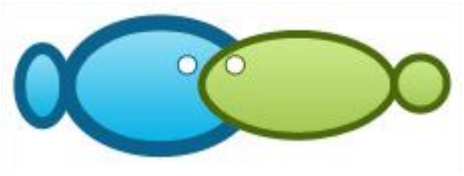

Reproductive biology of Indian mackerel *Rastreliger kanagurta* (Cuvier, 1816) in Makassar coastal waters, South Sulawesi, Indonesia

[1]Wayan Kantun, [2]Mauli Kasmi, [2]Syamsul Hadi, [2]Asti Sugiarti

[1] Balik Diwa Marine Technology University, Makassar, Indonesia; [2] Pangkep State Polytechnic of Agriculture, Makassar–Pare Rd, Mandalle, Pangkep Regency 90655, South Sulawesi, Indonesia. Corresponding author: W. Kantun, aryakantun@yahoo.co.id

Abstract. This study aimed to investigate the reproductive biology of Indian mackerel *Rastreliger kanagurta* in Makassar waters. Sample collection was conducted from March to October 2017. Gonadosomatic Index (GSI) was analyzed based on the comparison between gonad weight and body weight of Indian mackerel, while gravimetric method was applied for fecundity. The result showed the gonad maturity of Indian mackerel in Makassar coastal waters occurred throughout the year with the peak between July and August in which GSI was between 0.306 and 2.481. The first size of mature gonad in both female and male Indian mackerel was 21.02 and 21.19 cm respectively. After reaching the peak stage of gonad maturity, spawning occurred. However, GSI was gradually decreasing one month later. Total fecundity of Indian mackerel was between 21.420 and 50.592 eggs.
Key Words: gonad index, spawning, fecundity, *Rastreliger kanagurta,* Makassar waters.

Introduction. Indian mackerel *Rastreliger kanagurta* (Cuvier, 1816) is one of the common pelagic fish which is found abundant in Indo-West Pacific region and Indian waters (Collette et al 2011). This fish has been known as one of sought-after commercial fisheries species in Indonesia. It can be marketed in the form of dried salted, fresh, canned, smoked and frozen (Collette 2001).

A number of different fishing gears are used to catch Indian mackerel including drift nets, gill-nets, cast, purse-seines, fish corals (Al-Abdessalaam 1995). However, the trawl has been widely used in fishing activities due to its effectiveness. Consequently, combination and mixed size structure of Indian mackerel is often found in fish landing places and the local market. Fishing status of Indian mackerel has been reported at overexploited level (Rohit & Gupta 2004). Current status of wild population for Indian mackerel declined from 23.590.20 tons to 16.340.65 tons between 2007 and 2014 (Marine and Fisheries Department of South Sulawesi 2015). Thus, a comprehensive knowledge base on the reproductive biology aspect of particular fish is required in providing scientific advices for fisheries management in the near future (Begg et al 1999; Morgan 2008).

Few documented studies of Indian mackerel have been reported, including studies on its reproductive biology. Indian mackerel in the Mahout seas of Arabia produced 64.024-151.844 eggs while North Aceh produced between 300.000 and 520.000 eggs (Hariati & Fauzi 2011; Zaki et al 2016). Reproductive characters set of each species is unique, including its spawning pattern, duration and gamete development (Bhendarkar et al 2013). This is highly influenced by the environmental variations over the year (Zaki et al 2016). Furthermore, the spawning periods for Indian mackerel is restricted between 4 and 6 months. The Indian mackerel in Kakinada waters has maximum growth of 286 mm, growth rate of 1.89 per year, natural mortality of 2.61, capture mortality of 2.08 and total mortality of 4.06 and sustainable production of 2239 tons (Abdussamad et al 2006).

The percentage of gonadosomatic index (GSI) of Indian mackerel in North Java range from 0.49 to 6.98% (Zamroni et al 2008). However, Octaviani et al (2014) found that GSI of females and males of Indian mackerel in the waters of West Papua ranged between 38.80 and 30.70% respectively. Moreover, two spawning peaks were observed in the western of Aceh water (January-March and July-October). The GI ranged from 0.32 to 3.37% while the fecundity ranged from 28,542 to 123,760 eggs (Arrafi et al 2016). Furthermore, the biological potential sustainablity of Indian mackerel reached 2,293,808 kg with utilization rate about 85.59% (Tamti & Hafid 2016). Gonad maturity occurred throughout the year and the peaks between July and August (Kasmi et al 2017). Nevertheless, it gradually declined a month later. Moreover, the GSI ranged from 0.928 to 4.490% with length of female and male Indian mackerel when they attained first sexual maturity was 21.18 cm and 21.31 cm, respectively. The total fecundity of Indian mackerel was 11,235-40,878 eggs.

Even though Indian mackerel is locally found and commercially important in the Makassar waters, South Sulawesi, little information is available about its reproductive biology which is important for its future management and policy. Therefore, this study aimed to investigate the reproductive biology of Indian mackerel Indian mackerel in coastal waters of Makassar.

Material and Method. The study was conducted in fishing ground of Indian mackerel of Makassar waters, South Sulawesi Indonesia for eight months from March to October 2015 (Figure 1). Sampling collection was performed at first and third weeks for each month at fish landing and direct observation on fishing vessel in fishing ground between March, June and September to determine the location of the capture. Hand line was used as fishing gear with hook size 10/0 and 12/0.

