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

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**Abstract.** The management of fish stocks is essential for the maintenance of a healthy and profitable fishery. One of important knowledge regarding the matter is the stock structure of the target fish, and fish morphology can be used to determine the stock structure. In fishery point of view, Indonesian waters are divided into 11 Fisheries Management Area. This study was aimed to reveal the stock structure of the Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) in Fisheries Management Area (FMA) 712. The fish collection was made in three different locations, i.e. Lancang Island, Cirebon, and Madura Island. Thirty-four morphological characters were measured to determine the stock structure with Truss Network Analysis (TNA). The results showed that both of conventional method and TNA revealed two stocks of Indian mackerel in the in FMA 712. The first stock was the fish population of Lancang Island and Cirebon, and the other was the population of Madura Island. The discriminant analysis also showed a similar result. For best future sustainable fishery management in Indonesian waters, more research on stock structure of any commercial fish in each fisheries management area of Indonesia is warranted.

**Keywords:** fishery management; fish stock; Java Sea; morphometric; TNA.

1. **Introduction**

Indonesian marine waters are divided into 11 Fisheries Management Area of Indonesia (WPP NRI) to achieve optimal fishery management. One region of them is the Fisheries Management Area 712 (FMA 712) which includes the Java Sea (KEPMEN-KP No. 18, 2014). The status of the ecosystem in
this region is categorized as poor based on several indicators, i.e. fish resources, habitat, socio-economic of fishers, etc. In FMA 712 the utilization rate for small pelagic fish is classified as fully-exploited (KEPMEN-KP No. 47, 2016) with a dominant commodity such as mackerel, horse mackerel, and sardinella [1].

Mackerel (*Rastrelliger* spp.) is one of the potential small pelagic fish and has important economic value in the local and regional market. In some fishery centre of Indonesia, mackerel became a large portion of the total catches [2]. It was also a commodity with highly favoured because of soft texture meat, high omega-3 content, affordable prices, and not causing allergies [3]. Mackerel was reported to have high protein (18.5%) and low fat (2.1%) [4].

There are three species of mackerel (*Rastrelliger* spp.) in the world, i.e. namely *R. branchysoma*, *R. kanagurta*, and *R. faugnhi* [5]. All species have different distribution area and morphological characteristics. *Rastrelliger kanagurta* can be found in the Indo Pacific West and the Mediterranean through the Suez Canal waters [6]. In fishery point of view, the species has a significant value for the tropical countries because it is considered as an inexpensive protein source [7]. Therefore, effective fisheries management in Indonesian waters, especially for the Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) is needed to implement for sustainable fisheries.

Effective fisheries management requires information on the stock structure of species, and each fish stocks should be managed separately [8]. However, the division of fisheries management area in Indonesia is still based on ecosystems conditions. These conditions led the assumption that the same species living in the same fisheries area is considered as one stock. Assuming one stock in huge marine area can be a problem because a species in the same area might have different population characteristics and is probably not from the same stock [9]. Thus, stock identification is an essential study as the basis for management, particularly for Indian mackerel. One approach to identify the stock is morphometric characters using truss network analysis [10]. This study was aimed to reveal the stock structure of the Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) in Fisheries Management Area 712 of Indonesia.

2. Methodology

2.1. Study site

This research was conducted from July until December 2018. Samples were collected in three locations situated in Fisheries Management Area 712 of Indonesia, i.e. Lancang Island, Cirebon, and Madura waters (Figure 1). Measurement of morphometric characters was conducted at the Laboratory of Aquatic Molecular Biology, Department of Aquatic Resources Management, IPB University.

Figure 1. Map of sampling location in three different locations at Fisheries Management Area 712.
2.2. Procedure
A total of 333 individuals were collected randomly from local fisher and was transported to the laboratory for morphometric measurements. The measurement was conducted by truss network analysis method following Sajina et al. [11] with 36 characters from 16 landmarks (Figure 2). The specimen was placed on the top of styrofoam with millimetre block, and the pin was put in every landmark points. Then, the specimen was photographed using a Canon EOS 1300D equipped with a tripod to produce the same condition of distance, magnification, and light settings for each specimen. The image was extracted to generate the morphometric data using a combination of two software, namely tpsDig2 and Paleontological Statistics (PAST).

![Figure 2](image)

**Figure 2.** Landmark points of morphometric measurement in Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) for truss network analysis. Sixteen landmarks were used to produce 34 characters.

2.3. Data analysis
Data were transformed to reduce influence age with divided each data by total length. Comparison of all morphometric characters in three different locations was made using the Kruskal-Wallis test at $p = 0.05$. Cluster and discriminant analysis was performed using all data measurements using a relevant program. Cluster analysis was used to determine the grouping of each population, and discriminant analysis was done to get distribution plots of Indian mackerel in three locations.

3. Results
3.1. Differences in morphometric characters
Some differences in morphometric characters of Indian mackerel among three locations were detected by the Kruskal-Wallis test. The results of the test obtained that thirty-two from thirty-four characters were significantly different in three locations. The two characters were considered not to influence the grouping populations, i.e. character 2-3 and 15-16.

3.2. Grouping population
The result of cluster analysis showed the kinship degree of between Indian mackerel from Madura, Cirebon, and Lancang Island. Cluster analysis of the morphometric characters indicated that Indian mackerel from the three locations are divided into two groups (Figure 3) with the distance of kinship presented in Table 1. The first group was Indian mackerel populations originating from Cirebon and Lancang Island, while the second group contained population originating from Madura.
Figure 3. The result of Cluster Analyses of Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) using a truss network analysis method in three locations.

