A morphometric approach into mackerel (Rastrelliger spp.) diversity in Fisheries Management Area 711 as a management base

Y Wardiatno\textsuperscript{1,2,3}, A Aziz\textsuperscript{1}, Zairion\textsuperscript{1,2}, L Meilana\textsuperscript{4} and A A Hakim\textsuperscript{1,*}

\textsuperscript{1}Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Bogor 16680, West Java, Indonesia
\textsuperscript{2}Center for Coastal and Marine Resources Studies (PKSPL), IPB University (Bogor Agricultural University), IPB Baranangsiang Jl. Raya Pajajaran, Bogor 16143, West Java, Indonesia
\textsuperscript{3}Environmental Research Center (PPLH), IPB University (Bogor Agricultural University), IPB Darmaga, Bogor 16680, West Java, Indonesia
\textsuperscript{4}Coastal and Ocean Management Institute, Xiamen University, Xiamen 361102, China

*Corresponding author: agusalim@apps.ipb.ac.id

Abstract. Rastrelliger spp. is a small pelagic fish with important ecological and economic value in Indonesia. Genus Rastrelliger has three species with different distribution patterns, so they have diversity in morphology and populations in several waters. The study aimed to analyze the morphometric diversity of mackerel (Rastrelliger spp.) in Bintan, Bangka, and Ketapang waters (Fisheries Management Area 711) using standard morphometric methods and truss network analysis. 310 samples were collected from all locations based on simple random sampling. The growth pattern of Rastrelliger spp. was negative allometric in each location. The cluster analysis showed that the mackerel populations from Ketapang and Bangka formed one group, while Bintan tended to be different. Based on the discriminant analysis, there are overlapping populations between Ketapang and Bangka. The difference of morphometric characters on mackerel (Rastrelliger spp.) can indicate different species, so there is potential for more than one population or stock in FMA 711.

Keywords: allometric; FMA 711; population; stock

1. Introduction
Rastrelliger spp. is a small pelagic fish with important ecological and economic value in Indonesia. The high demand of mackerel has impact to increase fishing activity with various fishing gears [1]. Mackerel is marketed as fresh, frozen, canned, salted, and smoked. Genus Rastrelliger in the word has three species, there are Rastrelliger faughni, Rastrelliger kanagurta, and Rastrelliger brachysoma [2]. Mackerel are found in almost all Indonesian waters. \textit{R. kanagurta} are found in the Indo-West Pacific and distributed in Mediterranean waters via the Suez Canal, while \textit{R. brachysoma} and \textit{R. faughni} are limited to the Indo-Central Pacific [3]. The different distribution patterns of all species of mackerel cause morphometric variations that can indicate differences in growth, mortality, and reproduction rates.
Morphometric studies are studies that related to variations and changes in the shape and size of organisms or objects [5]. Morphometric variations between populations in different geographical conditions are caused by different genetic structures and environmental conditions. Therefore, a population with the same morphometric character can be considered as one stock [6]. To assess morphometric characters can use the standard morphometric and the truss network analysis (TNA) method. The TNA method can identify possible differences in the morphology of organisms that have a close kinship, both inter-species and intra-species [7]. The basis of the TNA method is the existence of different growth patterns between male and female fish with an impact on different body parts or distances truss [7].

Indian mackerel (R. kanagurta) and short mackerel (R. brachysoma) have almost the same morphological characters. One technique to identify the possible morphological differences in organisms that have close kinship uses measurements of TNA [7]. TNA provides a better distinction between species analysis than traditional methods [8]. TNA is based on points of morphometric truss that are connected horizontally, vertically, and diagonally, so obtained a more detailed and specific body image.

There are three species of mackerel with a wide distribution in Indonesian waters. Furthermore, the wide distribution can create population mixing in an aquatic area, so the stock consists of different populations which can affect the form of management. On the other hand, the wide distribution of the same species can cause different characters in mackerel as a result of adaptation to different environmental conditions. This adaptation can give rise to morphometric variations of the same species and can cause changes in the stock structure in a water area that affect the management process. The study aimed to analyze the morphometric diversity of mackerel (Rastrelliger spp.) in Bintan, Bangka, and Ketapang waters (Fisheries Management Area 711) using standard morphometric methods and truss network analysis.

