp) (Anonimous,2014). Global catches on tropical tuna fish dominated by skipjack 47,91%, yellowfin 21,51%, and other tuna 0,40%. Recent data showed that global catch of skipjack in 2016, which was around 2.8 million tons, ranked at the third for sevenconsecutive years (FAO, 2018).

The products of skipjack tuna together with other fish products covered 40% of the world food trade (FAO, 2001 *in* Suhana *et al.*, 2016) then increased to 52% in 2016 with prices remained low and consumer demand for end-products increased in many markets (FAO, 2018a). Market demand for skipjack tuna products continues to increase, thereby encouraging over-exploitation which is indicated by high fishing mortality above the maximum sustainable yield level in some areas (Miyake *et al*., 2010).

To fulfill market demand and sustainability of skipjack tuna resources, a management strategy based on biological aspect is needed. This biological aspect is the identity of population characteristics that are very important in applying rational resource use (Matsumoto *et al*., 1984; Jin *et al.*, 2015) and factors related to migration trajectory which are important in implementing comprehensive management for sustainable exploitation (Kumar *et al*., 2019).

The purpose of this research is to know the biological aspect of skipjack tuna, including the relationship of length of weight, sex ratio, maturity stage of gonad, average length at first capture, and length of first maturity. The results of this study are

correspondence author:
e-mail: umi_chodriyah@yahoo.co.id
DOI: http://dx.doi.org/10.15578/ifrj.26.1.2020.1-10

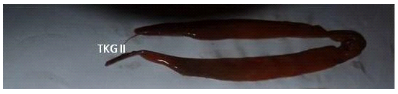
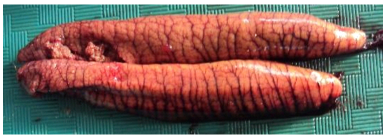
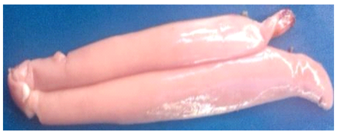
expected to be used as a consideration for the management of skipjack tuna resources in the West Pacific Region especially in the Celebes Sea Waters.

MATERIALS AND METHODS

Data Collection

The study was conducted from February to December 2015. Skipjack tuna samples were obtained from the catch of fishers using pole and line, hand line, and small purse seine. Sampling was done on tuna fish landed from the Sulawesi Sea. Sampling and observation of biological aspect (length, weight, and gonad maturity) of skipjack tuna samples were conducted at the Tandoleo Fish Landing Center, Toli-Toli, Central Sulawesi. Sample of gonads were preserved using 10% formalin solution and Gilson. Further sample analysis was conducted at the Laboratory of Research Institute Marine Fisheries, Cibinong Bogor. Determination of maturity stage follows the criteria of I to V (Holden & Raitt, 1974), listed in Table 1.

Table 1. Gonad Maturity Stage of Skipjack tuna

Stage	Female	Male
I (Immature)	Ovary and testis about 1/3rd length of body cavity. Ovary pinkish, translucent.	Testis whitish. Ovary not visible to naked eye.
II (Maturing virgin and recovering spent)	Ovary and testis about 1/2 length of body cavity. Ovary pinkish, translucent. 	Testis whitish, more or less symmetrical. Ovary not visible to naked eye. 
III (Ripening)	Ovary and testis is about 2/3rds length of body cavity. Ovary pinkish-yellow colour with granular appearance. 	Testis whitish to creamy. No trans- parent or translucent ova visible. 
IV (Ripe)	Ovary and testis from 2/3rds to full length of body cavity. Ovary orange-pink in colour with conspicuous superficial blood vessels. Large transparent, ripe ova visible. 	Testis whitish-creamy, soft. 
V (Spent)	Ovary and testis shrunken to about 1/2 length of body cavity. Walls loose. Ovary may contain remnants of disintegrating opaque and ripe ova, darkened or translucent.	Testis bloodshot and flabby.

Data Analysis

Length-weight data analysis is a standard method in fisheries stock assessment to describe fish growth (Kuriakose, 2014). The relationship between length and weight was described by Effendie (1979):

W = a * Lb .... (1)

where:

W = weight of fish (gram)
L = fork length fish (cm)
a and b = constants

The length-weight relationship that has been obtained was tested by t-test, that is testing the hypothesis:

H0: b = 3 (isometric)

H1: b $\neq$ 3 (allometric)
If t-count is smaller than t-table then H0 is accepted.
If t-count is greater than t-table then H0 is rejected.

Length-at-first-capture are among vital scientific information needed for the management and sustainability of a fishery (Udoh & Ukpatu, 2017). Length at first capture (Lc=50%) was fraction retained from fishing gear. The value of Lc is obtained from the length distribution examined by the formula (Sparre & Venema, 1992):

$$SL_{est} = 1/(1+\exp(S_1 - S_2 * L)) \quad (2)$$

$$Lc = S_1/S_2 \quad (3)$$

where:
SL_{est} : logistics curve
S1 and S2: constants

Sex ratio can influence ecological and population conditions (Fryxell *et al*., 2015). The sex ratio was analyzed by comparing the number of male fish with female fish:

$$X = M:F \quad (4)$$

where:
X = sex ratio
M = number of male fish observed
F = number of female fish observed

Sex ratio was tested by chi-square according to Sugiyono (2004) as follows:

$$X^2 = \sum_i^k \frac{(f0 - fn)^2}{fn} \quad (5)$$

where:
X^2 = Chi – Square
Fo = observed frequency
Fn = expected frequency

With the hypothesis (H0): there is no significant difference between the number of male and female fish. If, ÷2 calculated < ÷2 tables, H0 is accepted, and conversely.