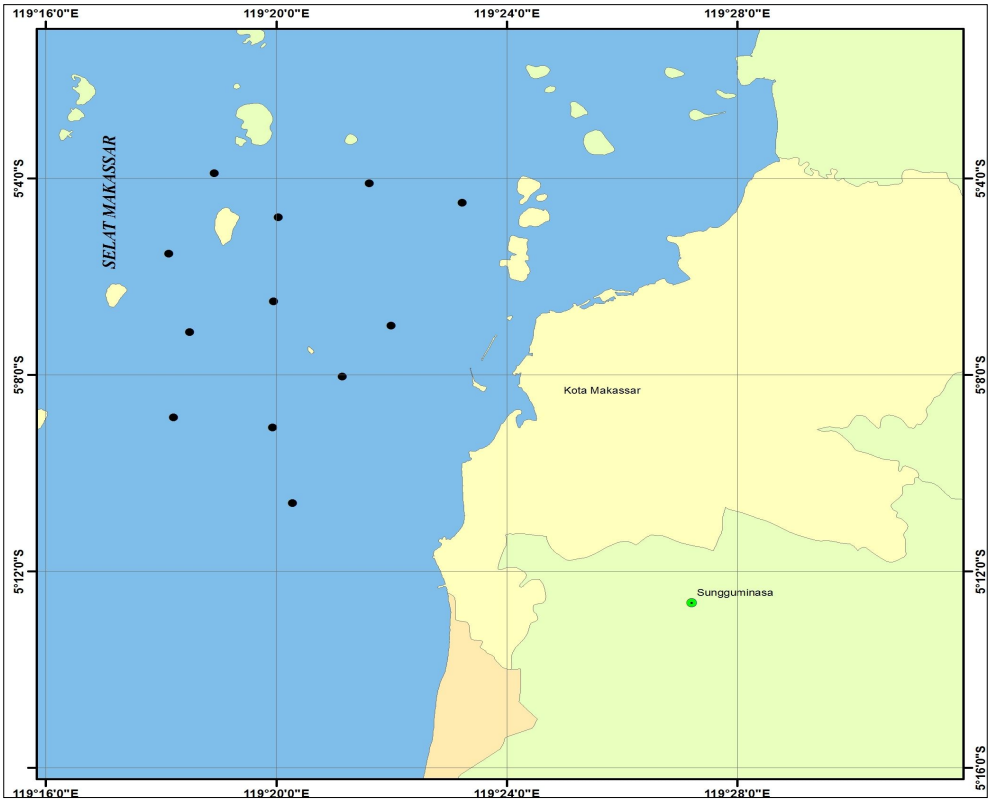

Figure 1. Fishing grounds of Indian mackerel in the coastal waters of Makassar.

Fish samples. The fish samples consisted of 597 female and 572 male of Indian mackerel.

Length and weight measurements. The total length (TL) of the fish was used for data collection. The fish was firstly placed in the buckets and direct observation was performed. A ruler with a precision of 0.1 cm was used to measure the total length of all fish. Sartorius digital balance with 0.01 g precision was used to obtain the initial whole fish weight, while the fish was dissected to take the gonad out. The gonad was weighed with Sartorius digital balance with 0.001 g precision.

Gonadosomatic index. GSI and fecundity were observed at the Laboratory of Fisheries Biology, Agricultural Polytechnic State of Pangkep. The gonad morphology of Indian mackerel was observed macroscopically with five stages: immature (stage I), maturing (stage II), nearly ripe (stage III), ripe (stage IV), spawning (stage V). GSI was observed at stages from III to V (Effendie 2002). In addition, the stages III and IV were classified into the mature stages while stage V was categorized into spawning stage.

The length at first gonad maturity for male and female was at stages III and IV which were randomly taken from total sample. One hundred forty four (144) samples of Indian mackerel were used in the study (72 females and 72 males). GSI was calculated based on formula below:

$$GSI = \frac{\text{Gonad weight (g)}}{\text{Total body weight (g)}} \text{ x } 100$$

The maturity was analyzed according to Udupe (1986):

$$\log m = xk + \frac{x}{2} - (x \times \Sigma pi)$$

At 95% confidence level was applied with following formula:

$$anti \log m = (m \pm 1.96 \sqrt{x^2 \times \frac{pi \times qi}{n_i - 1}}$$

Where: Log m = logarithm of length of fish at first sexual maturity;
Xk = logarithm of mean value of 100% mature gonad;
X = logarithm of adding length of mean value;
pi = number of mature gonad in length to - i with number of fish in the length interval to – i;
qi = 1-pi;
n_i = number of fish in length to – i;
m = length of fish at first gonad maturity as much as antilog m.

Fecundity. The fecundity of female Indian mackerel was observed at stages III and V. The subsamples were also taken in the anterior, middle (median) and back (posterior) side and placed in the sample bottle which contained the Gilson solution and soaked for one month. Furthermore, the number of eggs was counted a month later.

