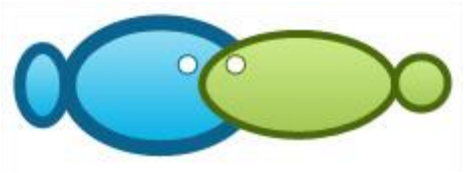

Size composition, growth pattern and condition factor of Indian mackerel (*Rastrelliger kanagurta*) at Bone Bay, South Sulawesi, Indonesia

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Abstract. The study aims to analyze the growth pattern and condition factor of Indian mackerel (*Rastrelliger kanagurta*) in the northern waters of Bone Bay, landed at the Pontap Fish Landing Site, Palopo City, South Sulawesi. This research is expected to provide an overview of the population condition of Indian mackerel in Bone Bay waters as a basis for the management and utilization of these fisheries resources. The study was conducted at the TPI Pontap, Palopo City for 6 months, starting from March to September 2022. Length measurements were done using a measuring board with an accuracy of 1 mm and fish weighing with an accuracy of 0.1 g were carried out every two weeks. 1764 individual samples were measured with lengths between 12–21 cm and weights between 21–175 g. The result of the length-weight relationship analysis obtained a b value of 2.523, indicating that the growth pattern of Indian mackerel landed at TPI Pontap, Palopo City is negative allometric. The average condition factor value is 1. This research shows that the population of Indian mackerel in the waters of Bone Bay, which is landed at the TPI Pontap, Palopo City, is classified as thin.
Key Words: allometric, biology, management, pelagic.

Introduction. The Indian mackerel (*Rastrelliger kanagurta*) is one of the small pelagic fish that has economic significance (Bintoro et al 2019; Osman et al 2021; Wujdi et al 2022). This fish has a high selling value, production volume, and production power. The Indian mackerel is also one of the fish consumed by the Indonesian community because it contains high levels of omega-3 (Nurjanah et al 2015).

Bone Bay waters are rich in small pelagic fish, one of which is the Indian mackerel. The potential of these fisheries resource is 0.5 million tons per year (Hastuti et al 2023). Based on the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 19 of 2022 (Minister of Marine Affairs and Fisheries of the Republic of Indonesia 2022), the Fisheries Management Area of the Republic of Indonesia (WPPNRI) 713, which includes the waters of Bone Bay, Makassar Strait, Flores Sea, and Bali Sea, has an estimated potential of small pelagic fish resources of 162506 tons. The allowable catch is set at 337050 tons, with an exploitation rate of 0.3.

This fish is the primary target for fishermen in the Bone Bay waters, including fishers in Palopo City. However, continuous fishing efforts on Indian mackerel can lead to disturbances in their population. In 2022, mortality rates were determined as follows: natural mortality (M) at 1.64 per year, fishing mortality (F) at 2.47 per year, and total mortality (Z) at 4.11 per year. The exploitation rate (E) was calculated at 0.6, indicating that 60% of the stock is being exploited, surpassing the maximum sustainable exploitation rate of 50% (Jalil & Makkatenni 2024). This suggests that the Indian mackerel population in northern Bone Bay is experiencing overexploitation, necessitating effective fisheries management to prevent further population decline.

Growth patterns and condition factors are two important categories of parameters that can be used to analyze fish populations' conditions. The growth pattern of fish indicates how the size of the fish increases with age (Helfman et al 2009; Jisr et al 2018; Osman et al 2021). Growth patterns are analyzed by calculating the length-weight relationship of fish. This relationship provides an overview of fish somatic growth, which can be used to calculate fish biomass even with only knowing the length of the fish. Fish condition factors can describe the ecological conditions of a body of water (Batubara et al 2019).

Research on the length-weight relationship and condition factor of Indian mackerel has been carried out in Raja Ampat (Oktaviani et al 2019), Sunda Strait (Putera & Setyobudiandi 2019), Malacca Strait waters (Hsb et al 2015), Beringin Lempasing port (Hasani et al 2023), Sibolga waters (Sinaga & Afriani 2020), western waters of Aceh (Arrafi et al 2016). Based on this, it is very important to conduct research aimed at analyzing the composition of size, weight length relationships and factors of Indian mackerels conditions in the waters of Bone Bay landed at the Pontap Fish landing site Palopo City, South Sulawesi Province, Indonesia.