The figuring of length at first maturity was examined according to Spearman-Karber method with the following equation (Udupa, 1986):

$$m = Xk + \frac{1}{2} - (Xx\sum pi) \quad (6)$$

Where :
M = logarithm length of the first gonadal maturity
Xk = logarithm of mid length class where the fish was 100% mature.
X = average logarithm of difference length class
pi = proportion of mature fish in the-i class

Gonad maturity is useful for estimating reproductive potential, spawning stock biomass, and recruitment potential (Yaragina, 2010). Visual stage maturity determination refers to the classification of Gonado Somatic Index (GSI) using the formula according to Effendie (1979):

$$GSI = Wg / Wt \times 100\% \quad (7)$$

where:
GSI = gonado somatic index (%)
Wg = weight of gonad (gram)
Wt = total weight of fish (gram).

Fecundity is a measure of reproductive performance, related to population density and environmental stochastic influences (McMahon & Bradshaw, 2008). The calculation of skipjack tuna fecundity is done by taking adult fish gonads that have reached TKG III and IV. Measurement of diameter size and number of eggs was done by using a magnification microscope 4 x 10. Observation of the number and distribution of egg size by using egg samples as much as 0.5 grams. Fecundity is calculated gravimetrically with the formula by Holden & Raitt (1974):

$$F = n \times G / g \quad (8)$$

where:
F = fecundity
n = number of eggs in subsample
g = gonad weight
g = weight of sub sample gonad (0.5 gram).

RESULTS AND DISCUSSION
Results

Length Weight Relationship

Based on 445 samples of skipjack tuna *(K. pelamis*), ranged between 35-61 cmFL (male) and 35-63 cmFL (female), the mean lengths were 43.54 cmFL (male) and 44.25 cmFL (female). The growth pattern of male and female were allometrically positive with the equation $W = 0,005L^{3,318}$ (male) and $W = 0,0057L^{3,3049}$ (female) with correlation coefficients (r^2) of 0.9722 and 0.9708 respectively (Figure 1).

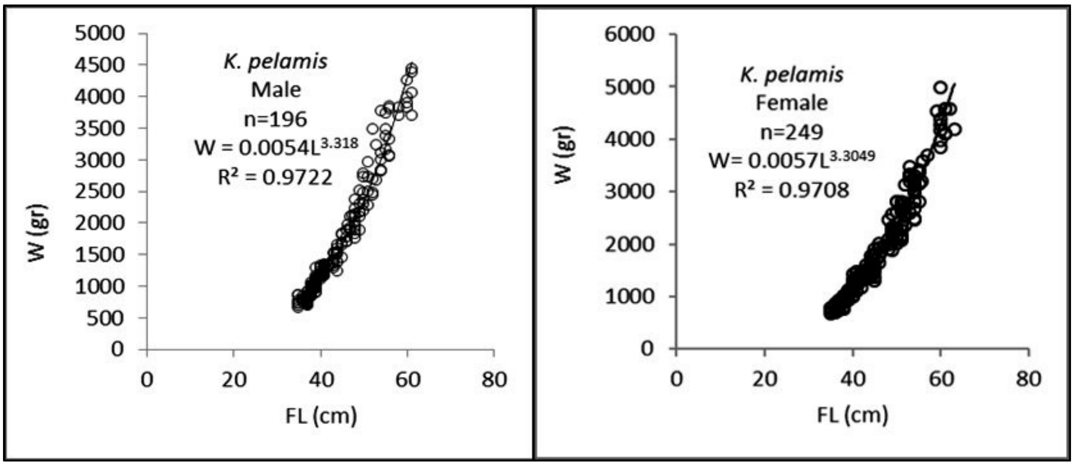


Figure 1. The length-weight relationship of male (left) and female (right) of skipjack tuna (*Katsuwonus pelamis*) caught by pole and line, purse seine and handline in Toli-Toli waters.

Length of First Capture (L_c)

The analysis of length at first capture (Lc) of skipjack tuna (*Katsuwonus pelamis*) from Toli-Toli waters caught by handline, pole and line, and purse seine found 36.55 cmFL, 43.49 cmFL, and 38.27 cmFL, respectively (Figure 2). While using Spearman-Karber (Udupa, 1986), the method shows that length at first maturity (Lm) was 41,007 cmFL.