The fecundity of female Indian mackerel was sampled for monthly observation. Nine fish samples were taken from female population, which consisted of 3 gonad stages III, IV and V respectively. The total fecundity was estimated by gravimetric method (Effendie 1979). Subsample taken was 0.01 g of total gonad weight and calculated using following formula:

$$F = \frac{Q}{q} \text{ x } n$$

Where: F = total fecundity;
Q = total gonad weight (g);
q = gonad subsample weight (g);
n = number of eggs in gonad subsample.

Data analysis.The data collected was computed and statistically analyzed using Microsoft Excel 2010.

Results and Discussion. In the present study, the total samples were 1169 fish which consisted of 597 female and 572 male fish. The TL and weight of female fish ranged from 16.6 to 23.7 cm and 35.12 to 211.02 g, respectively. While the TL and weight of male fish ranged from 17.3 to 24.1 cm and 35.21 to 210.26 g, respectively (Figure 2).

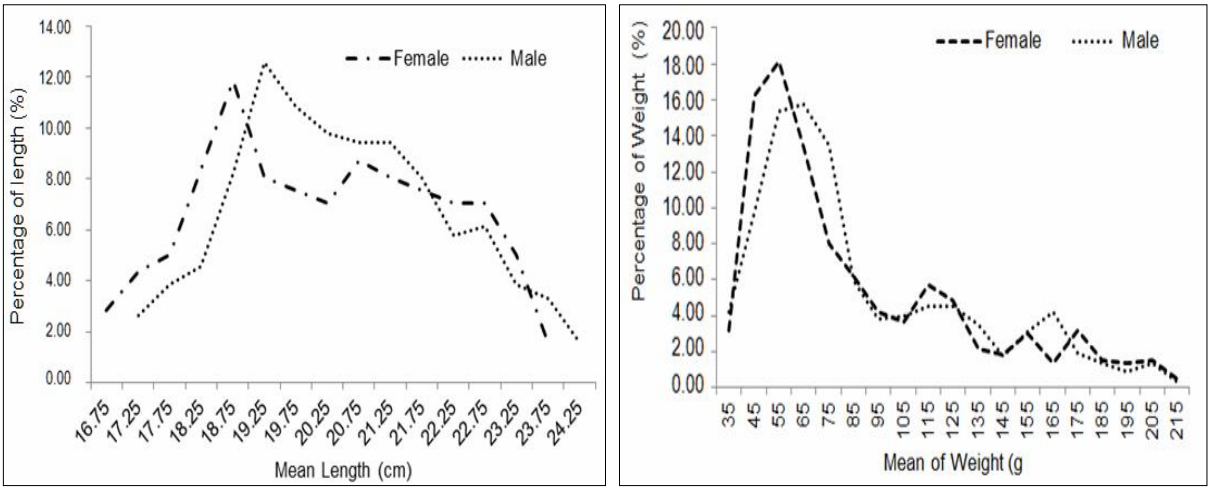

Figure 2. Total length and weight distributions of males and females of Indian mackerel from March to August 2015.

Figure 3 illustrates the development of gonad maturity of Indian mackerel for males and females based on macroscopic observation. The size of female fish in immature stages ranged from 17.0 to 20.25 cm, maturing (19.5-23.5 cm) and spawning (22.5-25.5 cm) (Figure 3A), while the male fish in immature phase ranged (17.0-20.5 cm), maturing (20.0-23.5 cm) and spawning (22.5-25.5 cm) (Figure 3B).

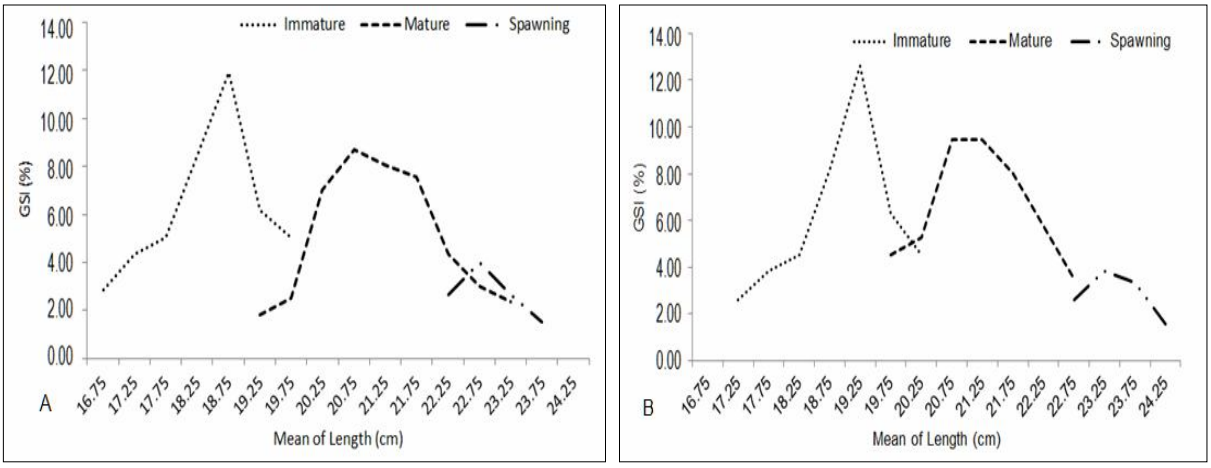

Figure 3. Distribution of GSI for females (A) and males (B) of Indian mackerel per total length from the coastal waters of Makassar (March-August 2015).