2. Material and methods

2.1. Time and location

Samples of mackerel were obtained on June-August 2019 from several locations of fishing landings at FMA 711 which include Bintan (Riau Islands), Bangka (Bangka Belitung), and Ketapang (West Kalimantan) (figure 1). Morphometric analysis was conducted at the Aquatic Molecular Biology Laboratory, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University.

2.2. Data collection

A total of 310 samples of mackerel (Rastrelliger spp.) were collected from three locations, i.e., Bintan, Bangka, and Ketapang with several samples of 105, 104, and 101 individuals. Collecting samples from each location was conducted by simple random sampling technique. Thirteen characters were measured by the standard morphometric method as shown in figure 2 [2]. Measurement of morphometric characters by the standard method used a caliper digital scale (smallest scale 0.01 mm) and ImageJ software. The application of the software was obtained more accurate data. ImageJ measurements were based adjusting a predetermined scale. The weight was measured using digital scales (smallest scale 0.01 g).

For measurement with truss network analysis method, the sample is placed on a paper millimeter block with the head on the left. Landmark points around the outline of the body were created using pins as markers which each point is marked consistently and homologous from one example to another. A total of 16 reference points (figure 3) were made dividing the outline of the fish body to produce 36 characters [9]. Each sample was captured by Canon EOS 1300D camera with the same distance, magnification, and light settings. Furthermore, the results of the images were extracted to produce morphometric data using tpsDig2 and PAleontologi cal Statistics (PAST) software [9].
Figure 1. Research location in FMA 711 including Bintan, Bangka, and Ketapang.

Figure 2. Measurement of morphometric characters mackerel (Rastrelliger spp.) by standard methods.

Figure 3. Measurement of morphometric characters mackerel (Rastrelliger spp.) by truss network analysis methods.
2.3. Data analysis

2.3.1. Length-weight relationship. Analysis of length-weight relationship can predict fish growth parameters. The analysis can use the following formula [10]:

\[ W = aL^\beta \]

With: \( W \) = fish weight (gram), \( L \) = fish length (mm), \( a \) = constant (intercept), \( \beta \) = regression coefficient. Then it is derived so that it becomes a form of the following relationship:

\[ \log W = \log a + \beta \log L \]

The growth parameters from the length-weight relationship can be seen from the constant \( \beta \) as an estimator of growth patterns [10], with the hypothesis:

1. \( \beta = 3 \): isometric (the length growth is the same as the weight growth pattern)
2. \( \beta \neq 3 \): allometric, that is
   - \( \beta > 3 \): allometric positive (the weight is more dominant)
   - \( \beta < 3 \): allometric negative (the length is more dominant)

After that, the statistical test using t-test against the \( \beta \) value is the same or not with the value of 3.

2.3.2. Data transformation. Data from the measurement results were transformed through modification of the formula by Poulet et al. [11]. The transformation aims to eliminate the effect of size and to get the variations from differences in body shape not from the relative size [11]. The data is transformed using the following formula:

\[ M_{\text{trans}} = \log M - b (\log \text{SL} - \log \text{SL}_{\text{mean}}) \]

With: \( M_{\text{trans}} \): measurement truss transformed, \( M \): original measurement (mm), \( \text{SL}_{\text{mean}} \): average of standard length of all fish (mm), \( \text{SL} \): standard length of each fish sample (mm), \( b \): slope regression of log \( M \) and log \( \text{SL} \).

2.3.3. Comparison and differences of morphometric characters. Morphometric characters of mackerel in all locations were compared using the Kruskal-Wallis test. The Kruskal-Wallis test is a technique with the initial hypothesis that form several samples coming from the same or identical population. This approach resulted in different morphometric characters of mackerel (\( \text{Rastrelliger} \) spp.) from several locations in FMA 711. The Kruskal-Wallis test was used to identify characters with significant differences [12]. Discriminant analysis was used to determine differences in morphometric characters between populations of mackerel (\( \text{Rastrelliger} \) spp.) from three locations. The analysis can also determine morphometric characters which are very important to differentiate populations. This estimation can explain the population mixing of mackerel in one location with another [13]. The results of the discriminant analysis are presented in the form of a population distribution plot in three locations.

