Morphometric variations of tropical eel *Anguilla bicolor* (McClelland, 1844) harvested from different locations within Aceh waters, Indonesia

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Abstract. *Anguilla bicolor* is a commercial and predominant species within the eels group in Aceh waters. The objective of the present study was to analyze the morphometric variation of the *A. bicolor* collected from three different locations in Aceh waters, Indonesia. A total of 18 individuals of fish samples (6 individuals from every location) were measured for traditional-truss network morphometric characters. The univariate (ANOVA) analysis showed that the morphometric of the three eel populations were not significantly different (P > 0.05). Multivariate (Discriminant function analysis, DFA) analysis was successfully grouping three eel populations into three groups, where *A. bicolor* SKL and *A. bicolor* TB were more similar than *A. bicolor* KJU populations.

1. Introduction

Eels (*Anguilla* spp.) is one of the commercial groups of fish that has the potency to export, especially to Japan, China, Germany, Italy, and others [1]. According to Affandi et al. [2], Japan is the largest consumer of eel in the world, eel consumption in Japan reached 136,955 metric tons in 1999 and increases to 300,000 tons in 2014 [3]. Besides, China requires a supply of eel reaching 70,000 tons per year, but this production is only able to meet less than 30% of its total needs [3].

According to Muchlisin and Siti-Azizah [4] and Muchlisin et al. [5] recorded three species of eel occurs in Aceh waters, namely *Anguilla bicolor*, *A. marmorata* and *A. bangelensis*, where the first is predominant. According to The IUCN Red List of Threatened Species, *A. bicolor* are categorized as near threatened, while *A. marmorata* is the least concern (needs special attention).

According to Miller and Tsukamoto [6] that there are 19 species of eels in the world, where several species, for instance, *A. Anguilla*, *A. japonica*, *A. rostrata*, and *A. dieffenbachii* are threatened with extinction due to overfishing and habitat perturbation.

Several reports on eel in Indonesian waters have been published, including the distribution of two tropical short-finned eels (*A. bicolor bicolor* and *A. bicolor pacifica*) in Indonesian waters [7], metamorphosis and migration of tropical eel *Anguilla* spp. in the Indo-Pacific [8], the nutritional value and fatty acids of Indonesian eel (*A. bicolor*) [3], the fish culture of eel with a circulating water system [2] and the identification of two short-finned eels in Sukabumi, West Java [9], glass eel migration, genetic variations [5], feeding experiment [11,12], parasite infection [13] and the bio-ecology [14-16], while research on morphometrics has never been done. Therefore, the objective of the present study was to examine the morphological variations of *A. bicolor* collected from three different locations within Aceh waters.
Aceh Province, Indonesian. This information is important to plan a better conservation strategy of the eel in Aceh waters in the future.

2. Material and Methods

2.1. Time and site
Surveys and data collection were conducted from September-November 2016. Eel samples were collected from three different locations, namely; Tibang waters, Banda Aceh City (GPS coordinate: 5°35'34.80"N, 95°20'31.65"E); Kajhu waters, Aceh Besar District (GPS coordinate: 5°36'4.46"N, 95°23'3.46"E); Singkil waters, Aceh Singkil District (GPS coordinate: 2°16'32.55"N, 97°50'39.47"E). Sample from Tibang was labeled as *A. bicolor* TB, *A. bicolor* KJU from Kajhu, *A. bicolor* SKL from Singkil.

2.2. Sampling procedure
The eel was collected using a trap and hand-line, then placed on the waters (rivers and ponds) from 6 PM to 6 AM. The soil worms, chicken intestines, and fish were used as the bait.

The sample of eels was measured in length (total length (PT) and standard length (PS) using digital calipers (Mitutoyo, CD-6CS. Error = 0.01 mm), and weight also be measured using a digital scale (Toledo, AB-204. Error level = 0.01 g). Measurement of morphometric characters will be conducted in the laboratory after the sample is preserved using 10% formalin solution.