Material and Method. This research was conducted over 6 months from March to September 2022. The object of this research is Indian mackerel (*Rastrelliger kanagurta*) caught in the northern waters of Bone Bay and landed at the Pontap Fish Landing Site, Palopo City, South Sulawesi (Figure 1). Samples were measured every two weeks, comprising 15–20 kg of Indian mackerel caught by fishers in the northern waters of Bone Bay and landed at the TPI Pontap, Palopo City. The selection of samples was carried out randomly against all catches at the research site.

Figure 1. Research location, Bone Bay, South Sulawesi, Indonesia (https://www.worldometers.info, https://mediaindonesia.com/).

The data collected included the fork length (FL) of fish samples. FL measurements were conducted using a measuring table. After measuring the length, the weight was determined using a digital scale with an accuracy of 0.01 g.

Growth pattern analysis was done by calculating the relationship between length (L) and weight (W) of fish using the cubic equation. The general form of the equation is:

$W=aL^b$ or $\log W = \log a + b \log L$

Where: W - individual fish weight (g); L - fork length (cm); a - intercept (intersection between the regression line and the y-axis); b - regression coefficient (angle of the line slope). Fork length (FL) is the length of a fish measured from the tip of the snout to the deepest point of the fork in the caudal fin for fish with a forked caudal fin. The growth pattern of Indian mackerel can be determined based on the obtained b value. If b=3, the growth is classified as isometric growth, meaning the increase in length is equal to the weight gain of the fish. If b>3, the growth is classified as positive allometric growth,

indicating that the weight increase is faster than the length increases of the fish. If b<3, the growth pattern is negative allometric, which means the length increase is faster than the weight gain of the fish. To determine whether the b value is greater, equal to, or less than 3, a t-test will be conducted at a 95% confidence interval.

Furthermore, the condition factor value is calculated based on the results of the length-weight relationship analysis. To calculate the condition factor value, the following equation (Kurnaengsih 2015) was used:

$$K = \frac{10^5}{L^3} W$$

or

$$Kn = \left[\frac{W}{FL^3}\right] x100$$

Where: K - condition factor; Kn - relative condition factor; L - fork length of the fish sample; W - body weight of the fish sample. If the length-weight relationship calculation yields a b value equal to 3 or an isometric growth pattern, the calculation uses the first equation, i.e., the absolute condition factor. If the results of the length-weight relationship calculation yield a b value different than 3 or an allometric growth pattern, the calculation uses the Kn formula.

Results and Discussion

Size composition of Indian mackerel. The Indian mackerel samples collected during the study amounted to 1764 individuals. The length of the sampled fish ranged between 10.9-21.9 cm, with an average of 17.03±1.743 cm. The weight of the sample fish ranged between 21-152 g, averaging 78.65±21.8 g (Figure 2).

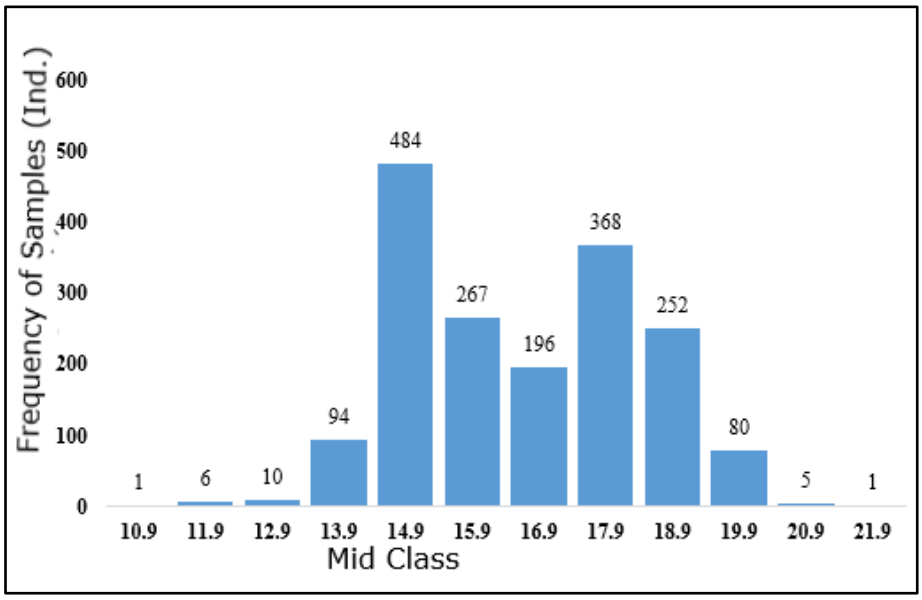

Figure 2. Composition of the length size of Indian mackerels (*Rastrelliger kanagurta*) landed at TPI Pontap, Palopo City, Indonesia.