2.3.4. Cluster analysis of mackerel population. Cluster analysis is used to determine the grouping, the difference level, and the population similarity based on morphometric character. The results of cluster analysis are presented in dendrogram form based on the distance of Euclidean from the mackerel population at three locations. Euclidean calculates distance which the shortest distance obtained from the two calculated points [14]. If the distance of Euclidean was smaller, then the kinship between populations was higher.

3. Results

3.1. Length-weight relationship

The equations based on length-weight relationship in Ketapang, Bangka, and Bintan are \( W = 0.00002L^{2.7998} \), \( W = 0.000009L^{2.9441} \), and \( W = 0.000007L^{2.9698} \) with the determination coefficient of 0.852.
0.9349, and 0.7499 (figure 4). Based on t-test, mackerel in three locations have the same growth pattern that is negative allometric with the b value of 2.7998 in Ketapang, 2.9441 in Bangka, and 2.9698 in Bintan.

**Figure 4.** Length-weight relationship of mackerel (*Rastrelliger* spp.) from (a) Ketapang, (b) Bangka, and (c) Bintan.

### 3.2. Comparison and differences of morphometric characters

Comparison of morphometric characters of mackerel at three locations was obtained from the results of discriminant analysis using the Kruskal-Wallis test. There are 10 characters that have differences (*p*-value <0.05) from 13 characters measured by the standard morphometric method (table 1). Meanwhile, there are 22 characters that have differences (*p*-value <0.05) from 36 characters analyzed by the truss network method (table 2).

**Table 1.** The morphometric characters form the discriminant function by the standard method.

| Characters | Wilks lambda | *p*-value |
|------------|--------------|-----------|
| 2          | 0.340        | 0.010     |
| 5          | 0.184        | 0.058     |
| 6          | 0.515        | 0.221     |
| 7          | 0.637        | 0.365     |
| 8          | 0.071        | 0.016     |
| 9          | 0.447        | 0.016     |
| 10         | 0.077        | 0.070     |
| 11         | 0.015        | 0.035     |
| 12         | 0.049        | 0.022     |
| 13         | 0.410        | 0.026     |
Table 2. The morphometric characters form the discriminant function by the truss network analysis method.

| Characters | Wilks lambda | p-value       |
|------------|--------------|---------------|
| 1 - 2      | 0.022        | 2.03 $10^{-05}$ |
| 1 - 16     | 0.017        | 7.88 $10^{-05}$ |
| 2 - 3      | 0.042        | 2.58 $10^{-04}$ |
| 2 - 15     | 0.047        | 7.38 $10^{-04}$ |
| 2 - 16     | 0.071        | 3.22 $10^{-03}$ |
| 3 - 4      | 0.050        | 3.72 $10^{-04}$ |
| 3 - 15     | 0.014        | 1.14 $10^{-05}$ |
| 4 - 5      | 0.015        | 1.20 $10^{-05}$ |
| 4 - 14     | 0.049        | 1.11 $10^{-04}$ |
| 4 - 15     | 0.054        | 3.71 $10^{-04}$ |
| 5 - 6      | 0.035        | 3.60 $10^{-05}$ |
| 5 - 13     | 0.058        | 4.44 $10^{-04}$ |
| 5 - 14     | 0.032        | 3.76 $10^{-05}$ |
| 5 - 15     | 0.013        | 5.67 $10^{-05}$ |
| 6 - 12     | 0.039        | 2.46 $10^{-05}$ |
| 6 - 13     | 0.040        | 1.69 $10^{-05}$ |
| 7 - 8      | 0.019        | 3.19 $10^{-05}$ |
| 7 - 11     | 0.122        | 4.34 $10^{-03}$ |
| 9 - 10     | 0.056        | 5.09 $10^{-04}$ |
| 12 - 13    | 0.020        | 1.32 $10^{-05}$ |
| 13 - 14    | 0.016        | 3.62 $10^{-05}$ |
| 14 - 15    | 0.131        | 1.17 $10^{-02}$ |

Figure 5. Morphometric distribution plots using (a) the standard and (b) TNA method.