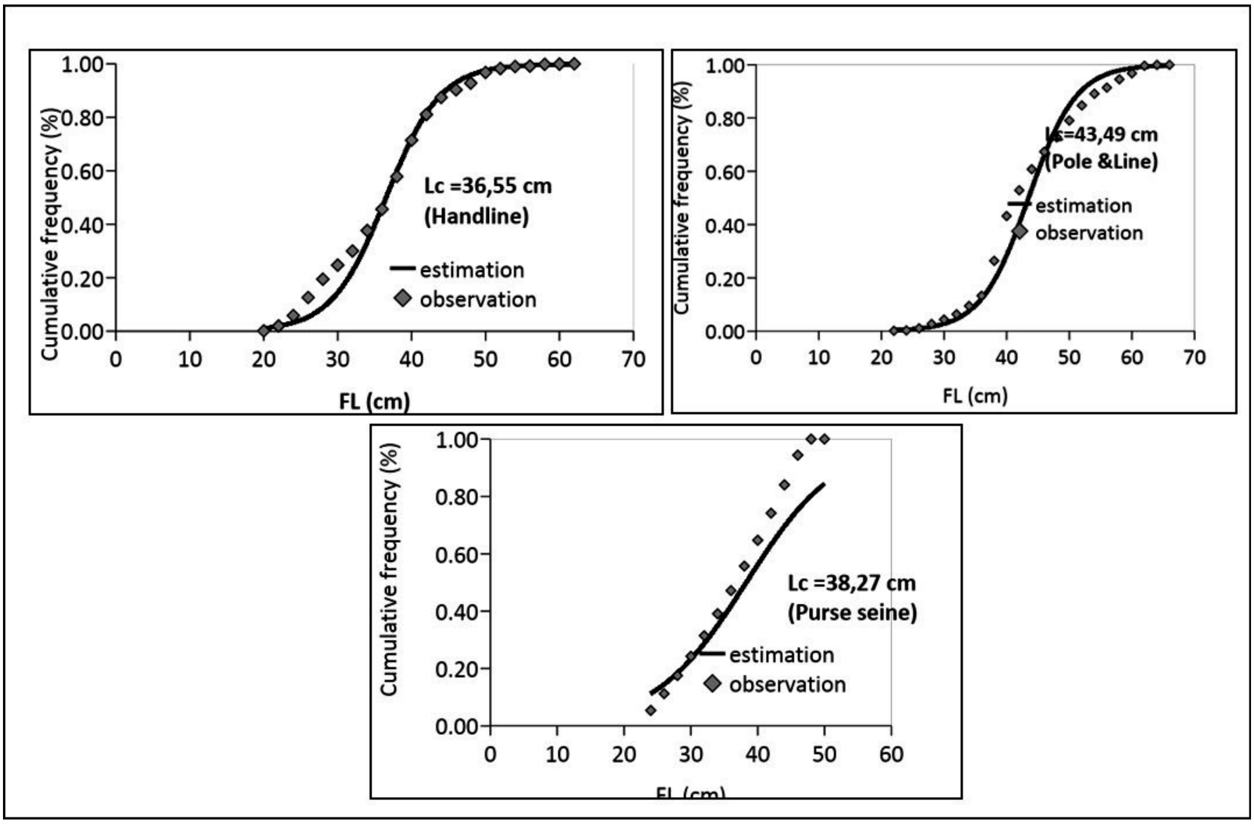


Figure 2. Length at first capture (Lc) of skipjack tuna caught by handline, pole and line and purse seine in the Toli-Toli waters.

Sex Ratio and Maturity Stages of Gonads

The number of female skipjack tuna measured during this study was 249 while the the male was 196 specimens. Based on the chi-square test, the female and male tuna ratio is statistically in an unbalanced state. Understanding sex ratio is related to maintaining the sustainability of fish populations (Budd *et al.*, 2015; Fryxell *et al.,* 2015; Madenjian *et al.,* 2016; Benevenuto *et al*., 2017; Maskill *et al.*, 2017; Provoost *et al.,* 2017). Therefore, it is expected that the ratio of male and female fish is balanced. The balance of male and female condition allows the fertilization of eggs by spermatozoa to become new individuals have bigger chance (Effendie, 2002, Chan *et al.,* 2012). This would also describe the status of its demographic structure within population.

The results showed that the development of gonad maturity stage of skipjack tuna varied on monthly basis. Figure 3 showed the composition of gonad maturity stage. It shows phases classified into 5 stages of both male and female. Stage I to IV spread almost in every month. The gonad maturity of female skipjack tuna that had stage I was dominant in May (46.4%), stage II in June (58.33%), stage III in February (50%), and stage IV in August (53.8%). The gonad maturity of male skipjack tuna that had stage I was dominant in March (75%), stage II in October (62%), stage III in August (41.67%), and stage IV in July (50%). Most of the male and female tuna are caught in immature gonads. The highest of the gonad maturity stage IV of male skipjack tuna was found in July, while the female one was found in August.