Bhendarkar et al (2014) reported that the size of fish from commercial catches ranged from 22 to 24 cm. According to Erzini et al (1998), the size of fish caught is strongly influenced by the fishing equipment applied during the fishing activity. Eighani et al (2018) added that the overall catch efficiency and size structure of fish caught are highly affected by the bait type and size. In the present study, the size of fishing rods was between size 10/0 and size 12/0. The fish caught were generally large during the data collection. Different sizes of fishing rods lead to the different size of fish caught. Similarly, Erzini et al (1998) said that type and size of the fishing rod can affect the variety of fish caught. Meanwhile, different fishing times, feeding times, feed types and depth of the fishing operations contribute to the size of the fish caught (Kantun et al 2014).

The biological behavior of the fish is associated with huddling behavior, which often found same size and the type of fish in the wild. These behaviors are characteristics of adult fish population (Dewanti et al 2014). This is in line with Soria & Dagorn (1992), that the similarity in size, biological cycle and biological ability, creates mutually beneficial and demonstrates the ability to coordinate when swimming in a group.

Percentage of GSI of Indian mackerel during the study from immature stage to spawning is shown in Table 1.

Table 1

Percentage of GSI of Indian mackerel from Makassar coastal waters (March 2015 - October 2015)

Stages	*Female*		*Male*	
	597 fish	(%)	572 fish	(%)
Immature (I-II)	261	43.72	244	42.66
Mature (III-IV)	271	45.39	263	45.98
Spawning (V)	65	10.89	65	11.36

The female and male fish of Indian mackerel were having a synchronization of gonad maturity process. The gonad of male fish firstly reached its maturity level and it was followed by gonad maturity of female fish. Similarly, this condition also occurred nearly at the same time in the spawning stage between female and male fish (Figure 4). This finding suggested that the process of gonadal maturation occurs simultaneously. It increases the chances of fertilization and spawning. It also indicated that spawning occurs after the peak of gonadal maturity (Araffi et al (2016).

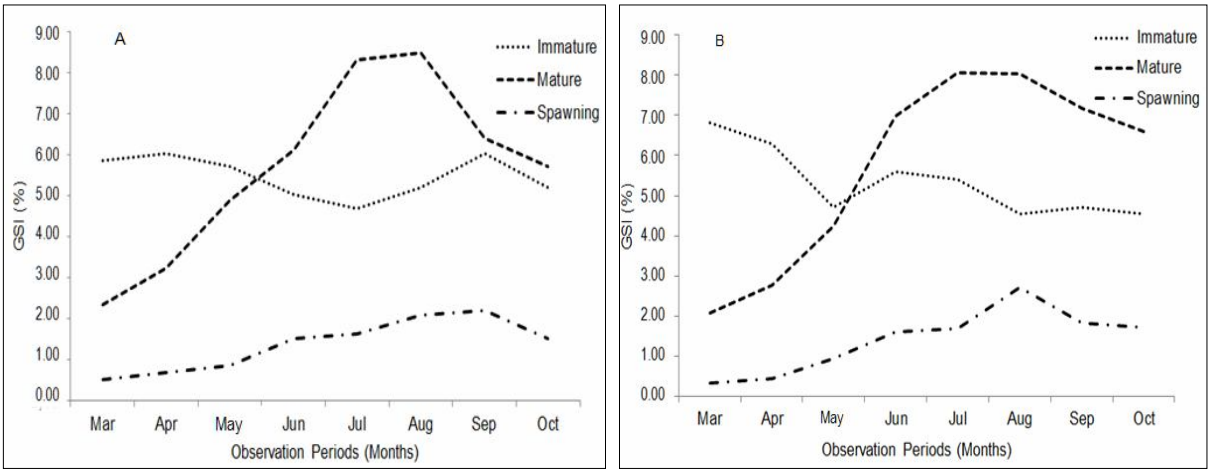

Figure 4. Monthly percentage of GSI for females (A) and males (B) of Indian mackerel from Makassar coastal waters.

GSI of female ranged from 0.31 to 2.11 and in case of males ranged from 0.50 to 2.48 (Figure 5). The first sexual maturity size of female was 21.02 cm with 95% confidence level ranged from 20.91 to 21.14 cm and males was 21.19 cm ranged from 21.07 to 21.32 cm (Figure 6). The total fecundity of Indian mackerel caught in Makassar coastal waters ranged from 21,420 to 50,592 eggs.