Table 1. The distance of kinship of Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) by morphological characters.

| Location          | Madura | Cirebon | Lancang Island |
|-------------------|--------|---------|----------------|
| Madura            | 0.000  | 0.055   | 0.070          |
| Cirebon           | 0.055  | 0.000   | 0.038          |
| Lancang Island    | 0.070  | 0.038   | 0.000          |

The results of the discriminant analysis based on the distribution plot using truss network analysis methods showed that the population in three study locations were seemed not strongly separated (Figure 4). However, it could be seen that there was an allusion between three populations and indicated the similarity of samples based on morphometric characters. The allusion in three populations was identified by the value of the sharing component (Table 2).

Table 2. Value (%) of sharing component between three populations based on discriminant analysis.

| Location          | Madura | Cirebon | Lancang Island |
|-------------------|--------|---------|----------------|
| Madura            | 94.7   | 2.1     | 3.2            |
| Cirebon           | 1.9    | 90.6    | 7.5            |
| Lancang Island    | 4.1    | 4.9     | 91.0           |
4. Discussion

Differences of morphometric character supposedly because of the difference in environmental conditions. The responses of this condition were biochemical, physiological, genotype and phenotype. At the beginning of a change in environmental conditions, biochemical and physiological of animal reacted as the first responses to external changes. After passing through several periods and stages of environmental changes, phenotype character variations would perform [12].

Fish had very high phenotypic plasticity that could quickly change their morphological characters as a form of adaptation to environmental changes [13]. For example, in a study conducted by Suryana et al. [14] noted that the difference in the size of the tail fins was affected by the flow velocity. The high current required fish to adapt with more active against the current. In agreement with this, the difference in the size of the tail fin was also a distinctive character in the morphometric study of Indian mackerel. Additionally, Ruiyana et al. [15] also stated that the differences and changes in environmental conditions were very dynamic, especially in terms of competition, predation, and self-protection from fishing activities, forcing the fish to change the morphological character as adaptation measures.

Differences in fish morphology, according to Darlina et al. [16] were mainly caused by the ecological environment as food availability, the food chain, water temperature, current, and wave. The temperature in Madura waters had a range of 27.70-28.30°C [17], Cirebon waters had more than 29.00°C with a range of 29.00-30.00°C [18] and Lancang Island had temperature 29.40°C for Island [19]. From the same research, the salinity value in Madura waters ranged from 33.70 to 34.00 psu, while Cirebon and Lancang Island tent below 30.00 psu.

The population of Indian mackerel in Cirebon and Lancang Island had a closer kinship than the population in Madura waters. The closeness of kinship base on morphological characters can be caused by similar geographic locations or by the long adaptation to environmental conditions. According to Abinawanto et al. [20], the grouping of a population into a single cluster may be caused by geographical that might have a similar water quality. Azrita et al. [21] stated that the morphometric characteristics of forest snakehead (Channa lucius) in several close locations affiliated to a group. The environmental conditions were not much different and therefore caused connectivity in those locations.

The results of the discriminant analysis obtained the value of sharing component that showed a measurable mixing between populations based on morphological similarities. This value has explained some characters that were maintained and also discharged during a gene flow [22]. Nevertheless, this grouping was still limited to characters observed. Therefore, more characters were observed then more accurate the resulting grouping.

The allusion of the population from Cirebon and Lancang Island based on truss network analysis methods could be due to geographical proximity. According to Jayasangkar [23], Indian mackerel was categorized as migratory species, so it was possible to move from one place to another. The main reason to migrate was food (feeding), spawning, and some changes in environmental parameters (Nikolsky et al., 1963 in Indaryanto [24]). In addition, changes in oceanographic conditions such as water temperature, chlorophyll-a concentration, monsoon also affected the distribution and abundance of fish.

The decree by the Minister of Marine and Fisheries Number 79 (KEPMEN-KP 2016) concerning to the Fishery Management Plan in Fisheries Management Area 712 of Indonesia mentioned a priority group of fish species to be managed was small pelagic and demersal fish, including the mackerel (Rastrelliger spp.). Based on a morphometric study of Indian mackerel, it could be presumed that mackerel in FMA 712 population was divided into two groups. The result of the study was consistent with the finding by Indaryanto et al. [2] that the population structure of Indian mackerel in the Java Sea was separated into two groups. Two groups were the eastern part of Java Island (Bali Strait and surrounding areas), and the western part of Java Island (Palabuhanratu, Banten, Jakarta, and Lampung) populations.
The important thing before applied management based on this research, we needed an evaluation of the management of mackerel in FMA 712 as one group. The management should be based on the consideration that in this area, there was potential for more than one stock structure of Indian mackerel. In this regard, it was necessary to do genetic diversity analysis of mackerel with environment characteristics at the same location to ensure the potential of stock structure for more accurate information.

5. Conclusions
Indian mackerel (Rastrelliger kanagurta Cuvier, 1816) at FMA 712 from Lancang Island, Cirebon and Madura waters showed different morphometric characters and indicated potential to have two stock structures. The mackerel from Cirebon and Lancang Island has a close kinship, while mackerel from Madura water was separated.

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