The results of discriminant analysis based on the morphometric distribution plot of mackerel by the standard method and the truss network analysis method showed the same results that two locations were not separated, while one location was completely separated (figure 5). Classification based on measurements using the truss network analysis method shows that there are three distribution centers (centroids) for each population. Mackerel from Ketapang and Bangka appear to have a high overlap
between locations, while mackerel from Bintan appear to be separate from other locations. The overlap of the location means that there is a certain character similarity in the population of each location.

3.3. Cluster analysis of mackerel population

Based on the kinship analysis by both methods, the euclidean distance from the three research locations showed the farthest kinship distance from the population of Bintan. The results of cluster analysis by both methods also illustrated the same results that there were two clusters produced where mackerel from Ketapang and Bangka create the first cluster and from Bintan form the second cluster (figure 6). The highest level of kinship is obtained on the mackerel fish population from Ketapang and Bangka Belitung than from Bintan.

![Dendrogram of mackerel population-based on cluster analysis using (a) standard and (b) truss network analysis method.](image)

4. Discussion

The mean total length of mackerel obtained was 187.8 mm, 212.7 mm, and 273 mm from Ketapang, Bangka, and Bintan locations, respectively. Different sizes of mackerel may allow for species differences between locations. The difference at each location is caused by the influence of environmental conditions and food. The size variation between locations also depends on the influence of aquatic environmental conditions, especially temperature and food availability [15].

The ratio between the head length to the body width and the fork length to the body width in each location is 1:1 and 4:1. The results obtained in this study showed the same results as previous research [16]. The Indian mackerel (*Rastrelliger kanagurta*) and the short mackerel (*Rastrelliger brachysoma*) have a fork length of 4.3-5.2 times and 3.7-4.3 times compared to the body height at the operculum boundary [17]. This is consistent with the results of this study that the mackerel fish population originating from Ketapang and Bangka has a fork length of 3.8 times, while the mackerel fish population originating from Bintan has a fork length of 4.4 times than the body height at the operculum boundary. It is suspected that there might be differences in mackerel species.
The estimation of the growth pattern of mackerel in Ketapang, Bangka, and Bintan had varied the b values, there are 2.7998, 2.9441, and 2.9698 (figure 4). Based on the results of the t-test, the growth pattern of mackerel in all locations shows allometric growth that mean that the length grows faster than the weight. Analysis of length-weight relationship is related to the level of health and fish fitness which is directly related to the food availability in an area and does not have a direct relation with fish morphometric [18].

Differences in b values can be influenced by several factors such as food availability, differences in body size [19], and fish behavior [20]. Besides, the number of species observed, the condition, and the survival level of the fish are also a factor affecting the b value [21]. The currents and wave conditions also affect the b value that fish habitat with calm waters tend to have a large b value [22]. Active swimming fish have a small b value due to the allocation of energy for movement and growth [23].

The mackerel is thought to have different morphometric characters at three different locations. The different morphometric characters from mackerel are phenotypic variations [24]. Fish populations in an area have certain characteristics with different growth rates due to the influence of environmental conditions [25]. The adaptation to environmental conditions can produce morphometric differences in the species [26]. The adaptation strategy of an organism in adapting itself to environmental conditions by changing the phenotype and then making changes to the genotype in a vulnerable time [27].

The results of the cluster analysis showed that was the formation of different groups of mackerel populations in Ketapang, Bangka, and Bintan (figure 6). The populations of mackerel in Ketapang and Bangka form the same group, while mackerel originating from Bintan tends to be different. The result of cluster analysis is consistent with the result of discriminant analysis which shows overlapping populations from Ketapang and Bangka, while population from Bintan is seen separately from other populations. This is presumably due to differences in environmental conditions, causing an adaptation made by mackerel fish.