The composition of the length size of the Indian mackerel caught in the northern waters of Bone Bay, which were landed at the Pontap Fish Landing Site in Palopo City, is presented in Table 1. Table 1 shows that the size of fish caught in the northern waters of Bone Bay varies monthly. The largest fish were caught in July, with an average length of 20.9±1.498

cm and an average weight of 93.99±23.49 g. The smallest fish were caught in August, with an average length of 19.8±0.76 and an average weight of 62.91±8.85 g.

Table 1

Composition of the total length size of *Ratraliger kanagurta* caught in the northern waters of Bone Bay and landed at the fish landing site in Palopo City

Month	*Number of samples*	*Fork length (cm)*			*Weight (g)*		
		Max	*Min*	*Mean*	*Max*	*Min*	*Mean*
Mart	80	20.0	16.2	18.03±0.6	115.0	62.0	82.23±8.18
April	234	21.9	16.0	18.92±1.42	137.0	57.0	103.24±22.95
May	220	21.0	12.0	17.07±2.01	152.0	26.0	80.34±28.48
June	143	20.5	16.0	18.03±0.752	124.0	64.0	88.62±11.66
July	295	20.9	12.8	18.23±1.49	175.0	34.0	93.99±23.49
August	642	19.8	12.8	15.52±0.76	111.0	35.0	62.91±8.85
September	150	20.0	10.9	17.76±36.99	111.0	21.0	81.66±16.54
Total	1764						

The size of the Indian mackerel varies across different waters in and around Indonesia. The smallest size was found in the Indian Ocean waters, with an average length of 18 cm. The largest was found in the South China Sea, with an average length of 19 cm. The range of the length of Indian mackerel caught in several waters in Indonesia is 10.9-27.4 cm, which is smaller compared to those caught in the Persian Gulf reaching a length of 35.5 cm (Table 2).

Table 2

Comparison of the length sizes of Indian mackerel (*Ratraliger kanagurta*) caught in the northern waters of Bone Bay

Location	*Range of fork length (cm)*	*Average fork length (cm)*	*References*
Northern Bone Bay	10.9–21.9	17.3	This study
Sibolga	16.5-19	-	(Sinaga & Afriani 2020)
Ternate	13.4-27.4	-	(Tangke 2014)
Bali Strait	16-20	18.2	(Wujdi et al 2022)
Persia Bay	13.9–35.5	23.5	(Daghooghi et al 2019)
Lempasing Coast	12–25	21.5	(Caesario et al 2022)

The size difference of Indian mackerel in different waters can be caused by several external and internal factors. External factors such as environmental conditions, like water temperature, salinity, and availability of food, can affect the growth of Indian mackerels. They can grow faster in waters with optimal environmental conditions. Warm water temperatures can enhance the metabolism of Indian mackerels, allowing them to grow faster. Genetic factors play a role as well. Another factor is fishing activity, which can also affect the size of the caught Indian mackerels. Larger mackerels are more prone to being caught by fishers (Wujdi et al 2014).

Length-weight relationship. The regression statistical analysis shows a correlation (R) of 0.95 and an R^2 value of 0.89. This indicates a remarkably high correlation between the length and weight of the fish. The relationship between the length and weight of the fish, as well as the calculation of the intercept value (b) and the value of a for the Indian mackerel caught in the northern waters of Bone Bay, is presented in Table 3.

Table 3

Relationship between the length and weight of Indian mackerel (*Ratraliger kanagurta*)

	Coefficients	*Standard error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.22173	0.0253	-48.1406	0	-1.272	-1.1719
log L	2.523356	0.0206	122.27	0	2.4829	2.5638

The temporal analysis of the length-weight relationship of Indian mackerels in the northern waters of Bone Bay is presented in Table 4.