2.3. Morphometric measurements

2.3.1. Traditional morphometric
Traditional morphometric measurements refer to Hwang et al. [17] (Figure 1). The measurement method is as follows:

![Figure 1. Measurement technique of traditional morphometric](image)

| No. | Code | Characters | Information |
|-----|------|------------|-------------|
| 1   | TL   | Total length | The distance from the left foremost tip of the snout to the posterior edge of the forked portion of the caudal fin. |
| 2   | SL   | Standard length | The distance from the left foremost tip of snout to the end of the caudal peduncle. |
| 3   | HL   | Head length | The distance from the tip of the snout to the posterior edge of the operculum. |
| 4   | HD   | Head Depth | The distance from top to bottom of the head. |
| 5   | Pree-D | Pre-dorsal fin length | The distance from the tip of the snout to the origin of the dorsal fin. |
| 6   | Pree-A | Pre-anal fin length | The distance from the tip of the snout to the origin of the anal fin. |
| 7   | ED   | Eye diameter | The distance between the anterior and posterior edge of the eyeball. |
| 8   | AD   | distance between verticals from the origin of the dorsal fin to the anus | The distance from the origin of the dorsal fin to the origin of the anal fin. |
2.3.2. Truss morphometric

The truss network morphometric was employed in this study. This technique is used to measure the fish’s body by connecting predetermined diagonal points (homolog points), both horizontally and vertically [18]. The measured morphometric character aims to analyze the extent of the closeness or similarity of the morphological among the samples from different locations or populations [19] (Figure 2).

Figure 2. Measurement technique of truss morphometric

### Table 2. Truss morphometric measurement in this study

| No | Code | Homolog point | Information |
|----|------|---------------|-------------|
| 1  | A    | 1-2           | The distance from the tip of the head to the curve of the top of the head. |
| 2  | B    | 2-3           | The distance from the curve of the top of the head to the beginning of the dorsal fin. |
| 3  | C    | 3-4           | The distance from the start of the dorsal fin to the curve of the upper caudal shaft. |
| 4  | D    | 4-5           | The distance from the curve of the upper tail stem to the tip of the tail. |
| 5  | E    | 5-6           | The distance from the tip of the tail stem to the indentation of the lower tail stem. |
| 6  | F    | 6-7           | The distance from the curve of the lower caudal shaft to the beginning of the anal fin. |
| 7  | G    | 7-8           | The distance from the start of the anal fin to the crease of the gills. |
| 8  | H    | 8-1           | The distance from the fold of the gills to the tip of the head. |
| 9  | i    | 2-8           | The distance from the curve of the top of the head to the crease of the gills. |
| 10 | j    | 2-7           | The distance from the curve of the top of the head to the beginning of the anal fin. |
| 11 | k    | 3-8           | The distance from the start of the dorsal fin to the crease of the gills. |
| 12 | l    | 3-7           | The distance from the start of the dorsal fin to the beginning of the anal fin. |
| 13 | m    | 4-7           | The distance from the curve of the upper caudal shaft to the beginning of the anal fin. |
| 14 | n    | 4-6           | The distance measured from the curve of the upper tail stem to the indentation of the lower tail stem. |

2.4. Data analysis

The morphometric data are then transformed using Microsoft Excel with the formula proposed by Schindler and Schmidt [20] as follows:

\[ M_{\text{trans}} = \frac{M \times 100}{\text{TL}} \]

Note: \( M_{\text{trans}} = \) data transformation, \( M = \) measurement data, \( \text{TL} = \) total length.

