Biologycal aspect of Indian Scad (Decapterus russelli) (Ruppell,1830) caughth in Bali and Madura Straits, and Southern waters of East Java, Indonesia

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Abstract. The way to determine whether the Indian scad (D. russelli) comes from the same stock or not, is using estimation morphology and biology. The kinship of D. russelli in the three waters is not too close, and it has a very distant kinship with D. macarellus and D. kurroides. D. russelli and D. macrosoma in Bali Strait and South Java is close. The results of the analysis show that two of five components of the characteristic morphometric factor of D. russelli in the three waters have a character differential percentage of 37.73% and similarity of 62.27%. The growth rate obtained (L∞) from Bali Strait is 26.16 cm FL, the growth rate coefficient (K) is 0.63 per year, and (t0) is -0.20 years length maturity (Lm) male 13.9 cm FL and female 16.1 FL. The type of foods that is found are 12 phylums. The growth rate obtained (L∞) from Southern Waters of East Java of 28.28 cm FL, the growth rate coefficient (K) is 0.83 per year, and (t0) is -0.18 year, length maturity (Lm) male 15.3 cm FL female 16.7 cm FL. Type of foods that is found are 6 phylums. The growth rate obtained in Madura strait has an asymptotic length (L∞) 24.63 cm FL ; K 0.63 per year and t0 -0.27 year. Indian scad is a carnivore with the main food is Zooplankton (61%). using the morphological and biological approach, it is found that the D. russelli caught in the three waters come from a different stock.

1. Introduction
One kind of small pelagic fish that has a significant economic value in East Java waters is scad (Decapterus spp.). This fish is mostly found in East Java waters and caught throughout the years. There are four species of the scads (Decapterus spp) in Indonesian waters, namely Decapterus russelli, Decapterus kurroides, Decapterus macarellus, and Decapterus macrosoma. [1][2]. Indian scad (Decapterus russelli) is mostly caught in Bali Madura Straits and Southern Waters of East Java. In international waters, Indian scad (D. russelli) lives in the east and west coasts of India [3][4]. In this waters, the fish is as important species used as foods and sometimes used as bait. This species has an essential link in the more massive predatory
food chain. Up to now, there is no report on the stock structure of Indian scad (D. russelli) along the Indian Waters [5].

Morphological knowledge which is based on a series of continuous measurements that explain variation in shape and size have been long used to restrict marine fish stocks. Explanation of their spatial distribution is significant in the management strategy for better exploitation of fisheries resources [6] [7] [8] [9]. Measuring fish morphometrics besides horizontally and vertically can also be done using the truss network system method. This method calculates the distance dots mark or called landmark or truss made in the framework of the fish's body. Meanwhile, a truss network system was built with the help of dots truss as a crucial tool to identify stocks of certain fish species. This is a more precise and effective strategy to describe a form, and the data is more accurate than traditional morphometric methods. This method can phenotypically discriminate stock through images of fish bodies formed from truss points [10]. [11]. Morphometrics method is generally used for statistical analysis of a large number of distances, angles or angular ratios.

Morphometric measurements and the number of meristic were considered as the most convenient and authentic method for the identification of specimens known as systemic morphology [12] [13]. Morphological knowledge has long been used to describe the spatial distribution, limit fish stocks in the sea, and it is essential for management information strategies to exploit fish resources [8] [9] [7]. Morphological and functional characteristics of fish can be used to calculate diversity index, the possibility to analyze the evolution of fish assemblies over time, analyze the structure of fish assemblies. These are the key factors that can be used to determine the ecological and biological habits of species in ecosystems. [14] [15] [16]. So that morphology can be used to observe fish species in several different locations. Morphological identification can also determine changes in morphological characters that occur in a group of fish species that migrate or immigrate to other regions. Morphology as a method for identifying fish by using features or characters in a fish's body. Wherein the character includes body, jaw and head shapes, tooth location, and fish body and fins colors.