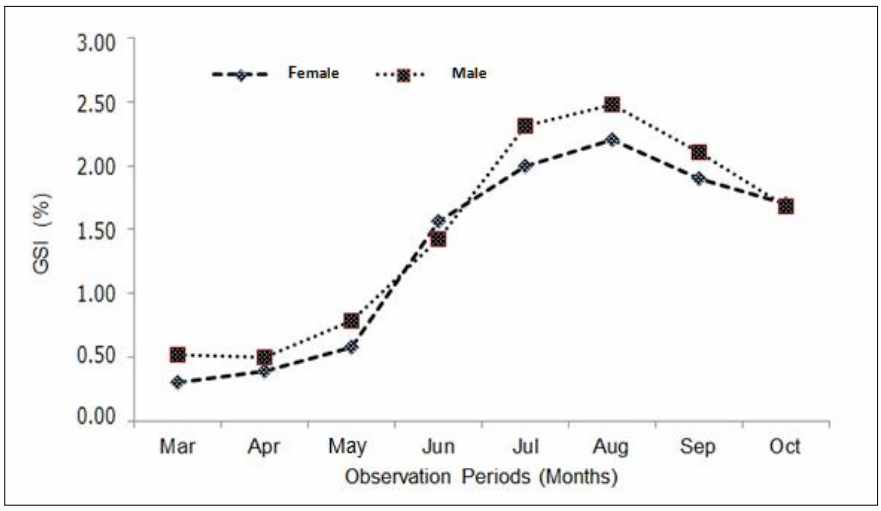

Figure 5. Development of GSI of Indian mackerel in Makassar coastal waters.

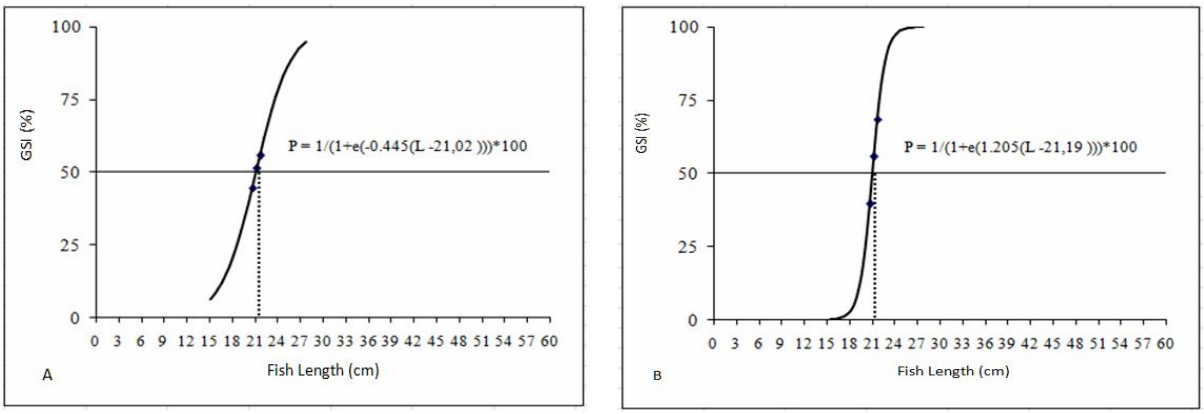

Figure 6. Size of first sexual maturity for females (A) and males (B) of Indian mackerel from Makassar coastal waters.

In the present study, the development of GSI of females and males of Indian mackerel from Makassar coastal water showed that the GSI of female fish was immature (43.72%), mature (45.39%) and spawning (10.89%), respectively and GSI of male fish was immature (42.66%), mature (45.98%) and spawning (11.36%) (Table 1). Conversely, Oktaviani et al (2014) reported the percentage of GSI (mature stage) of Indian mackerel in West Papua was 38.80% (female fish) and 30.70% (male fish). The results of the present study showed a greater developmental composition of gonad maturity stages than previous finding. This is due to the sampling period, the number and representation of the sample and the environmental conditions in the fishing ground.

Figures 5 and 6 illustrated that the development of GSI of male Indian mackerel based on observation time in the present study was mature stage (III-IV) higher than immature stages (I-II) and spawning stage (V). Non-uniform GSI indicates that there was a group of fish which did not spawn simultaneously. It is shown that the spawning time of Indian mackerel occur throughout the year. The differences in gonad development of fish are due to the different spawning ways (Brojo & Sari 2002). Meanwhile, the differences in the development of gonadal maturity stage are due to population genetic characteristics, differences in growth rates and water quality (Paugy 2002; Lalèyè et al 2006). Furthermore, the different fishing ground and fishing pressure can lead to differences in the development of fish gonads (Reynolds et al 2001; de Graaf et al 2003).

In the present study, the fecundity of Indian mackerel ranged from 21,420 to 50,592 eggs. It is slightly less than previous studies, for instances, the fecundity of Indian mackerel ranged from 11,235 to 40,878 eggs in coast of Takalar (Kasmi et al 2017); fecundity of 300,000 to 520,000 eggs in North Aceh (Hariati & Fauzi 2011);

fecundity of 64,024 to 151,844 in Arabian seas (Zaki et al 2016); fecundity of 28,542 to 123,760 eggs in Western of Aceh (Arrafi et al 2016) and fecundity of 86,744 to 94,376 eggs Mangalore Region (Hulkoti et al 2013). The discrepancy in total fish fecundity is greatly affected by the size of the fish, including its length and weight (Vila-Gispert & Moreno-Amich 2000); egg diameter size (Suzuki et al 2000) and environmental factors (Abidin 1986). Similarly, Rochmatin et al (2014) added that fertility, spawning frequency, parent protection, egg size, environmental conditions and population density are several factors that affect the fish productivity. In addition, according to Siby et al (2009) the differences in total fecundity are influenced by the reproductive strategy of the fish, and different adaptation to the environment. Furthermore, large fish produce high fecundity. In optimum condition, female fish produce high fecundity (Kantun et al 2015).

