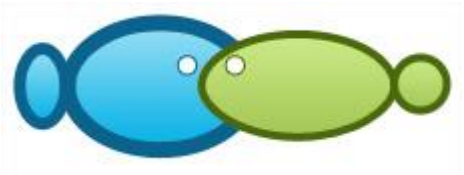

Reproductive biology of Indian mackerel captured from Tangerang Regency coastal waters

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Abstract. Reproductive biology of Indian mackerel (*Rastrelliger kanagurta*) captured from Tangerang Regency coastal waters was determined based on gonad macroscopic observations, gonadosomatic index (GSI), length-weight relationship, condition factor, length at first capture, length at first maturity and asymptotic length. 292 fish samples landed at Kronjo and Cituis Port were collected. The fishing ports are two of the largest fish landing ports in Tangerang regency. Immature gonads (55.63%) were discovered in a higher percentage than mature gonads (44.37%). The GSI of female Indian mackerel was higher (1.52) compared to that of male Indian mackerel (0.77). Average weight (51.78±10.59 g) and total length (16.07±0.91 cm) of *R. kanagurta* from Tangerang regency water were smaller compared to other regions. Pooled condition factor, length at first capture, length at first maturity and asymptotic length were 1.01, 15.4 cm, 15.94 cm, 19.89 cm, respectively. These results indicate that Indian mackerel captured from Tangerang regency is over exploited.

Key Words: gonad macroscopic observations, gonadosomatic index (GSI), length-weight relationship, *Rastrelliger kanagurta*.

Introduction. Indian mackerel (*Rastrelliger kanagurta*) is part of small epipelagic fish groups that live in the coastal area of the Indo-Pacific region. Its distribution is affected by primary productivity, water temperature, salinity and chlorophyll content (Nair et al 2023). Most Indian mackerel catches are found between 30-100 m depth zones (Das et al 2017). Indian mackerel food items differ depending on life stages. Larvae feed on micro zooplankton and later feed on copepods. Juveniles feed on phytoplankton and small zooplankton, while adult Indian mackerel mainly feed on phytoplankton, crustaceans (Bagheri et al 2013; Hakimelahi et al 2018) and fish (Sekadende et al 2020).

In the Indo-Pacific region, Indian mackerel can be found in the Persian Gulf (Hakimelahi et al 2018), Pakistan (Asif et al 2019), Tanzania (Sekadende et al 2020), Madagascar (Kielpinski et al 2014), Australia (Griffiths et al 2017), Samoa (Wass 1984), Philippines (Gomez et al 2020), Vietnam (Kielpinski et al 2014), Myanmar (Aye & Tint 2020), Malaysia (Amin et al 2014) and Indonesia, at the center of Indo-pacific region. In Indonesian waters, Indian mackerel distribution is widespread (Oktaviani et al 2014; Arrafi et al 2016; Faizah et al 2017).

Fisheries Management Area (FMA) 712 is one of the most productive FMAs. This area covers Java Sea that connects 8 major provinces, 53 regencies and 192 fisheries landing ports. Tangerang Regency of Banten Province is located at the western side of FMA 712. In 2020, capture fisheries production in this area reached 20814 tonnes (BPS 2021). Fisheries catches mainly consist of mackerels, anchovies, shrimps, bivalves and squids. One of the main catches is the Indian mackerel. Indian mackerel is captured using conventional gill nets by small scale fishermen with small fishing vessel less than 5 GT.

The catch of small pelagic fish in Java Sea has been declining (Sadhotomo & Atmaja 2012), including of Indian mackerel. Total catch of Indian mackerel in 2020 was 1126 tonnes, down by 60% compared to total catch in 2014 (BPS 2015). This decline could be

an indicator of fisheries resources depletion and could cause problem to the livelihood of local fishermen. Assessment of aspects of reproductive biology such as gonad maturation index and sex ratio can be used to identify spawning periods and recommend capture bans during the spawning periods. This study aimed to record and evaluate the reproductive biology status of the Indian mackerel captured in Tangerang Regency and provide recommendations for sustainable capture fisheries.

Material and Method

Study area. This research was conducted in July 2022 at two of the largest fisheries landing ports in Tangerang Regency, the Kronjo and Cituis Port (Figure 1). 292 fish were purchased from fishermen and measured to determine total length (TL) and total weight (W). This data comes from 2 sampling times at each fishing port (4 sampling periods).