2. Material and methods

Samples were collected from three areas, namely Bali and Madura Straits, and Southern Waters of East Java. Data collection were taken in three periods of time. They were July - August 2019, December 2019, and January - March 2020. Morphology was carried out by the identification of Indian scad (D. russelli). Hierarchical cluster analysis is an analytical method used to identify the morphological kinship of Indian Scad. The assessment was done using 18 morphological characters, namely body shape, eye size, jaw shape, presence or absence of teeth, number of upper limbs, number of lower limbs, number of dorsal fins, number of first dorsal spines, number of second dorsal spines, presence or absence of anal fins, number of anal fins, back color, belly color, tail fin color, dorsal fin color, anal fin color, abdominal fin color and the presence or absence of a black rash. The morphological analysis will produce dendrogram output. The kinship status can be determined with the following assumptions:

Distance 0–5 : Close kinship relationship.
Distance 5–10 : Not too close kinship relationship.
Distance 10-15 : Real kinship differences.
Distance 15–25 : Distant kinship differences.
2.1 Morphometric Character Analysis
According to [5] in his study titled Stock Structure Analysis of D. russelli (Rüppel, 1830) from East and West Coast of India Using Truss Network Analysis, the determination of landmarks in D. russelli samples consisted of 11 points and 23 landmarks. The type of analysis used is an analysis factor using the Principal Component Analysis (PCA) method. The PCA method was used as a display of relationships in groups of species divided by shape. There are 14 morphometric characters used (Figure 1), namely TL (Total Length): SL (Standard Length), FL (Forked Length): SL, PDL (Pre-Dorsal Length): SL, DFB 1 (1st Dorsal Fin Base): SL, IDL (Interdorsal Length): SL, DFB 2 (2nd Dorsal Fin Base): SL, UPCL (Upper Caudal Peduncle Length): SL, LPF (Length Pectoral Fin): SL, PVL (Pre-Pelvic Length): SL, PAL (Pre-Anal Length): SL, AFB (Anal Fin Base): SL, OL (Orbital Length): HL (Head Length), PrOL (Pre Orbital Length): HL, POL (Post Orbital Length): HL (Figure 1).

Figure 1. Morphometric identification of Indian scad (D. russelli) in East Java Waters.

2.2 Analysis of Length Weight Relationships
The mathematical equation describing the Length–Weight relationships (LWR) used is $W= a \times (TL)^b$, where $W$ is the total weight (g), TL is the total length (cm), and $a$ and $b$ are the regression coefficients [17]. Regression coefficients ($a$ and $b$) and $r^2$ (coefficient of determination) were estimated using the least-square fitting method applied to the logarithm-transformed length-weight relationships (LWR) $\log W = \log a + b \log TL$ [18]. To find out $b$ is allometric or isometric, there needs to be a student test or a $t$ test. With the following formula and hypothesis:

$$t_{count} = |(3-b) / (Sb)|$$

H0: Count> $T$ table; value of $b = 3$ (isometric).
H1: Table> $T_{count}$; value of $b \neq 3$ (allometric).

To find out the Indian Scad (D. russelli) in the waters of the Bali and Madura Straits and southern waters of East Java from one stock or different stock can be calculated using the following equation:

$$t_{count} = (b 1-b 2) / (\sqrt{(S ^ 2 joined (1 / n1 + 1 / n2)))}$$

Where:
H0: Indian Scad (D. russelli) in the waters of the Bali Strait, Madura Strait, Southern Waters of East Java come from one stock.
H1: Indian Scad (*D. russelli*) in the waters of the Bali Strait, Madura Strait, Southern Waters of East Java come from different stocks.

In the test of t distribution, if the value of \( t_{\text{count}} > t_{\text{tab}} \) then reject H0 accept H1, but if \( t_{\text{count}} < t_{\text{tab}} \) then accept H0 and reject H1.

2.3 Aspects of Fish Population Dynamics. Length at First Capture (Lc)

The value of Lc can be seen from the length frequency data which is the result of the calculation of the highest mode middle value of the frequency of the middle value class. Analysis of length frequency distribution was done using the normal distribution approach. The length at first capture (Lc) value can be calculated using the formula below: [19],

\[
\frac{1}{\sqrt{\pi}} \times \left( \frac{-(x - \bar{x})^2}{2\sigma^2} \right)
\]

Where \( Fc(x) \) is a normal distribution curve that has the following equation:

\[
Fc = \frac{n.dL}{s\sqrt{\pi}} \times \left( \frac{-(x - \bar{x})^2}{2\sigma^2} \right)
\]