In the present study, the female Indian mackerel showed high fecundity. The fish productivity can be measured based on reproduction index through their fecundity. Nonetheless, it is highly affected by environmental factors, genetics, growth, age and gonad maturity level. Fecundity of 10 eggs is classified very low and 10 to 100 eggs also low. Fecundity of 100 to 1000 eggs is moderate and above 1000 eggs are high (Musick 2000).

The data in Figure 5 indicated that the gonad of female and male fish slowly developed from March to May. It started to develop drastically by the end of May. The gonad peak occurred between July and August. The spawning took place in September. Similarly, the spawning time of Indian mackerel in Mayalibit occurred between September and November (Octaviani et al 2014). More interestingly, two spawning times of Indian mackerel were recorded in the Mahout seas of the Arabian seas (September-October and December-April) (Zaki et al 2016). Similar spawning time of Indian mackerel also found in the Western waters of Aceh (January-March and July-October) (Arrafi et al 2016). Nevertheless, Abdussamad et al (2006) reported the development gonad of Indian mackerel occurs throughout the year depending on the environmental condition. The food availability and fishing pressure affected the spawning time of the Indian mackerel (Schaefer 1987; Koido & Suzuki 1989).

Although the male and female Indian mackerel reached gonad maturity state almost simultaneously, the gonad size of female Indian mackerel was larger than its male. As said by Siby et al (2009) the mean value of the gonad weight of the female is always higher than the male in the same stages, because the weight gain of the ovary is always greater than testes. Increased ovary weight is associated with the process of vitellogenesis in gonadal development, whereas the increase in weight of testes is related to the process of spermatogenesis and an increase in the volume of semen in the seminiferous tubules. However, according to Effendie (1979), the weight of gonads decrease rapidly during spawning until completion.

The initial size of first sexual maturity of the fish is strongly associated with the increase of GSI (Figure 6). In the present study, Indian mackerel size was smaller than the size which recorded in the previous study, particularly the study of Indian mackerel in the Mahout Coast of Arabia (Zaki et al 2016) (Table 2). Several factors such as species, environment, age, size and physiological conditions of fish are considered to affect the size of the fish (Udupe 1986).

Furthermore, different sampling periods and fish reproduction seasons contribute to the size of the first sexual maturity (Schaefer 1987; Koido & Suzuki 1989). Fishing techniques and fishing gear can lead to different first size of fish caught during the sampling periods (Kantun et al 2014). Consequently, the caught fish was small but it already reached mature gonad. According to Siby et al (2009) the first-size maturation of gonads in different fish and occurring at smaller sizes is a reproductive strategy of fish to restore its population balance due to environmental changes, abiotic factors, and unsustainable fishing activities. Several finding related to first sexual maturity of Indian mackerel can be seen in Table 2.

Table 2

The first sexual maturity of Indian mackerel Indian mackerel from several study sites

Location	Gender		Length of first sexual maturity (cm)	Sources
	♀	♂		
Malaka strait	♀	♂	17.0	Hariati et al (2005)
Calicut India	♀	♂	17.3	Sivadas et al (2006)
North Coast Aceh	♀	-	19.97	Hariati & Fauzi (2011)
Mangalore, India	♀	-	21.0	Hulkoti et al (2013)
Mahout sea Arabia	♀	♂	♀ 25.7; ♂ 25.2	Zaki et al (2016)
Western Aceh	♀	-	19.58	Arrafi et al (2016)
Takalar Coast	♀	♂	♀ 21.18; ♂ 21.31	Kasmi et al (2017)
Makassar waters	♀	♂	♀ 21.02; ♂ 21.19	Present study

Conclusions. GSI of Indian mackerel varies in size from immature to mature (Gonad stage I-V). However, the number of spawned fish is still low. Nonetheless, the GSI of female Indian mackerel is higher than male. The first sexual maturity both female and male gonads is relatively similar and their fecundity are high.

Acknowledgements. This research was funded by the Ministry of Research, Technology, and Higher Education Republic of Indonesia through National Research Strategy 2017.

References

Abdussamad E. M., Kasim H. M., Achayya P., 2006 Fishery and population characteristics of Indian mackerel, *Rastrelliger kanagurta* (Cuvier) at Kakinada. Indian Journal of Fisheries 53(1):77-83.

Abidin A. Z., 1986 The reproductive biology of a tropical cyprinid, *Hampala macrolepidota* from Zoo Negara Lake, Kuala Lumpur, Malaysia. Journal of Fish Biology 29:381-391.

Al-Abdessalaam T. Z. S., 1995 Marine species of the Sultanate of Oman. Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries, Sultanate of Oman, Publication 46/95, 412 pp.

Arrafi M., Ambak M. A., Rumeaida M. P., Muchlisin Z. A., 2016 Biology of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1817) in the western waters of Aceh. Iranian Journal of Fisheries Sciences 15(3):957-972.

Begg G. A., Hare J. A., Sheehan D. D., 1999 The role of life history parameters as indicators of stock structure. Fisheries Research 43(1):141-163.