Table 4

The length-weight relationship of Indian mackerels (*Ratraliger kanagurta*) in the northern waters of Bone Bay

Month	*a value*	*b value*	*Formula*	*Growth pattern*
March	-1.3701	2.6143	W=-1.3701 $L^{2.6143}$	Negative allometric
April	-2.0836	3.2042	W=-2.0836 $L^{3.2042}$	Positive allometric
May	-1.4571	2.7160	W=-1.4571 $L^{2.7160}$	Negative allometric
June	-1.6273	2.8440	W=-1.6273 $L^{2.8440}$	Negative allometric
July	-1.8198	2.9992	W=-1.3701 $L^{2.9992}$	Negative allometric
August	-0.9940	2.3424	W=-0.9940 $L^{2.3424}$	Negative allometric
September	-1.4034	2.6472	W=-1.4034 $L^{2.6472}$	Negative allometric

Indian mackerel caught in the northern waters of Bone Bay, especially those landed at TPI Pontap in Palopo City, have varying b values ranging from 2.3424 to 3.2042. This indicates negative allometric growth over a 5-month period. A positive allometric growth pattern was only found in April.

The graph showing the length-weight relationship of the Indian mackerels caught in the Northern Waters of Bone Bay and landed at TPI Pontap, Palopo City, is presented in Figure 3.

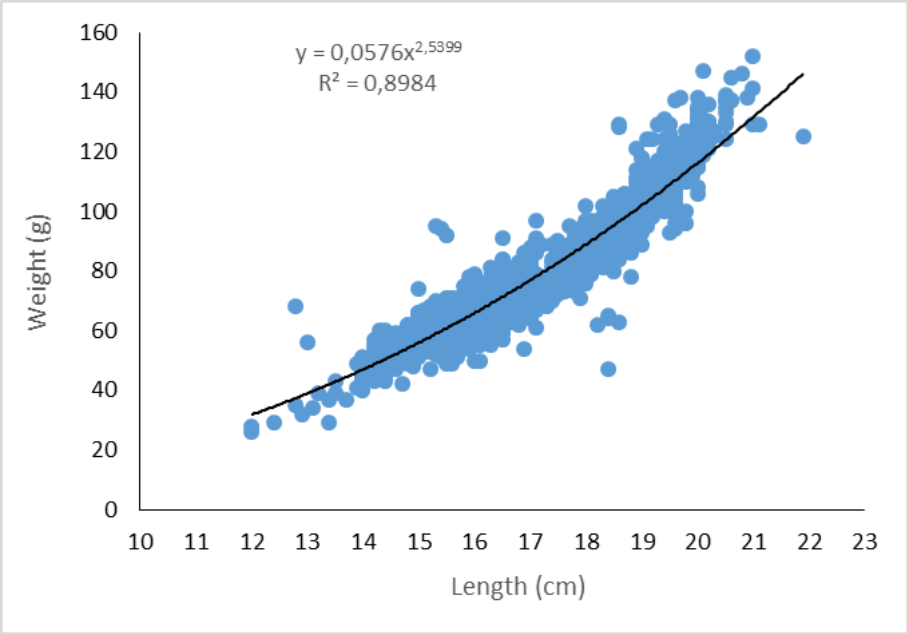

Figure 3. Length-weight relationship of Indian mackerel (*Ratraliger kanagurta*) landed at TPI Pontap, Palopo City, Indonesia.

The analysis of the length-weight relationship and growth patterns of Indian mackerels obtained in several waters is presented in Table 5.

Table 5

Values of length-weight relationship of Indian mackerels (*Ratraliger kanagurta*) in several previous studies

Location	*b value*	*References*
Sorong	♂♀=2.88–2.98	(Suruwaky & Gunaisah 2013)
Mangaluru (Mangalore) waters	♂=3.17 ♀=3.2686	(Hulkoti et al 2013)
Malaka strait	♂♀=3.09	(Hsb et al 2015)
Western Aceh	♂♀=2.625-3.449	(Arrafi et al 2016)
Madura strait	♂=3.26 ♀=3.6	(Susanti et al 2019)
Karachi waters	♂♀=2.838	(Ahmad et al 2019)
Muoro Demak waters	♂=2.59 ♀=2.03	(Rachmanto et al 2020)
Biak Coast waters	♂♀=3.12	(Marasabessy 2020)
Bone Bay	♂♀=2.52	This study

This study indicates an allometric growth pattern, both negative and positive. Negative allometric growth patterns were found in several previous studies in Sorong waters (Suruwaky & Gunaisah 2013), Aceh waters (Arrafi et al 2016), and Muoaro Demak waters (Rachmanto et al 2020), as well as in Karachi waters (Ahmad et al 2019). Meanwhile, different research results with positive allometric growth patterns were found in Madura Strait waters (Susanti et al 2015).