Where:
- \( Fc \) = Calculated frequency
- \( N \) = Total of observations
- \( dL \) = Class interval
- \( s \) = Standard deviation
- \( \bar{x} \) = Average count
- \( \pi \) = 3.14

2.4 Length at First Mature (Lm)

Length at first mature (Lm) is used to estimate the length of the fish when the gonad is at first mature which can then be used to determine the age of the fish. The Lm formula is as follows ; [19]

\[
Q = Q_l \left( 1 - Q \right)
\]

Where:
- \( Q \) = The long class fraction that is mature gonads
- \( Q_l \) = The maximum value indicates 100% mature
- \( e \) = 2,718
- \( a \) = Konstanta
- \( L \) = Class length interval
- \( Lm \) = Fish length when 50% is mature

The equation is transformed into a linear form:

\[
\ln \left( Q \right) = -a \times L_{50} + a \times L
\]

Then, the length of the gonad ripe fish is calculated through:

\[
Lm = \frac{a}{b}
\]

Where:
- \( a \) = slope
- \( b \) = slope
Analysis of length estimation when the fish at first mature is used to find out at what length the fish begins to mature. It is assumed that the sample taken represents the existing population.

2.5 Growth Rate.
Estimation of growth rate value is done using the Von Bertalanffy formula through the FISAT-II application with Length Frequency Analysis (ELEFAN-II). [20] as follows:

\[ L_t = L_\infty (1 - e^{(K(t-t_0))}) \]

Where:
\( L_t \) = The length of fish at the age of \( t \) (mm)
\( L_\infty \) = Maximum fish length (mm)
\( K \) = Growth coefficient (t-1)
\( t_0 \) = Hypothetic fish age at zero length (year)

Determination of \( t_0 \) is performed using equation below [21]:

\[ \log(-t_0) = -0.3922 - 0.2752(\log L_\infty) - 1.038(\log K) \]

3. Results and Discussion

3.1 Morphological Character Analysis Results.
Based on 18 morphological characters used, the following result (Figure 2) illustrates that kinship of Indian scad (\( D. russelli \)) in three different regions of East Java Waters, Bali and Madura Straits, and Southern Waters of East Java is not too close kinship relationship because it has a distance of 7 units. Differences in morphological characters of Indian scad (\( D. russelli \)) of East Java Waters is found in the number of the upper limb and lower limb, the number of fingers of the second dorsal and anal.

![Figure 2. Dendrogram kinship of Indian Scad (D. russelli) in East Java Waters.](image)

3.2. Morphometry Character Analysis Results
A total of 14 morphometric character variables were used. After being analyzed using PCA, five factors were formed (PC1-PC5). Each component of the formed factor has an eigenvalue > 1 and a variant value. The highest variant value of the 5 PCAs is depicted in the principal component chart.

PC1 has a variant value of 16.883% with the most dominating character being TL_SL. Next, PC2 has a variant value of 14.877% with the dominating character of DFB2_SL. So that the cumulative variant value is 31.76%. Another result indicates that PC3 has a variant value of 10.830% with the dominating character of PrOL_HL. Hence the cumulative value is 42.59%. In comparison, PC4 has a variant value of 9.153%
with the dominating character of OL_HL so the cumulative value is 51.744%. Finally, PC5 has a variant value of 8.573% with the most dominating character being IDL_SL. Therefore the cumulative value changes to 60.497%.

From the elaboration of the five PCs, two PCs that have the highest variant values have a major effect on the morphometry of the Indian scad (D. russelli) in the waters of the Bali and Madura Straits, and Southern Waters of East Java, namely PC1 and PC2. So that it is obtained based on the morphometry of the Indian scad (D. russelli) in Bali Strait waters and Madura Strait waters has a character difference percentage value of 31.76% and a percentage of character equality of 68.24% (Figure 3). PC1 is the dominance of the TL_SL character and PC2 is the dominance of the DFB2_SL character.

Figure 3. Distribution of PC1 and PC2 Indian Scad.