Bhendarkar M. P., Naik S. D., Mohite S. A., Kulkarni G. N., 2013 Reproductive biology of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1817) off Ratnagiri coast, Maharashtra, India. Discovery Science 3(9):24-26.

Bhendarkar M. P., Naik S. D., Joshi H. D., Sonuwane S. S., Hussain T., 2014 Length frequency analysis of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1817) off Ratnagiri coast, Maharashtra, India. Ecology Environment and Conservation 4(20):1549-1551.

Brojo M., Sari R. P., 2002 [Reproductive biology of fivelined threadfin bream (*Nemipterus tambuloides* Blkr.) what landed in place of Fish Auction Labuan, Pandeglang]. Jurnal Iktiologi Indonesia 2(1):9-13. [in Indonesian]

Collette B. B., 2001 Scombridae. In: The living marine resources of the Western Central Pacific. Carpenter K. E., Niem V. (eds), FAO, Rome, pp. 3721-3756.

Collette B., Di Natale A., Fox W., Juan Jorda M., Nelson R., 2011 *Rastrelliger kanagurta*. The IUCN Red List of Threatened Species 2011: e.T170328A6750032.

De Graaf M., Machiels M., Wudneh T., Sibbing F. A., 2003 Length at maturity and gillnet selectivity of Lake Tana's *Barbus* species (Ethiopia): implications for management and conservation. Aquatic Ecosystem Health and Management 6(3):325-336.

Dewanti R. O. N., Ghofar A., Saputra S. W., 2014 [Biological aspects of anchovy (*Stolephorus devisi*) caught by seine net on Pemalang waters]. Diponegoro Journal of Maquares 3(4):102-111. [in Indonesian]
Effendie M. I., 1979 [Methods in fish biology]. Dewi Sri Foundation, Bogor, 112 pp. [in Indonesian]
Effendie M. I., 2002 [Fish biology]. Nusatama Foundation, Yogyakarta, 163 pp. [in Indonesian]
Eighani M., Paighambari S. Y., Herrmann B., Feekings J., 2018 Effect of bait type and size on catch efficiency of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Persian Gulf handline fisheries. Fisheries Research 199:32-35.
Erzini K., Gonçalves J. M. S., Bentes L., Lino P. G., Ribeiro J., 1998 Species and size selectivity in a 'red' sea bream longline 'métier' in the Algarve (southern Portugal). Aquatic Living Resources 11(1):1-11.
Hariati T., Fauzi M., 2011 [Reproductive aspect of Indian mackerel *Rastreliger kanagurta* (Cuv. 1817) of northern Aceh waters]. Jurnal Iktiologi Indonesia 11(1):47-53. [in Indonesian]
Hariati T., Taufik M., Zamroni A., 2005 [Some aspects of reproduction of the Indian scad (*Decapterus russelli*) and Indian mackerel (*Rastrelliger kanagurta*) in Malacca Strait]. Jurnal Penelitian Perikanan Indonesia 11(2):47-57. [in Indonesian]
Hulkoti S. H., Shivaprakash S. M., Anjanayappa H. N., Somashekara S. R., Benakappa S., Naik A. S. K., Prasad L. G., Panda K., Kumar J., 2013 Breeding biology of Indian mackerel, *Rastrelliger kanagurta* (Cuvier) from Mangalore Region. Environment and Ecology 31(2A):683-688.
Kantun W., Mallawa A., Rapi N. L., 2014 [Comparison of the size structure of yellowfin tuna *Thunnus albacares* caught in deep and shallow seas of Makassar Strait]. Jurnal IPTEKS PSP 1(2):112-128. [in Indonesian]
Kantun W., Syamsu A. A., Achmar M., Ambo T., 2015 [Reproductive potential of yellowfin tuna *Thunnus albacares* in Makassar Strait]. In: Proceedings of the National Symposium on Sustainable Fishing Tuna Management, Bali 10-11 December 2014, II-142, Zainuddin I. M. (ed), World Wide Foundation-Indonesia, 1259 pp. [in Indonesian]
Kasmi M., Hadi S., Kantun W., 2017 [Reproductive biology of Indian mackerel, *Rastreliger kanagurta* (Cuvier, 1816) in Takalar coastal waters, South Sulawesi]. Jurnal Iktiologi Indonesia 17(3): 259-271. [in Indonesian]
Koido T., Suzuki Z., 1989 Main spawning season of yellowfin tuna, *Thunnus albacares,* in the western tropical Pacific Ocean based on the gonad index. Bulletin Far Seas Fisheries Research Laboratory 26:153-164.
Lalèyè P., Chikou A., Gnohossou P., Vandewalle P., Philippart J. C., Teugels G., 2006 Studies on the biology of two species of catfish *Synodontis schall* and *Synodontis nigrita* (Ostariophysi: Mochokidae) from the Ouémé River, Bénin. Belgian Journal of Zoology 136(2):193-201.
Marine and Fisheries Department of South Sulawesi, 2015 Fisheries statistical data for South Sulawesi. Available at: http://www.fao.org/fi/oldsite/FCP/en/idn/profile.htm. Accessed: August, 2017.
Morgan M. J., 2008 Integrating reproductive biology into scientific advice for fisheries management. Journal of Northwest Atlantic Fisheries Science 41:37-51.
Musick J. A., 2000 Ecology and conservation of long-lived marine animals. In: Life in the slow lane: ecology and conservation of long-lived marine animals. Musick J. A. (ed), American Fisheries Society Symposium 23:1-10.
Oktaviani D., Supriatna J., Erdmann M., Abinawanto A., 2014 Maturity stages of Indian mackerel *Rastreliger kanagurta* (Cuvier, 1816) in Mayalibit Bay, Raja Ampat, West Papua. International Journal of Aquatic Science 5(1):67-76.
Paugy D., 2002 Reproductive strategies of fishes in a tropical temporary stream of the upper Senegal basin: Baoulé River in Mali. Aquatic Living Resources 15:25-35.