The variation in fish growth patterns can be influenced by many factors, both internal and external. Internal factors include gonad maturation condition, sex, diseases, etc. Meanwhile, external factors might involve food availability, water conditions, etc. (Jalil et al 2020; Rachmanto et al 2020). The b value difference or growth patterns can also be affected by geographical conditions and seasonal variations (Ahmad et al 2019; Guzman & Rosario 2020).

Condition factor value. The condition factor value ranged between 0.503 and 1.821, with an average of 1.00±0.089. This value indicates that condition of Indian mackerel in Bone Bay waters is healthy or normal. This aligns with research findings in various waters as shown in Table 7. The range of this condition factor value is wider compared to the values in Morodemak waters, Demak district, between 1 and 2 (Rachmanto et al 2020). The condition factor value of Indian mackerel in various locations is presented in Table 6.

A higher value indicates a good environmental condition, whereas a lower value signifies a poorer condition (Le Cren 1951). The condition factor depicts the level of maturity, health, and environmental conditions of the fish. This can be influenced by numerous factors including diet, availability, and quality of food. Fish with quality and abundant food will have a higher condition factor. Age is another factor, as the condition factor value tends to increase with age, since older fish have more time to grow and develop. Sex is another factor, where male and female fish have different condition factor values. Female fish usually have higher condition factor values than male fish, especially during the spawning season. Other factors include reproductive status and stress, which can be caused by environmental changes, predator disturbances, and diseases. Lastly, environmental conditions such as water temperature, salinity, and dissolved oxygen content can also affect the condition factor. Fish living in poor environments will have lower condition factor values (Hsb et al 2015; Arrafi et al 2016; Hulkoti et al 2013; Katiandagho & Marasabessy 2017).

Table 6

Condition factor of Indian mackerel (*Ratraliger kanagurta*) in other locations

Locations	*Condition factor*	*References*
Biak waters, Indonesia	♂=0.11–1.75 ♀= 0.04–2.28	(Marasabessy 2020)
Lempasing waters	0.96	(Hasani et al 2023)
Banten Bay, Karangantu	0.85–1.18	(Safarini & Mashar 2018)
Tanjung Beringin, Malaka Strait	1.12–1.18	(Hsb et al 2015)
Megalore	1.05	(Hulkoti et al 2013)
Western Aceh	0.92–1.45	(Arrafi et al 2016)
Bone Bay	0.5–1.8	This study

The condition factor value of Indian mackerel in the northern part of Bone Bay is lower than that of fish from other waters, possibly due to factors including: 1) diet, with food availability in Bone Bay possibly not as high as in other waters; 2) age, where mackerels in Bone Bay might be still in the growing phase, hence having a lower condition factor; 3) environmental conditions, which might be less ideal in Bone Bay, hence resulting in a lower condition factor (Abdul et al 2017; Le Cren 1951).

Conclusions. Indian mackerel in the northern waters of Bone Bay have a diverse age group, ranging from juvenile to adult. Juvenile Indian mackerel have an average length of 12.8 cm, while adult males have an average length of 19.9 cm. The growth pattern of Indian mackerel in the northern waters of Bone Bay is negatively allometric, with an average b value of 2.52, indicating slow growth. The condition factor value in the northern waters of Bone Bay is 1.00, indicating that the fish are healthy or normal. Based on these conclusions, the following management recommendations for Indian mackerel in the northern waters of Bone Bay are proposed: conducting further research to assess factors affecting the growth and condition factors of Indian mackerel, and implementing sustainable Indian mackerel fishing management, considering ecological, economic, and social aspects. Efforts to manage sustainable mackerel fishing can be carried out by: 1) establishing reasonable and sustainable catch quotas; 2) enforcing strict supervision and law enforcement against fishing violations; 3) providing education to fishers and the community about the importance of sustainable fish resource management. These sustainable mackerel fishing management efforts are expected to preserve the stock of Indian mackerels in the northern waters of Bone Bay, thereby optimizing community utilization.

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

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