Figure 1. Location of landing ports Kronjo and Cituis in Tangerang Regency.

Data analysis. The sex ratio was analyzed based on the number of male and female Indian mackerels using the Chi-square test (X^2). The gonads were removed and weighted using an electronic balance (to 0.01 g precision). The sex and gonad maturity stage were determined by macroscopic examination (Zaki et al 2016; Soe et al 2022). Based on the gonad size relative to abdominal cavity, gonad color and appearance of blood vessels, gonads were grouped into 5 categories: immature (Stage I), maturing (Stage II), ripening (Stage III), mature (Stage IV) and spent (Stage V).

The gonadosomatic index (GSI) of each studied fish was measured based on fish weight (W) and gonad weight (GW), according to the following formula:

$$GSI=GW/W \times 100$$

Welch's t-test analysis was performed with IBM Statistic SPSS 26 to compare GSI from fish landed at Kronjo Port and Cituis Port ($p<0.05$).

W and TL were used in the $W=aTL^b$ equation to establish the length-weight relationship (LWR) (Le Cren 1951). LWR was calculated both separately according to sex and combined.

The condition factor (K) was calculated to determine the health condition of each captured fish based on the following formula (Pauly 1983):

$$K=100W/(TL^3)$$

Length at first capture was calculated based on the following formula (Sparre & Venema 1999):

$$SL=\frac{1}{1+\exp\left(S_1-S_2*L\right)}$$

$$L_{50\%}=\frac{S_1}{S_2}$$

$$Ln\left[\frac{1}{SL}-1\right]=S_1-S_2*L$$

Where: SL - logistic curve; L - fish length; $L_{50\%}$ - body length at which 50% of the fish are retained; S_1 - a; S_2 - b; X - midpoint; Y - Ln [1/SL-1]; exp - exponential; Ln - natural logarithm.

Length at first maturity was analyzed according to the Spearman-Karber method (Sparre & Venema 1999):

$$m = xk + \frac{X}{2} - (X.qi)$$

$$Lm = antilog\left(m \pm 1.96\sqrt{X^2\Sigma\frac{pi\ x\ qi}{ni-1}}\right)$$

Where: Lm - length at first maturity (cm); xk - logarithm of the middle value when the fish gonads are mature 100%; X - the difference in the logarithm of the mean values; ri - number of gonad mature fish in class-i; ni - number of fish in class-i; pi - ri/ni; qi - 1 – pi.

Asymptotic length is the estimated length of fish in a population if they would grow indefinitely. Asymptotic length was estimated based on the von Bertalanffy growth coefficient (G) and was analyzed using FiSAT II Ver 1.2.2 software. The formula for calculating asymptotic length is:

$L(t) = L\infty*[1-\exp(-G*(t-t_0))]$

Where: L(t) - fish length at age-t (per unit time); L∞ - theoretical maximum length (infinity length); G - growth coefficient (per unit time); t - the age of the fish at the time of measurement; t_0 - theoretical life when length is equal to zero; exp - exponential.

Results and Discussion

Sex ratio. 292 Indian mackerels were collected from fish landing ports. Based on gonad observations, the number of males was 168 (59%), while the number of females was 116 (41%). The gonads of 8 fish were too small to determine by macroscopic observation. Sex ratio analysis from 4 sampling periods showed that there was no significant difference between males and females fish captured from Tangerang regency waters (Table 1). Based on the sex ratio, the status of mackerel fisheries in the area is classified as ideal because the differences in number between males and female fish are not significant. A balanced comparison of male fish with female fish shows that the water conditions are very good for the sustainability of fishing because the fish population will quickly recover from fishing activities (Kudale & Rathod 2016; Tampubolon et al 2019; Limbong et al 2022). Similar results were also discovered in Semarang province (Pratama et al 2019) and Lombok straits (Bunyamin et al 2016).