The transformed data were analyzed using SPSS version 22.0 and PAST (Paleontological Statistics) version 4.03 software. Then the univariate (ANOVA) and multivariate (discriminant function analysis) tests were carried out. The results are described in tabulations and scatter plots.
3.3. Results and Discussions

3.1. Univariate analysis of traditional-truss morphometric

The ANOVA test showed that sampling location as representative of the population did not give a significant effect on traditional and truss morphometric character variation (P>0.05). Therefore, the Duncan multi-range test showed that the morphometric characters both traditional and truss of the three eels were not significantly different (P > 0.05) among the population (Table 3 and 4). It means that the traditional morphometric characters of *A. bicolor* from Singkil, Kajhu Aceh Besar, and Tibang Banda Aceh are identical. But, only one truss morphometric character was significantly different (P < 0.05) between *A. bicolor* from Singkil and *A. bicolor* from Kajhu populations, namely D character (the distance from the curve of the upper tail stem to the tip of the tail).

### Table 3. The mean transformed values of traditional morphometric characters according to three eel populations. The values in the same row followed by different superscripts are significantly different (P<0.05).

| Characters (code)                          | Presumed Taxa |          |          |          |
|--------------------------------------------|---------------|----------|----------|----------|
|                                            | *A. bicolor* SKL (n=6) | *A. bicolor* TB (n=6) | *A. bicolor* KJU (n=6) |
| Standard length (SL)                       | 97.71±0.22 a   | 97.90±0.25 a   | 97.95±0.14 a   |
| Head length (HL)                           | 13.02±0.56 a   | 12.53±0.58 a   | 13.72±0.23 a   |
| Head depth (HD)                            | 4.56±0.23 a    | 4.76±0.32 a    | 4.90±0.27 a    |
| Pre-dorsal fin length (Pree-D)             | 39.16±0.64 a   | 40.26±1.01 a   | 40.45±0.46 a   |
| Pre-anal fin length (Pree-A)               | 42.52±0.82 a   | 42.21±1.28 a   | 42.84±0.44 a   |
| Eye diameter (ED)                          | 1.38±0.21 a    | 1.29±0.09 a    | 1.48±0.17 a    |
| distance between verticals from the origin of the dorsal fin to the anus (AD) | 2.83±0.20 a | 2.50±0.28 a | 2.15±0.14 a |
| Pectoral fin length (PFL)                  | 3.88±0.51 a    | 3.22±0.29 a    | 4.10±0.52 a    |
| Mouth length (ML)                          | 3.95±0.23 a    | 3.97±0.23 a    | 4.31±0.16 a    |
| Snout length (SnL)                         | 1.97±0.11 a    | 2.07±0.13 a    | 2.18±0.08 a    |
| Dorsal fin base length (DFBL)              | 60.90±0.83 a   | 59.25±1.74 a   | 59.82±2.84 a   |
| Anal fin base length (AFBL)                | 56.31±1.38 a   | 57.68±0.72 a   | 57.33±0.46 a   |

### Table 4. The mean transformed values of truss morphometric characters according to three eel populations. The values in the same row followed by different superscripts are significantly different (P<0.05).

| No. | Characters (code) | Presumed Taxa |          |          |          |
|-----|------------------|---------------|----------|----------|----------|
|     |                  | *A. bicolor* SKL (n=6) | *A. bicolor* TB (n=6) | *A. bicolor* KJU (n=6) |
| 1.  | A                | 12.87±0.51 a  | 12.94±0.52 a | 12.56±0.31 a |
| 2.  | B                | 25.23±0.79 a  | 25.72±0.81 a | 24.42±2.09 a |
| 3.  | C                | 50.82±0.99 a  | 52.68±0.58 a | 52.80±0.86 a |
| 4.  | D                | 9.13±0.89 a   | 8.04±0.94 ab | 6.02±0.64 a  |
| 5.  | E                | 12.15±1.03 a  | 10.70±1.10 a | 9.10±0.96 a  |
| 6.  | F                | 46.37±2.02 a  | 47.49±2.16 a | 35.89±4.97 a |
| 7.  | G                | 30.95±0.91 a  | 31.44±1.20 a | 28.21±2.29 a |
| 8.  | H                | 10.61±0.56 a  | 11.45±0.69 a | 11.45±0.92 a |
| 9.  | I                | 4.52±0.21 a   | 4.89±0.41 a  | 5.22±0.40 a  |
| 10. | J                | 23.68±4.45 a  | 28.18±1.88 a | 27.26±1.67 a |
| 11. | K                | 26.04±0.54 a  | 25.97±0.48 a | 26.77±0.44 a |
| 12. | L                | 5.65±0.48 a   | 5.56±0.55 a  | 5.92±0.40 a  |
| 13. | M                | 46.22±1.09 a  | 46.33±1.45 a | 50.18±1.01 a |
| 14. | N                | 4.13±0.24 a   | 3.98±0.16 a  | 3.82±0.41 a  |
Figure 3. Scatter plot (a) traditional and (b) truss morphometric characters of three populations of *A. bicolor*, where (1) *A. bicolor* SKL, (2) *A. bicolor* KJU, and (3) *A. bicolor* TB