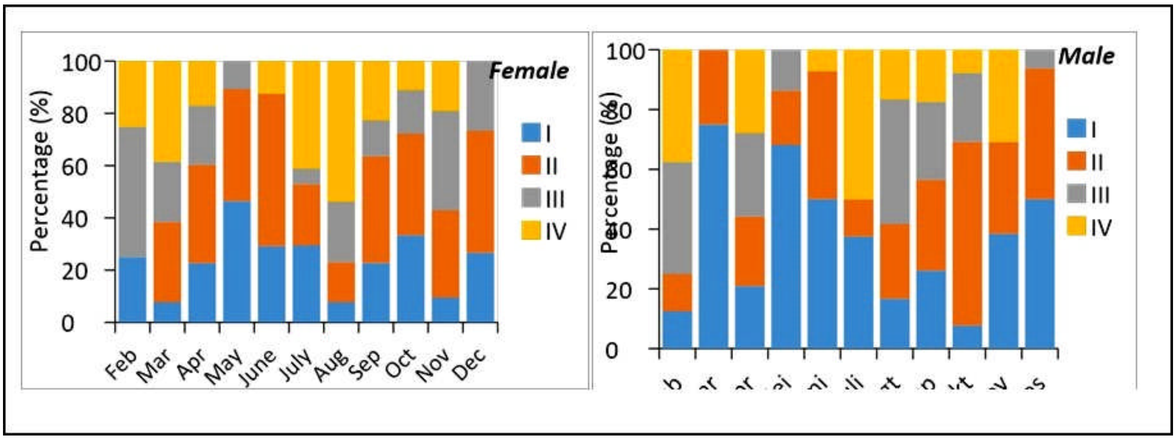


Figure 3. Maturity stages of female and male skipjack tuna in Toli-Toli waters.

Gonado Somatic Index (GSI)

Gonado Somatic Index (GSI) of female skipjack tuna ranged from 0.16% to 3.33% with an average of 1.31%. The highest index occurred in March and August then decreasing in each following months (Figure 4), suspected the spawning occurred in April and September.

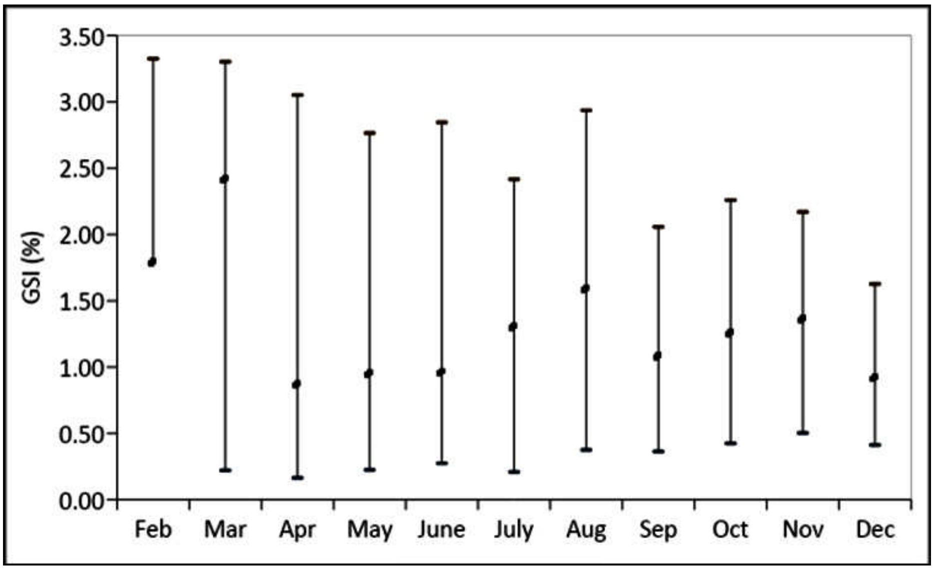


Figure 4. Monthly Gonado Somatic Index of skipjack tuna in Toli-toli water.

Fecundity and Egg Diameter

Fecundity is the number of female fish eggs before they are released at the time of spawning. Fecundity in the ovaries can be morphologically known from eggs that have matured gonad (level IV). The fecundity of skipjack tuna in Toli-toli ranged from 450,570 - 1,707,390 eggs in the fish length-range of 49-55.5 cmFL.

Based on the results of the analysis, the diameter of skipjack tuna (*Katsuwonus pelamis*) from Toli-toli waters obtained the distribution of eggs as presented in Figure 5. The size of skipjack tuna (*Katsuwonus pelamis*) in GSI IV was 0.22 - 0.67 mm, at mode on the diameter of 0.42 mm.