Table 1
Sex ratio of Indian mackerel (*Rastrelliger kanagurta*) captured from Tangerang regency waters

Sampling period	*n*	*Number*			*Sex ratio*	*Result*	*Chi-square test (χ^2)*
		Male	*Female*	*Unidentified*			
1	75	37	32	6	1.15:1	0.87	No significant difference
2	74	45	29	0	1.55:1	0.08	No significant difference
3	74	45	28	1	1.60:1	0.19	No significant difference
4	69	41	27	1	1.52:1	0.04	No significant difference
Total	292	168	116	8	1.45:1	1.18	No significant difference

Gonad maturity stage. Based on gonad macroscopic observations from identified males and females, immature gonads (55.63%) were discovered in a higher percentage than mature gonads (44.37%). However, the gonad maturity stages were different between males and females (Table 2). The percentage of immature males was higher (68.45%) compared to mature males (31.54%), while the percentage of immature females was lower (37.06%) compared to that of mature females (62.93%). The percentage of Stage II was the highest (52.11%) compared to Stage III (35.21%) and Stage I (3.52%). These results indicate that Indian mackerel captured from Tangerang regency has been over exploited. Similar results were also found in Madura straits, where the majority of captured Indian mackerel (91%) was at an immature gonad stage (Bintoro et al 2019). Susanti et al (2019) found that 74% of captured *R. kanagurta* from Sunda straits was immature.

Table 2
Gonad maturity stage of Indian mackerel (*Rastrelliger kanagurta*) captured from the Tangerang regency waters

Sex	*Gonad maturity stage*				*Category*	
	I	*II*	*III*	*IV*	*Immature*	*Mature*
Male	5	110	37	16	115	53
Female	5	38	63	10	43	73
Pooled sex	10	148	100	26	158	126
Percentage (%)	3.52	52.11	35.21	9.15	55.63	44.37

Gonadosomatic index (GSI). Gonad maturity stage of Indian mackerel landed at Kronjo port was dominated by Stage III, while at Cituis port it was dominated by Stage II. The GSI of Indian mackerel captured from the Tangerang regency waters is 1.08 (Table 3). The GSI of fish landed at Kronjo port was higher (2.17) than that of fish from the Cituis port (0.73). The result of the Welch's t-test analysis indicated that the GSI of fish landed at Cituis port is lower than Kronjo port. Based on sex, the GSI of female Indian mackerels was higher (1.52) compared to that of male Indian mackerels (0.77). The GSI of females is always higher than the GSI of males for this species because of the reproductive status and somatic development of females. In Takalar, South Sulawesi, the GSI of female *R. kanagurta* was higher than the GSI of males during the spawning season (Kasmi et al 2017). In the western waters of Aceh, the GSI of spawning Indian mackerel can reach 4.9 (Arrafi et al 2016).

Table 3

The gonadosomatic index (GSI) of Indian mackerel (*Rastrelliger kanagurta*) captured from Tangerang regency waters

Sex	*GSI*		
	Kronjo Port	*Cituis Port*	*Combined*
Male	1.85±0.8	0.46±0.29	0.77±0.73
Female	2.53±1.70	1.14±0.90	1.52±1.32
Pooled sex	2.17±1.33	0.73±0.69	1.08±1.08

Total length and weight. The TL of landed Indian mackerel ranged from 14 to 18.9 cm, while the average TL from all fish sample was 16.07±0.91 cm (Table 4). Fish W ranged from 24.2 to 86.9 g while the average W was 51.78±10.59 g. The W and TL of Indian mackerel captured from Tangerang regency water are smaller compared with those of Indian mackerel from other regions in the Indo-pacific region. The largest Indian mackerel was captured from the offshore area of Ratnagiri, India (Sonavane et al 2017; Pawase et al 2017). The TL of Indian mackerel captured from the region reached 30 cm. In Indonesia, the largest Indian mackerel was captured from Mayabilit coast, Raja Ampat (27 cm TL), followed by Indian mackerel from the west coast of Aceh (26 cm TL) and Madura strait (22.2 cm TL) (Bhendarkar et al 2014; Oktaviani et al 2014; Arrafi et al 2016; Susanti et al 2019).

Table 4

Total weight and length of Indian mackerel (*Rastrelliger kanagurta*) captured from Tangerang regency waters

Sampling period	*Total length (cm)*			*Weight (g)*		
	Minimum	*Maximum*	*Average*	*Minimum*	*Maximum*	*Average*
1	15.1	18.9	17.12±0.77	45.7	86.9	65.60±8,92
2	14.4	17.0	15.76±0.53	37.0	60.7	48.19±5.13
3	14.0	17.1	15.52±0.62	24.2	61.9	46.17±6.18
4	14.4	18.0	15.85±0.71	34.9	64.7	46.61±6.17

LWRs. Based on the R^2 value of 0.8169, the growth pattern of fish captured from Tangerang regency waters showed positive allometry, weight growth increment exceeding body length increment (Table 5). Positive allometry growth was also found from Indian mackerel captured from Madura strait (Bintoro et al 2019; Susanti et al 2019). Meanwhile, negative allometry growth was found in Indian mackerel captured from Banten coast (Safarini & Mashar 2017), Sorong waters (Suruwaky & Gunaisah 2013) and Pandeglang regency (Sari et al 2022).