3.3. Biological Analysis

Based on length frequency data, Indian scad (D. russelli) in the Madura Strait has the longest standard length (SL) with the middle value of 18:05 cm. It is followed by the second position by the fish in Southern waters with the middle value of 13.65 cm. In contrast, the fish in Bali Strait is the shortest with the middle value 10.80 cm. Results showed that two of five morphometry character component factors of D. russelli in three waters have a different character with percentage of 37.73% and similar percentage of 62.27%.

The length-weight relationship of the fish is isometric negative with equation W = 0.0193 FL^{2.817} in Madura Strait, positive isometric with equation W = 0.008775 FL^{3.190311} in Southern East Java Waters and positive isometric with equation W=0.0092 FL^{3.094} in Bali Strait.

In Southern Waters of East Java, Von Bertalanffy Growth Formula (VBGF) model is \( L_t/3920 = 28.28 \left\{ 1 - e^{-0.00(t - (-0.18))} \right\} \) and length at first maturity (L_m) male and female is 15.3 cm and 16.7 cm FL respectively. At the same time, types of foods found to consist of 6 phyllums. In Bali Strait, the VBGF model is \( L_t/3920 = 26.16 \left\{ 1 - e^{-0.63(t - (-0.20))} \right\} \) and value of Lm for male and female is 13.9 cm and 16.1 cm FL, respectively with types of foods found are 12 phyllums. In Madura strait, the fish has an asymptotic length (L_\infty) = 24.63 cm; K = 0.63/year and t_0 = -0.27 year. The fish is a carnivore with the main food of zooplankton (61%). It is also found that Indian scad (D. russelli) in these three waters is identified as different stock and mostly caught in an immature stage.
3.5 Discussion

There were morphological differences in the three sampling areas hence they were different stocks. Consequently sustainable management methods for them will be different. This is following FAO's definition of stock, namely "subsets of one species that have the same growth and mortality parameters, and which inhabit certain geographical areas" [1]. In terms of management, the stock is considered as a separate unit, and each stock can be exploited independently, knowing that stock can be used as a step, evaluation in management, or as a prerequisite in stock valuation. The young fish in the group are produced by the previous generations in the same group so the stock has different growth, maturity, homogenous death and a closed life cycle [22] [23] [24]. The stock structure information is essential to know as an aspect of stock assessment [25].

Based on the results of the study, the kinship of Indian scad (*D. russelli*) in three different regions of East Java Waters, Bali and Madura Straits, and Southern Waters of East Java was not too close kinship relationship. Differences in morphological characters of Indian scad (*D. russelli*) of East Java Waters was found in the number of the upper limb and lower limb, the number of fingers of the second dorsal and anal. Three sampling sites were far apart so that the displacement between the location was very difficult. Hence the fish caught in three regions are different stocks. This is following the research conducted by [26] toward four groups of Shemaya, *Alburnus chalcoides* (Guldenstadt, 1772). The differences in their habitats where they lived causes the reported difference in the stocks. This is consistent with what was reported by [27]. If there are different phenotypes on the stock, the movement between populations is minimal. However, the difference between stocks with low phenotypes will lead to the movement and mixing of the stock or population. A genetic examination is needed to prove whether the three samplings locations are different or not. Besides that, the morphological differences between populations are quite tricky to explain [28]. But keep in mind that morphometric characters can show a high level of plasticity in response to environmental conditions [29]. Besides differences in habitat such as temperature, turbidity of the water depth, water flow and availability of food can lead to differences in morphologies [30] [31] [29]. The morphometric discrepancies explain how the geographic and filo-geography make variations of the stock. [32]

The result of several pieces of research on the growth of Indian scad (*D. Russelli*) is illustrated in Table 1. There were differences in the forms of growth in each study area. This difference can be caused by the size of the fish which changes from time to time depending on the availability of food in the fishing grounds. It was probably also affected by fluctuations in environmental characteristics such as temperature and chlorophyll. Therefore several factors that influence fish growth are (1) intrinsic: fish species and race, fish size, swimming activity, maturity, age, and (2.) extrinsic: both biotic and abiotic such as chlorophyll, temperature, salinity, light, water depth, and season.
Table 1. Population parameters of *D. russelli* reported from different waters.