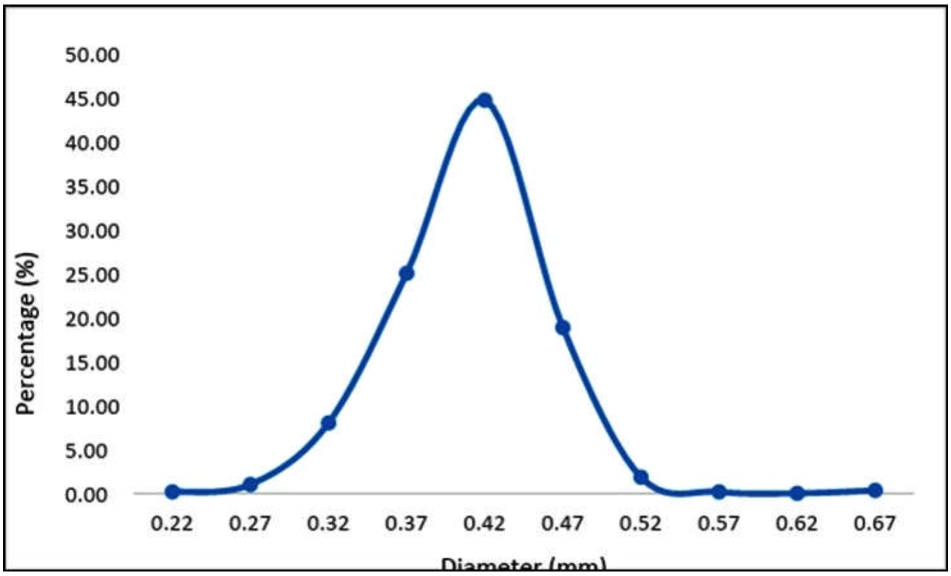


Figure 5. Eggs diameter of skipjack tuna (*Katsuwonus pelamis*) in Toli-toli.

Discussion

Length size structure of skipjack tuna in Toli-toli water was around 22-62 cmFL, with the mode at 42 cmFL. Anggraeni *et al.* (2015) found the same mode in Sadeng waters (Indian Ocean of Southern Java Island) with range of fish fork length were 20-68 cm. Tampubolon *et al*. (2014) stated that the fork length of the skipjack tuna captured by fishing lines and tents in the waters of the East Indian Ocean ranged from 35-68 cmFL with the mode at 50 cmFL. While according to Hidayat *et al*. (2014) skipjack tuna size caught by troll line at Banda Sea ranged from 20-70 cmFL with the mode 40-50 cmFL. The size of skipjack tuna caught between 20-60 cmFl with 40-50 mode were because these fish were caught around the FAD (fish aggregating device). It is stated by Fonteneau *et al*. (2000) that the skipjack tuna caught by purse seine in FAD mostly at size of 20-80 cmFL with mode 40-50cmFL, and Aprieto (1990) stated that the skipjack tuna caught by purse seine in FAD in the Philippine waters ranged from 20-60 cmFL with mode 45cmFL. This shows that the size of skipjack tuna caught in Toli-toli water was fish associated with FAD.

Analysis with t-test on parameter b at 95% confidence level (á = 0,05) found that t-count was larger than t-table, which means the length-weight relationship of male and female skipjack tuna were allometric positive, indicates the length increase is slower than the weight gain (Effendi, 2002). The results of several studies of this species were relatively similar, such as Anggraeni *et al*., (2015) in Sadeng waters (allometric positive); Manik (2007) in Seram Island and Nusa Laut waters (allometric); Nurdin (2017) in Pelabuhanratu waters (allometric positive). However, different result was showed by Jamal *et al*. (2011) in Bone Bay that the growth of skipjack tuna was isometric.

The variation of the value of b in the length-weight relationship shows that the growth can change over time. Furthermore, this difference can be caused by various factors, such as sea water properties and seasonal conditions (Gokhan *et al*., 2007 *in* Karna *et al*., 2011). Gulland (1983) and Sparre & Venema (1992) suggested that the variation of b value can be caused by various factors such as temperature, salinity, food (quantity, quality and size), sexes, gonadal maturity stage, and habitat preservation.

The length at first maturity (Lm) of skipjack tuna caught in Toli-toli (41.01 cmFL) that was different from length at first maturity (Lm) has been documented in other areas. Tampubolon *et al.* (2015) stated that Lm of skipjack tuna caught in the East Indian Ocean occurred at 42.9 cm in the range of 41.6-44.3 cm. Mallawa *et al*., (2014) stated that skipjack tuna fish in Flores Sea have matured gonads at more than 51 cm in size and are ready to spawn at sizes greater than 55 cm in females and over 60 cm in males. Ashida *et al*. (2009) stated the length at first maturity skipjack tuna in the central and western Pacific Ocean was 47.9 cm. Jamal *et al*. (2011) found that the length at first maturity of this fish in Bone Bay waters was 46.5

cm. According to Lowe-McConnel (1995) and Moresco & de Bemvenuti (2006), the first maturity size of different gonad ripen is a fish reproduction strategy to restore the population balance due to changes in condition, abiotic factors, and more capture. Furthermore, Nasution (2004) stated the length at first maturity difference has a strong association with fish growth, environmental factors, and reproductive strategies.

Most of skipjack tuna caught by hand line and pole-and-line was larger than length at first maturity (Lc>Lm). This indicates that the hand line and pole-and-line gear caught the mature fish, so skipjack tuna populations can recruit. Handline and pole-and-line gear can be maintained if there are additional efforts; these types of fishing gear are recommended. While the skipjack tuna caught by purse seine is mostly under length at first maturity or immature fish, so this type of fishing gear is not recommended.

From the development of the monthly GSI, the highest GSI occurred in March and August. According to Widodo (1986) *in* Mardlijah & Patria (2012), spawning season occurs about one month after the highest percentage of mature fish. So the spawning was estimated in April and September. These results are supported by previous research by Wagiyo & Rahmat (2013) stating that the peak of skipjack tuna spawning in the same waters occurred in April. The results of both studies showed that the peak of spawning occurred in the same season, although more detailed research is needed regarding the spawning season for skipjack tuna in the Sulawesi sea.