The overlap between populations can also be assured due to differences in location in which the mackerel population from Ketapang and Bangka is closer to the beach, while the population of mackerel originating from Bintan is some distance from the coast. Indian mackerel (R. kanagurta) can be found at some distance from the coast, while Short mackerel (R. brachysoma) can be found in waters near the coast [28]. The overlap between populations of mackerel is thought caused by the proximity of the location [29]. Distribution and abundance can be affected by changes in oceanographic conditions such as water temperature, season, and chlorophyll-a concentration [29].

5. Conclusions
The growth pattern of Rastrelliger spp. was negative allometric in each location. The cluster analysis showed that the mackerel populations from Ketapang and Bangka formed one group, while Bintan tended to be different. Based on the discriminant analysis, there are overlapping populations between Ketapang and Bangka. The difference of morphometric characters on mackerel (Rastrelliger spp.) can indicate different species, so there is potential for more than one population or stock in FMA 711. The best management strategy for exploitation can be developed based on the information of unit stock.

Acknowledgment
The study was funded by the Ministry of Science Technology and Higher Education of the Republic of Indonesia from Fiscal Year 2019.

References
[1] Sarasati W, Boer M, and Sulistiono 2016 Status stok Rastrelliger spp. sebagai dasar pengelolaan perikanan Jurnal Perikanan Universitas Gadjah Mada 18(2) 73-81 [in Indonesian]
[2] Goutham J and Mohanraju R 2015 Some aspects of mackerel diversity and morphometric studies of Rastrelliger genera from Port Blair Andaman waters International Journal of Fisheries and Aquatic Studies 3(1) 196-198
[3] Jamaluddin J A F, Ahmad A T, Basir S, Rahim M A and Nor S A M 2010 Rastrelliger systematics inferred from mitochondrial cytochrome b sequences African Journal of Biotechnology 9(21) 3063-3067

[4] Sen S, Jahageerdar S, Jaiswar A K, Chakraborty S K, Sajina A M and Dash G R 2011 Stock structure analysis of Decapterus russelli (Ruppell, 1830) from east and west coast of India using truss network analysis Fisheries Research 112(1) 38-43

[5] Taqwin N A A, Munawaroh Q, Sari D M, Suryani E M, Rayahu D A, and Listyorini D 2014 Studi morfometrik dan meristik ikan melem biru (Osteochilus sp.) di aliran sungai Ketro, Ponorogo, Jawa Timur Proceeding Seminar Nasional Biodiversitas 5 494-503 [in Indonesian]

[6] Tzeng T D, Chiu C S and Yeh S Y 2001 Morphometric variation in red-spot prawn (Metapenaeopsis barbata) in different geographic waters off Taiwan Fisheries Research 53(3) 211-217

[7] Suryaningsih S, Sagi M, Kamiso H N and Hadisusanto S 2014 Sexing pada ikan brek Puntius orphoides (Valenciennes, 1863) menggunakan metode truss morfometrics Biosfera 31(1) 8-16 [in Indonesian]

[8] Strauss R E and Bookstein F L 1982 The truss: body form reconstructions in morphometrics Systematic Zoology 31(2) 113-135

[9] Sajina A M, Chakraborty S K, Jaiswar A K, Pazhayamadam D G and Sudheesan D 2011 Stock structure analysis of Indian Mackerel, Rastrelliger kanagurta (Cuvier, 1816) along the Indian Coast Asian Fisheries Science 24 331-342

[10] Effendie I 2002 Biologi Perikanan (Yogyakarta: Yayasan Pustaka). [in Indonesian]

[11] Lal K K, Gupta B K, Punia P, Mohindra V, Saini V P, Dhawed A K, Singh R K, Dhawan S, Luhrayia R K, Basheer V S and Jena K J 2015 Revision of gonius subgroup of the Genus Labo Cuvier, 1816 and confirmation of species status of Labo rajasthancus (Cyrpiniformes: Cyprinidae) with designation of a neotype Indian Journal Fish 62(4) 10-22

[12] Fanani AF, Novarino W and Tjong D H 2012 Variasi morfologi Arachnothera longirostra (Passeriformes, Nectariniidae) (Latham, 1790) Jurnal Biologi Universitas Andalas 1(1) 78-85 [in Indonesian]