| Author(s) | Study area | $L_{mg}$ (cm) | $L_{ma}$ (cm) | $K$ (year$^{-1}$) | $T_x$ (year) | $L_c$ | $Z$ | $X$ | $M$ | $F$ | $E$ | $U$ |
|-----------|------------|---------------|---------------|------------------|-------------|------|-----|-----|-----|-----|-----|-----|
| (Marine, 1985) | Calkuda | 23.23 | 1.08 | -0.08 | 6.65 | 1.90 | 4.75 |
| (Kolev & Pak, 2015) | | 22.55 | 0.75 | 0.67 | 2.84 | 1.62 | 2.42 | 0.63 | - |
| (Panda et al., 2012) | Mumbai | 23.6 | 0.95 | -0.36 | - | 4.64 | 1.41 | 2.8 | 0.61 | - |
| (Pandol et al., 2019) | Kanyakumari | 23.5 | 0.58 | -0.29 | 13.8 | - | - | - | - | - |
| (Pandol & Narayanan, 2006) | West Bengal | 23.6 | 0.6 | -0.27 | - | 6.66 | 2.1 | 4.56 | - | - |
| (Marine, 1985) | Calkuda | 21.7 | 22.20 | 1.08 | -0.08 | 13.8 | 6.65 | 1.90 | 4.75 | 0.71 | 0.70 |
| (Balu & Narayanan, 2005) | Vizhinjam | 28.00 | 0.80 | -0.04 | - | - | - | - | - | - |
| (Jain et al., 2001) | Mumbai | 22.56 | 24.00 | 1.42 | - | 7.75 | 2.65 | 5.10 | 0.66 | 0.65 |
| (Gibbs & Street, 2005) | Karnataka | 23.20 | 0.76 | -0.162 | - | - | - | - | - | - |
| (Shanmugam, 2007) | Malabar | 27.10 | 1.22 | - | 14.50 | 3.79 | 2.08 | 1.71 | 0.49 | 0.44 |

It was found that the stomach content of Indian scad (*D. russelli*) consisted of arthropod phylum, cnidaria, ophiophyta, ciliophora, echinoderm, mollusca, small fish, larvae, and eggs. The results of the Index of Preponderance analysis indicated that main foods (IP > 25%) were mostly arthropod phylum. At the same time, supplementary foods (IP 4-25%) consisted of phyla of Ochrophyta, Ciliopora, and Cyanobacteria, and small fish. Also, complementary foods (IP <4%) were identified as phylum Cnidaria, Myzozoa, Bacillariophyta, Mollusca, Larva, Chlorophyta, and Echinoderms. Based on the type of food preferences, it can be assumed that Indian scad (*D. russelli*) is a carnivore fish because beside small fish and molluscs, the food is dominated by zooplankton with the proportion of 61% and 39% phytoplankton. [4] stated that Indian scad (*D. russelli*) in Malabar waters belongs to carnivorous fish because crustaceans dominate the contents of the stomach. [33], also found that the dominant food of Indian scad (*D. russelli*) is crustaceans and fish. Other types of crustaceans, such as shrimp and crabs, cephalopods, and plankton are found in small amounts.

4. Conclusion

Kinship of the Indian scad (*D. russelli*) in three different waters of East Java, the Bali and Madura Straits, and Southern Waters was not too close relationship. The fish in Bali Strait waters and Madura Strait waters have a character difference percentage value of 31.76% and a percentage of character equality of 68.24%. These percentages show that the fish in these waters have many characteristic similarities. The fish in Bali Strait waters have positive allometric growth. In contrast, the Madura Strait has negative allometric growth. Based on the T test, the Indian scad (*D. russelli*) in the waters of the Bali Strait and Madura Strait come from different stocks.