Based on the present study, the number of eggs (fecundity) of skipjack tuna (*Katsuwonus pelamis*) in Toli-toli ranged from 450,570 - 1,707,390 eggs in 49 - 55.5 cmFL. Previous studies of Mallawa *et al*., (2012) suggested that skipjack tuna fecundity in Bone Bay waters ranges from 900,000 to 1,500,000 eggs. Meanwhile, according to Baso (2013), the skipjack tuna fecundity was 600,000-960,000 eggs. Nugraha & Mardlijah (2007) also stated that the fecundity of these fish ranged from 1,000,000-14,000,000, while Ashida *et al*. (2008) said skipjack tuna fecundity was 615,000 eggs.

CONCLUSION

Skipjack tuna (*Katsuwonus pelamis*) in Toli-toli waters has a growth of weight was faster than the length increase. The skipjack tuna caught by pole and line and handline was mature fish, while from purse seine was immature. The spawning season is occur throughout the year with peak in April and September as well as fecundity ranging from 450,570 - 1,707,390 eggs. For sustainable skipjack tuna resources the caught is better use pole and line and no caught in peak GSI and peak spawning season (March-April).

ACKNOWLEDGEMENT

UC has contributed mainly to this work. TH and KW are supporting contributor to this work. This paper is a contribution of research activities Stock Assessment of tunas – skipjack tuna in Sulawesi Sea, 2015, at the Research Institute Marine Fisheries, Cibinong Bogor. The author would like to thank the Head and staff of the Toli-toli District Fisheries and Marine Service for his assistance in the process of collecting research data.

REFERENCES

Anonimous. (2014). Statistical report of Toli-toli District, Central Sulawesi.

Anggraeni, R., Solichin, A., & Saputra, S. W. (2015).Some aspects of skipjack biology (*Katsuwonus pelamis*) in relation to fisheries management in PPP Sadeng Gunungkidul Regency of Yogyakarta. *Diponegoro Journal of Maquares*. 4(3), 230-239.

Ashida H., Tanabe, T., & Suzuki, N. (2009). Recent progress on reproductive biology of skipjack tuna in the tropical region of the Western and Central Pacific Ocean (WCPFC)*. Scientific Committee Fifth Regular Session*, Port Vila, Vanuatu. 16 p.

Aprieto, V.L. (1990). Payao: tuna aggregating device (FAD) in the Philippines*. Symposium on Artificial Reefs and Fish Aggregating Devices as Resource Enhancement and Fisheries Management Tool*. Colombo, Sri Lanka. 1-15 p.

Baso, H., (2013). Study on biology population of skipjack tuna (*Katsuwonus pelamis*) in the waters of Luwu Bay of Bone. *Thesis*, Hasanudin University. Makassar 123 p.

Benevenuto, C., Coscia, I., Chopelete, J., Bozano, M.S., & Mariani, S. (2017). *Ecological and evolutionary consequences of alternative sex change pathways in fish*. Scientific Report 7-9084. WWW/nature.com/scientificreports.

Buana, E.E., Huang, W.C., & Hanani, N. (2018). The export performance of Indonesian canned skipjack in world market. *Agricultural Socio-Economics Journal*, 18(2), 86-92. DOI: https://doi.org/10.21776/ub.agrise.2018.018.2.6

Budd, A.M., Banh, Q.Q., Domingos, J.A., & Jerry, D.R. (2015). Sex control in fish: approaches, challenges and opportunities for Aquaculture. *J. Mar. Sci. Eng. 3, 329-355*; doi: 10.3390 / jmse3020329.

Chan, N.C.S., Connolly, S.R., & Mapstone, B.D. (2012). Effects of sex change on the implications of marine reserves for fisheries. *Ecological Applications, 22(3), p. 778–791*. Ecological Society of America

Directorate General of Capture Fisheries (DJPT). (2015). *Fisheries management plan on Tuna, Skipjack and Neritic tuna*. 208p.

Effendie, M.I. (1979). *Method of fisheries biology* (p. 112). Yayasan Dewi Sri, Bogor.

Effendie, M. I. (2002). *Fisheries biology* (p. 163). Yayasan Pustaka Nusantara.

FAO. (2015). *Species Fact Sheets Katsuwonus pelamis (Linnaeus, 1758).*WWW.faoorg/fishery/species/2494/en.

FAO. (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO. 210 p. http://www.fao.org/3/i9540en/i9540en.pdf

FAO (2018a). Globefish highlights. A quarterly update on world seafood. http://www.fao.org/3/ca4185en/ca4185en.pdf

Fonteneau, A., Farales, P., & Pianet R. (2000). *A woridwide review of purse seine fisheries on FADs*. Session I. Regional Syntheses. p. 15-35.