[13] Bungas K 2014 Keragaman fenotip ikan betok (Anabas testudineus Bloch) di perairan Rawa gambit Jurnal Ilmu Hewan Tropika 3(1) 33-38 [in Indonesian]

[14] Nielsen F 2016 Introduction to HPC with MPI for Data Science (Palaiseau: Undergraduate Topics in Computer Science. Springer

[15] Suwarso, Ernawati T and Hariati T 2015 Biologi reproduksi dan dugaan pemijahan ikan kembung (Rastrelliger brachysoma) di pantai Utara Jawa Bawal 7(1) 9-16 [in Indonesian]

[16] Roonjha A A, Bano A, Siddique S and Rasheed S 2019 Morphometric characteristics of indian mackerel (Rastrelliger kanagurta) landing at three fish harbors of Baluchistan, Pakistan Pakistan Journal of Marine Sciences 28(1) 35-43

[17] Collette B B and Nauen C E 1983 FAO species catalogue vol. 2 Scombrids of the world FAO Fisheries Synopsis 125(2) 1-137

[18] Muhotimah, Triyatmo B, Priyono S B and Kuswoyo T 2013 Analisis morfometrik dan meristik nila (Oreochromis sp.) strain i5 dan tetuanya Jurnal Perikanan 15(1) 42-53 [in Indonesian]

[19] Hasibuan J S, Boer M and Ernawati Y 2018 Struktur populasi ikan kurau Polynemus dubius di teluk Pelabuhanratu Jurnal Ilmu dan Teknologi Kelautan Tropis 10(2) 441-453 [in Indonesian]

[20] Utami M N F, Redjeki S and Supriyantini E 2014 Komposisi isi lambung ikan kembung lelaki (Rastrelliger kanagurta) di Rembang Journal of Marine Research 2(3) 99-106 [in Indonesian]

[21] Arrafi M, Azmi A M, Piah R M and 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

[22] Fadhil R, Muchlisin Z A and Sari W 2016 Hubungan panjang-berat dan morfometrik ikan julung-julung (Zenarchopterus dispar) dari perairan pantai Utara Aceh Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah 1(1) 146-159 [in Indonesian]
Muchlisin Z A, Musman M and Azizah M N S 2010 Length-weight relationships and condition factors of two threatened fishes, Rasbora tawarensis and Poropuntius tawarensis, endemic to Lake Laut Tawar, Aceh Province, Indonesia Journal of Applied Ichthyology 26 949-953

Riyadi B A 2019 Analisis keragaman morfometrik ikan kembung (Rastrelliger kanagurta Cuvier, 1816) di perairan Utara Jawa sebagai dasar pengelolaan [undergraduate thesis] (Bogor: IPB University) [in Indonesian]

Hadie W, Sumantadinata K, Carman O and Hadie L E 2002 Pendugaan jarak genetik populasi udang galah (Macrobrachium rosenbergii) dari sungai Musi, sungai Kapuas, dan sungai Citanduy dengan truss morphometric untuk mendukung program pemuliaan Jurnal Penelitian Perikanan Indonesia 8(2) 1-7 [in Indonesian]

Poulet N, Reyjol Y, Collier H and Lek S 2005 Does fish scale morphology allow the identification of population at a local scale? A case study for rostrum dace Leuciscus leuciscus burdigalensis in River Viaur (SW France) Aquatic Sciences 67 122-127

Butet N A 2013 Plastisitas fenotip kerang darah Anadara granosa L. dalam merespon pencemaran lingkungan; studi kasus di perairan Pesisir Banten [dissertation] (Bogor: IPB University) [in Indonesian]

Sari M R 2004 Pendugaan potensi lestari dan pola musim penangkapan ikan kembung di perairan Lampung Timur [undergraduate thesis] (Bogor: IPB University) [in Indonesian]

Hakim A A, Kurniavandi D F, Mashar A, Butet N A, Zairion, Maduppa H and Wardiatno Y 2020 Study on stock structure of Indian mackerel (Rastrelliger kanagurta Cuvier, 1816) in fisheries management area 712 of Indonesia using morphological characters with truss network analysis approach IOP Conference Series: Earth and Environmental Science 414 1-9