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References

[1] FAO, *FAO Species Identification Guide for Fishery Purposes*, vol. 1. 2001.
[2] B. Atmaja, S. K. Chaikraborty, and R. P. Swamy, “Study On The Reproduction Of ‘Layang Deles’ Shortfin Scad (*Decapterus macnosa*) in the Java Sea,” no. 1926, 2005.
[3] A. K. Jaiswar, S. K. Chaikraborty, and R. P. Swamy, “Studies on the age, growth and mortality rates of Indian scad *Decapterus russelli* ( Ruppell ) from Mumbai waters,” vol. 53, 2001.
[4] P. P. Manojkumar, “Food and feeding habits of *Decapterus russelli* ( Ruppell , 1830 ) along the Malabar coast,” vol. 54, no. 4, pp. 427–431, 2007.
[5] S. Sen, S. Jahageerdar, A. K. Jaiswar, S. K. Chakraborty, A. M. Sajina, and G. R. Dash, “Stock structure analysis of *Decapterus russelli* ( Ruppell , 1830 ) from east and west coast of In,” *Fish. Res.*, vol. 112, no. 1–2, pp. 38–43, 2011, doi: 10.1016/j.fishres.2011.08.008.
[6] C. Turan, “A note on the examination of morphometric differentiation among fish populations: The Truss System,” *Turkish J. Zool.*, vol. 23, no. 3, pp. 259–263, 1999.
[7] K. M. Bailey, “Structural dynamics and ecology of flatfish populations,” *J. Sea Res.*, vol. 37, no. 3–4, pp. 269–280, 1997, doi: 10.1016/S1385-1101(97)00018-X.
[8] P. E. Ihssen, H. E. Booke, J. M. Casselman, J. M. McGlade, N. R. Payne, and F. M. Utter, “Stock Identification: Materials and Methods,” *Can. J. Fish. Aquat. Sci.*, vol. 38, no. 12, pp. 1838–1855, 1981, doi: 10.1139/f81-230.
[9] J. Palma and J. P. Andrade, “Morphological study of *Diplodus sargus*, *Diplodus puntazzo*, and *Lithognathus mormyrus* (Sparidae) in the Eastern Atlantic and Mediterranean Sea,” *Fish. Res.*, vol. 57, no. 1, pp. 1–8, 2002, doi: 10.1016/S0165-7836(01)00335-6.
[10] M. To and A. Ci, “Advanced Techniques for Morphometric Analysis in Fish,” vol. 6, no. 8, pp. 6–11, 2015, doi: 10.4172/2155-9546.1000354.
[11] M. Kerschbaumer and C. Sturmbauer, “The Utility of Geometric Morphometrics to Elucidate Pathways of Cichlid Fish Evolution,” vol. 2011, 2011, doi: 10.4061/2011/290245.
[12] C. Turan, M. Oral, B. Öztürk, and E. Düzgüneş, “Morphometric and meristic variation between stocks of Bluefish (*Pomatomus saltatrix*) in the Black, Marmara, Aegean and northeastern Mediterranean Seas,” *Fish. Res.*, vol. 79, no. 1–2, pp. 139–147, 2006, doi: 10.1016/j.fishres.2006.01.015.
[13] S. Langer, Tripathi N K, and Khajuria B, “Morphometric and Meristic Study of Golden Mahseer (*Tor putitora*) from Jhajjar Stream (JandK), India,” *Res. J. Anim. Res. J. Anim.*, vol. 1, no. 7, pp. 1–4, 2013.
[14] M. Farré, V. M. Tuset, F. Maynou, L. Recasens, and A. Lombarte, “Geometric morphology as an alternative for measuring the diversity of fish assemblages,” *Ecol. Indic.*, vol. 29, pp. 159–166, 2013, doi: 10.1016/j.ecolind.2012.12.005.
[15] M. Farré, A. Lombarte, L. Recasens, F. Maynou, and V. M. Tuset, “Habitat influence in the morphological diversity of coastal fish assemblages,” *J. Sea Res.*, vol. 99, pp. 107–117, 2015, doi: 10.1016/j.seares.2015.03.002.
[16] M. Farré, V. M. Tuset, J. E. Cartes, E. Massuti, and A. Lombarte, “Depth-related trends in morphological and functional diversity of demersal fish assemblages in the western Mediterranean Sea,” *Prog. Oceanogr.*, vol. 147, pp. 22–37, 2016, doi: 10.1016/j.pocean.2016.07.006.
[17] R. Froese, “Cube law, condition factor and weight-length relationships: History, meta-analysis and
recommendations,” *J. Appl. Ichthyol.*, vol. 22, no. 4, pp. 241–253, 2006, doi: 10.1111/j.1439-0426.2006.00805.x.