Fryxell, D.C., Arnett, H.A., Apgar, T.M., Kinnison, M.T., & Palkovacs, E.P. (2015). Sex ratio variation shapes the ecological effects of a globally introduced freshwater fish. *Proc. Biol. Sci*. Vol.282 (1817). The Royal Society Publishing. doi: 10.1098/rspb.2015.1970

Gulland, J.A. (1983). *Fish stock assessment. A manual of Basic Methods* (p. 233). John Wiley & Sons. Chicester.

Holden, M.J., & Raitt, D.F.S. (eds.), (1974). Manual of fisheries science. Part 2: Methods of resource investigation and their application. *FAO Fish.Tech. Rep*. 115(Rev. 1), Rome, Italy.

Hidayat, T., Chodrijah, U., & Noegroho, T. (2014). Characteristics troll line fishery in the Banda Sea. *J. Lit. Perikan. Ind.* 20(1): 43-51. DOI: http://dx.doi.org/10.15578/jppi.20.1.2014.43-51

Jamal, M., Sondita, F.A., Haluan, J., & Wiryawan, B. (2011). Utilization of biological data of skipjack (*Katsuwonus pelamis*) in the framework of responsible fisheries management in the Bay of Bone. *Journal of Natur Indonesia*, 14, (107-113), 8 - 9.

Jin, S., Yan, X., Zhang, H. & Fan, W. (2015). Weight–length relationships and Fulton’s condition factors of skipjack tuna (*Katsuwonus pelamis*) in the western and central Pacific Ocean. *PeerJ*. DOI 10.7717/peerj.758

Karna, S. K., Panda, S., & Guru, B.C. (2011). Length-weight relationship (Lwr) and seasonal distribution of *Valamugil speigleri* (Valancienues) thrugh size frequency variation and landing assessment in Chilika Lagoon India. *Asian J. Exp. Bio. Sci*. 2(4), 654-662.

Khan, A., Rizal, A., Dewanti, L.P., Apriliani, J., Supriyadi, D., Ghiffary, W., Nasution, A.M., Gray, T.S., Mill, A.C., & Polunin, N.V.C. (2019). Skipjack (*Kasuwonus pelamis*) tuna pole-and-line marketing supply chains in Indonesia: Case Study in Pulau Bacan. *Bioflux. 1*2(2), 636-641.

Kumar, R., Sundaramoorthy, B., Neetheselvan, N., Athithans, S., Kumar, R., Rahangdale, S., & Sakthivel, M. (2019). Length based population characteristics and fishery of Skipjacktuna *Katsowonus pelamis* (Linnaeus, 1758) from Tuticorin waters, Tamil Nadu, India. *Indian Journal of Geo Marine Sciences.* 48(01), 52-59.

Kuriakose, S. (2014). *Estimation of length weight relationship in fishes. Training manual on Fish Stock Assessment anad Management (*p.150). ICAR-Central Marine Fisheries Research Institute.

Lowe-McConnell, R. H. (1995). *Ecological studies in tropical fish communities* (p. 382). Cambridge University Press, Cambridge.

Madenijian, C.P., Rediske, R.R., Krabbenholt, D.P., Stapanian, M.A., Cherenyah, S.M., & O’Keefe, J.P. (2016). Sex differences in Contaminant Concentrations of fish: synthesis. *BioMed Central*. 7-42. DOI 10.1186/s13293-016-0090-x

Majkowski, J. (2007). *Global fishery resources of tuna and tuna-like species. Fisheries Technical Paper* (p.483). Food and Agriculture Organization of United Nations.

Mallawa, A., Musbir, Amir, F., & Marimba, A.A, (2012). Structural analysis of skipjack tuna size (*Katsuwonus pelamis*) according to seasons, terrain and fishing technology in the Luwu waters of Bone Bay, South Sulawesi. *J. Science and Technology*. 3 (2), 29 - 38.

Mallawa, A., Amir F. & Zainuddin M. (2014). Biological preservation of skipjack population (*Katsuwonus pelamis*) caught with purse seine in east season in Flores Sea waters. *Journal IPTEKS PSP,* 1 (2), 129-145.

Manik, N. (2007). Some biologal aspects of skipjack (*Katsuwonus pelamis*) in the South of Seram Island waters. UPT Loka Conservation of Bitung Marine Biota, Center for Oceanographic Research - LIPI. 15 p.

Marcille, J., Boely, T., Unar, M., Merta, G.S., Sadhotomo, B., & Uktolseja, J.C.B. (1984). Tuna Fishing in Indonesia. *Institut Français de Recherche Scientifique pour le Developpemnt en Coopération* (O.R.S.T.O.M.) p, 125

Mardlijah, S., & Patria, M.P. (2012). Biology of reproduction of madidihang (*Thunnus albacares* Bonnatere 1788) in Tomini Bay. *BAWAL*. 4(1), 27-34. DOI: http://dx.doi.org/10.15578/bawal.4.1.2012.27-34

Maskill, P.A.C, Miller I.R, Halvorson, L.J., Treanor, H.B., Fraser, C.W., & Webb, M.A.H. (2017). Role of sex ratio and density on fertilization success of intensively cultured endangered woundfin. Journal of Fish and Wildlife Management 8(1):249–254; e1944-687X. Doi: 10.3996/062016-JFWM-048

Matsumoto, W.M., Skillman, R.A., & Dizon, A.E. (1984). *NOAA Technical Report NMFS Circular 451. Synopsis of Biological Data on Skipjack tuna, Katsuwonus pelamis.* FAO Fisheries Synopsis No.136. US Department of commerce. National Oceanic and Atmospheric. Administration National Marine Fisheries Service.