Table 5

Growth pattern of Indian mackerel (*Rastrelliger kanagurta*) captured from Tangerang regency waters

Sex	*Length-weight relationship*	*Growth pattern*	*R^2*
Male	$W=0.010L^{3.076}$	Isometry	0.8347
Female	$W=0.008L^{3.141}$	Isometry	0.7801
Pooled sex	$W=0.008L^{3.156}$	Positive allometry	0.8169

Condition factor, length at first maturity, length at first catch and asymptotic length. During the sampling period, the condition factor of Indian mackerel found at Tangerang regency waters reached 1.01 (Table 6). The condition factor changes seasonally based on available diet (Aydin & Ozdemir 2022). A similar condition factor was also

observed at Madura strait and Sunda strait, with 1.03 (Bintoro et al 2019) and 0.85-1.18 (Safarini & Mashar 2017), respectively.

Table 6

Length at first maturity (L_m), length at first capture (Lc), asymptotic length (L_∞) and condition factor (K) of Indian mackerel (*Rastrelliger kanagurta*) at Tangerang Regency waters

Sex	*L_m (cm TL)*	*L_c (cm TL)*	*L_∞ (cm TL)*	*K*
Male	16.13	15.25	19.89	1.23
Female	15.55	15.55	19.89	1.27
Pooled sex	15.94	15.40	19.89	1.01

L_m of male Indian mackerel was longer, 15.94 cm, compared to that of females, 15.55 cm. Compared to Indian mackerel captured from other regions in Indonesia, L_m of Indian mackerel captured from Tangerang regency was smaller (Table 7). Based on Fishbase, L_m of Indian mackerel is 19.9 cm. The difference L_m between each region can be caused by environmental parameters and the geographical position of the region. Regions with a 5 degree latitude difference can cause different gonad maturation status (Effendie 2002).

Table 7

Length at first maturity (L_m) of Indian mackerel (*Rastrelliger kanagurta*) at different region

No	*Location*	*Lm*	*Reference*
1	Mangalore, India	20.50 cm (male) 21.00 cm (female)	Hulkoti et al (2013)
2	Mahout beach, Oman	25.20 cm (male) 25.70 cm (female)	Zaki et al (2016)
3	Aceh western coast, Indonesia	19.58 cm (combined)	Arrafi et al (2016)
4	Takalar Coast, Indonesia	21.31 cm (male) 21.18 cm (female)	Kasmi et al (2017)
5	Madura Strait, Indonesia	22.85 cm (male) 22.47 cm (female)	Bintoro et al (2019)
6	Sunda Strait, Indonesia	19.38 cm (male) 17.79 cm (female)	Putera & Setyobudiandi (2019)
7	Aru Sea, Indonesia	20.19 cm (male) 19.96 cm (female)	Fauzi et al (2020)
8	Makassar Coast, Indonesia	21.19 cm (male) 21.02 cm (female)	Kantun et al (2018)
9	Tangerang regency waters	16.13 cm (male) 15.55 cm (female)	Current research

In this study, the L_c of *R. kanagurta* captured from Tangerang regency waters was 15.4 cm. For males, the length at first capture was smaller compared to females. Tangerang regency water had Indian mackerel with the lowest L_c compared to other regions. Indian mackerel captured from Kendal regency waters reached an L_c of 17 cm (Adlina et al 2016), while from Madura straits L_c reached 17.02 cm (Bintoro et al 2019).

Asymptotic length of Indian mackerel captured from Tangerang regency waters was 19.89 cm. This value is also smaller compared to that of Indian mackerel captured from Madura strait, 23.4 cm (Bintoro et al 2019). Based on Fishbase, asymptotic length for male Indian mackerel is 36 cm, while for females it is 42.1 cm.

Conclusions. The sex ratio of Indian mackerel captured from Tangerang regency waters was balanced. The majority of fish captured were in the maturity Stage II. The average

length of *R. kanagurta* was 16.07±0.91 cm, while the average body weight was 51.78±10.59 g. The condition factor of 1.01 indicates a slimmer body. The Indian mackerel resources in Tangerang regency waters are in optimum condition.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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