Reynolds J. D., Jennings S., Dulvy N. K., 2001 Life histories of fishes and population responses to exploitation. In: Conservation of exploited species. Reynolds J. D., Mace G. M., Redford K. H., Robinson J. G. (eds), Cambridge University Press, Cambridge, pp. 148-168.
Rochmatin S. Y., Solichin A., Saputra S. W., 2014 [The growth aspects and reproduction of nilem (*Osteochilus hasselti*) in Rawa Pening, District of Tuntang, Semarang Regency]. Diponegoro Journal of Maquares 3(3):153-159. [in Indonesian]
Rohit P., Gupta A. C., 2004 Fishery, biology and stock of the Indian mackerel *Rastrelliger kanagurta* off Mangalore-Malpe in Karnataka, India. Journal of the Marine Biological Association of India 46(2):185-191.
Schaefer K. M., 1987 Reproductive biology of black skipjack, *Euthynnus lineatus*, an Eastern Pacific tuna. Inter-American Tropical Tuna Commission Bulletin 19(2):166-260.
Siby L. S., Rahardjo M. F., Sjafei D. S., 2009 [Reproductive biology of red rainbowfish (*Glossolepis incisus* Weber 1907) in Sentani Lake]. Jurnal Iktiologi Indonesia. 9(1): 49-61. [in Indonesian]
Sivadas M., Radhakrishnan Nair P. N., Balasubramanian K. K., Bhaskaran M. M., 2006 Lenght weight relationship, relative condition, size at first maturity, and sex ratio of Indian mackerel *Rastrelliger kanagurta* from Calicut. Journal of the Marine Biological Association of India 48(2):274-277.
Soria M., Dagorn L., 1992 Rappels sur le comportement grégaire. In: Action Incitative Comportement Agrégatif (AICA), Compte-Rendu de Réunion, Doc. Centre ORSTOM Montpellier 9:5-9.
Suzuki H. I., Agostinho A. A., Winemiller K. O., 2000 Relationship between oocyte morphology and reproductive strategy in Loricariid catfishes of the Paraná River, Brazil. Journal of Fish Biology 57:791-807.
Tamti H., Hafid H., 2016 [Bioeconomy of Indian Mackerel *Rastreliger* spp. in Makassar Strait waters]. Jurnal Balik Diwa 7(2):7-14. [in Indonesian]
Udupe K. S., 1986 Statistical method of estimating the size at first maturity in fishes. Fishbyte 4(2):8-10.
Vila-Gispert A., Moreno-Amich R., 2000 Fecundity and spawning mode of three introduced fish species in Lake Banyoles (Catalunya, Spain) in comparison with other localities. Aquatic Sciences 62:154-166.
Zamroni A., Suwarso S., Mukhlis A., 2008 [Reproductive biology and genetic of Indian mackerel (*Rastrelliger kanagurta*, Family of Scombridae) in North Coast of Java]. Jurnal Penelitian Perikanan Indonesia 14(2):215-226. [in Indonesian]
Zaki S., Jayabalan N., Al-Kiyumi F., Al-Kharusi L., 2016 Reproductive biology of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1816) from the Mahout coast, Sultanate of Oman. Indian Journal of Fisheries 63(2):24-32.

Received: 18 May 2018. Accepted: 23 June 2018. Published online: 06 August 2018.
Authors:
Wayan Kantun, Balik Diwa Marine Technology University, 8/8 Perintis Kemerdekaan St Makassar 90245, South Sulawesi, Indonesia, e-mail: aryakantun@yahoo.co.id
Mauli Kasmi, Pangkep State Polytechnic of Agriculture, Makassar–Pare Rd, Mandalle, Pangkep Regency 90655, South Sulawesi, Indonesia, e-mail: maulikasmi@yahoo.com
Syamsul Hadi, Pangkep State Polytechnic of Agriculture, Makassar–Pare Rd, Mandalle, Pangkep Regency 90655, South Sulawesi, Indonesia, e-mail: samsulhady001@gmail.com
Asti Sugiarti, Pangkep State Polytechnic of Agriculture, Makassar–Pare Rd, Mandalle, Pangkep Regency 90655, South Sulawesi, Indonesia, e-mail: astisugiartiyahya@gmail.com

How to cite this article:
Kantun W., Kasmi M., Hadi S., Sugiarti A., 2018 Reproductive biology of Indian mackerel *Rastreliger kanagurta* (Cuvier, 1816) in Makassar coastal waters, South Sulawesi, Indonesia. AACL Bioflux 11(4):1183-1192.