McMahon, C.R. & Bradshaw, C.J.A. (2008). Fecundity. In Sven Erik Jørgensen and Brian D. Fath (Editor-in-Chief), Population Dynamics. Vol. [2] of Encyclopedia of Ecology, 5 vol. pp. [1535-1543] Oxford: Elsevier.

Miyake, M.P., Guillotreau, P., Sun, C.H., & Ishimura, G. (2010). Recent developments in the tuna industry Stocks, fisheries, management, processing, trade and markets. *FAO Fisheries and Aquaculture Technical Paper 543*. Food and Agriculture Organization of the United Nations : 125p.

Moresco, A., & de Bemvenuti A. (2006). Reproductive biology of silverside Odontesthes argentinensis (Valenciennes) (Atherinopsidae) of coastal sea region of the South of Brazil. *Revista Brasiliera de Zoology*, 23 (4), 1168-1174.

Nasution, S. H. (2004). Distribusi dan perkembangan gonad ikan endemik rainbow selebensis, Telmatherina celebensis Boulenger, di Danau Towuti, Sulawesi Selatan. *Tesis*. Program Pascasarjana Institut Pertanian Bogor, Bogor. 88 hal.

Nurdin, E., & Panggabean, U.S. (2017). Fishing Season and Size Structure of Skipjack Tuna (*Katsuwonus pelamis* Linnaeus) around FAD in Pelabuhan Ratu. *J.Lit Perikanan Indonesia*. 23(4), 299-308. http://dx.doi.org/10.15578/jppi.23.4.2017.299-308

Nugraha, B. & Mardlijah, S. (2008). Biological Aspects of Skipjack tuna (*Katsuwonus pelamis*), in Bitung, Noth Sulawesi. *BAWAL,* 2(1), 45-50. DOI: http://dx.doi.org/10.15578/bawal.2.1.2008.45-50

Provoost, M.M., Jensen, O.P. & Berlinsky, D.L. (2017). Influence of Size, Age, and Spawning Season on Sex Change in Black Sea Bass. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 9:126–138*. DOI: 10.1080/19425120.2016.1274696

Sparre, P., & Venema S.C. (1992). Introduction to Tropical Fish Stock Assessment. *Part I. Manual FAO Fisheries Technical Paper 306/1 Rev*.1. Danida FAO.Rome. Italy. 376.

Stell, R. G. D. & Torrie, J. H. (1981). *Principles and Procedure of Statistic* (p. 748). Second Edition. Mic Graw Hill Book Company, Inc. of New York.

Sugiyono. (2004). *Nonparametric statistic for Research* (p. 306). Penerbit CV. Alfabeta, Bandung.

Suhana, Kusumastanto T., Adrianto L., & Fahrudin, A. (2016) Tuna industries competitiveness in international market. Case of Indonesia. *AACL Bioflux,* 9(6),1251-1259.

Tadjuddah M., Anadi L., Mustafa A., Arami H., Abdullah, Kamri S., Wianti N. I., 2017 Growth pattern and size structure of skipjack tuna caught in Banda Sea, Indonesia. AACL Bioflux, 10(2), 227-233.

Tampubolon P.A.R.P., Jatmiko, I., Hartaty, H., & Bahtiar A. (2014). Reproductive biology of skipjack tuna (*Katsuwonus pelamis*) in Eastern Indian Ocean. *IOTC-2014-WPTT16*- 35. 7-10.

Tridge. (2019). Top Producing Countries of Skipjack Tuna. https://www.tridge.com/intelligences/skipjack-tuna/production.

Udoh J. P., Ukpatu J. E., 2017 First estimates of growth, recruitment pattern and length-at-first-capture of Nematopalaemon hastatus (Aurivillius, 1898) in Okoro River estuary, southeast Nigeria. *AACL Bioflux*, 10(5), 10741084.

Udupa, K.S. (1986). Statistical method of estimating the size at first maturity in fishes. ICLARM, Metro Manila, *Fishbyte*. 4 (2), 8-10.

Wagiyo, K., & Rahmat, E. (2013). Fishery and biology Aspects of skipjack tuna (*Katsuwonus pelamis*) in the waters of Toli-toli. *In* Suman, A, Wudianto, and B. Sumiono (Ed.). Status of Utilization of Fish Resources in Sulawesi Sea Waters. IPB Press. Bogor. 1-15.

Widodo, J.W. (1986). Dynamics pool models and management of fisheries. *Oseana XI*. 2, 36-47.

Yaragina, N. A. (2010). Biological parameters of immature, ripening, and non-reproductive, mature northeast Arctic cod in 1984–2006. *ICES Journal of Marine Science*, 67, 2033–2041. https://doi.org/10.1093/icesjms/fsq059