[18] L. M. B. Garcia, “Species composition and length-weight relationship of fishes in the Candaba wetland on Luzon Island, Philippines,” *J. Appl. Ichthyol.*, vol. 26, no. 6, pp. 946–948, 2010, doi: 10.1111/j.1439-0426.2010.01516.x.

[19] dan S. C. V. Sparre, P., “Sparre & Venema.” p. 434, 1999.

[20] P. Goyalino, F, P. Sparre, and D. Pauly, *FAO-ICLARM stock assessment tools II: User’s guide*. Food & Agriculture Org., 2005.

[21] D. Pauly, “On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks,” *ICES J. Mar. Sci.*, vol. 39, no. 2, pp. 175–192, 1980, doi: 10.1093/icesjms/39.2.175.

[22] S. X. Cadrin and K. D. Friedland, “The utility of image processing techniques for morphometric analysis and stock identification,” *Fish. Res.*, vol. 43, no. 1–3, pp. 129–139, 1999, doi: 10.1016/S0165-7836(99)00070-3.

[23] S. X. Cadrin, “Advances in morphometric identification of fishery stocks,” *Rev. Fish Biol. Fish.*, vol. 10, no. 1, pp. 91–112, 2000, doi: 10.1023/A:1008939104413.

[24] S. X. Cadrin, L. A. Kerr, and S. Mariani, *Interdisciplinary Evaluation of Spatial Population Structure for Definition of Fishery Management Units*, Second Edi. Elsevier, 2013.

[25] S. X. Cadrin, “Defining spatial structure for fishery stock assessment,” *Fish. Res.*, vol. 221, no. May 2019, p. 105397, 2020, doi: 10.1016/j.fishres.2019.105397.

[26] M. Mohaddasi, N. Shabanipour, and S. Abdolmaleki, “Morphometric variation among four populations of Shemaya (Alburnus chalcoides) in the south of Caspian Sea using truss network,” *J. Basic Appl. Zool.*, vol. 66, no. 2, pp. 87–92, 2013, doi: 10.1016/j.jobaz.2013.09.001.

[27] K. Miyan, M. A. Khan, D. K. Patel, S. Khan, and N. G. Ansari, “Truss morphometry and otolith microchemistry reveal stock discrimination in Clarias batrachus (Linnaeus, 1758) inhabiting the Gangetic river system,” *Fish. Res.*, vol. 173, pp. 294–302, 2016, doi: 10.1016/j.fishres.2015.10.024.

[28] N. Poulet, P. Berrebi, A. J. Crivelli, S. Lek, and C. Argillier, “Genetic and morphometric variations in the pikeperch (Sander lucioperca L.) of a fragmented delta,” *Arch. fur Hydrobiol.*, vol. 159, no. 4, pp. 531–554, 2004, doi: 10.1127/0003-9136/2004/0159-0531.

[29] P. H. Wimberger, “Plasticity of fish body shape. The effects of diet, development, family and age in two species of Geophagus (Pisces: Cichlidae),” *Biol. J. Linn. Soc.*, vol. 45, no. 3, pp. 197–218, 1992, doi: 10.1111/j.1095-8312.1992.tb00640.x.

[30] F. W. Allendorf, “Conservation Biology of Fishes,” *Conserv. Biol.*, vol. 2, pp. 145–148, 1988.

[31] D. P. Swain and C. J. Foote, “Stocks and chameleons: The use of phenotypic variation in stock identification,” *Fish. Res.*, vol. 43, no. 1–3, pp. 113–128, 1999, doi: 10.1016/S0165-7836(99)00069-7.

[32] P. C. Chen, T. Der Tzeng, C. H. Shih, T. J. Chu, and Y. C. Lee, “Morphometric variation of the oriental river prawn (Macrobrachium nipponense) in Taiwan,” *Linnologica*, vol. 52, pp. 51–58, 2015, doi: 10.1016/j.limno.2015.03.002.

[33] N. Poojary, L. R. Tiwari, and A. K. Jaiswar, “Food and feeding habits of the Indian scad, Decapterus russelli (Ruppell, 1830) from Mumbai waters, north-west coast of India,” *Indian J. Fish.*, vol. 57, no. 4, pp. 93–99, 2010.