Table 5. Eigenvalues, % variance, and matrix structure of traditional and truss morphometric characters. The star indicates higher loading.

| Character                                      | Traditional Morphometric | Truss Morphometric |
|------------------------------------------------|--------------------------|--------------------|
|                                                | Function 1 | 2 | Function 1 | 2 |
| % Variance                                     | 96.37       | 3.625 | 94.11       | 5.89 |
| Snout length (SnL)                             | 10.611*     | 1.297 | A           | 49.217* | 28.736 |
| Head length (HL)                               | 6.306*      | 0.922 | D           | 35.589* | -22.297 |
| Standard length (SL)                           | 4.186*      | 0.510 | N           | -25.096* | 0.326 |
| Pre-dorsal fin length (Pree-D)                 | -3.630*     | -0.436 | L           | 24.704 | 28.327* |
| Anal fin base length (AFBL)                    | 2.896*      | -0.104 | C           | 24.079 | 26.073* |
| Head depth (HD)                                | 2.037*      | -0.522 | E           | -16.996 | 21.104* |
| Eye diameter (ED)                              | 1.804*      | 0.999 | K           | 0.854* | 0.726 |
| distance between verticals from the origin of the dorsal fin to the anus (AD) | -1.772* | 0.951 | G           | -0.785* | -0.443 |
| Mouth length (ML)                              | 1.371       | -1.491* | M           | -0.755 | -0.770* |
| Pectoral fin length (PFL)                      | 1.209*      | 0.784 | H           | -0.708* | -0.411 |
| Pre-anal fin length (Pree-A)                   | 0.306*      | 0.129 | F           | 0.435* | 0.052 |
| Dorsal fin-base length (DFBL)                  | 0.075*      | -0.001 | B           | 0.356* | 0.203 |
|                                                | I           | 0.062 | -20.431* |
|                                                | J           | -0.030* | 0.010 |

3.2. Multivariate analysis of traditional-truss morphometric

The discriminant function analysis (DFA) of traditional and truss morphometric produces two functions. The first function of traditional morphometric has an eigenvalues value of 24.602 with a percentage variance value of 96.37%, while the second function has an eigenvalues value of 0.925 with a percentage variance value of 3.625% (Table 5). The eigenvalue of the second function is less than 1, where the contribution of morphometric characters to this function can be neglected. The first function of truss morphometric has an eigenvalues value of 27.391 with a percentage variance value of 94.11%, while the second function has an eigenvalues value of 1.715 with a percentage variance value of 5.89% (Table 5).

The traditional morphometric characters that contribute to the second function are only one character, namely ML (the distance from the tip of the to the last of the lip), while the other morphometric characters contribute to the first function. A total of nine truss morphometric characters that contribute
to the first function, namely; A (the distance measured from the tip of the head to the curve of the top of the head), B (the distance from the curve of the top of the head to the beginning of the dorsal fin), D (the distance from the curve of the upper tail stem to the tip of the tail), F (the distance from the curve of the lower caudal shaft to the beginning of the anal fin), G (the distance from the start of the anal fin to the crease of the gills), H (the distance from the fold of the gills to the tip of the head), J (the distance from the curve of the top of the head to the beginning of the anal fin), K (the distance from the start of the dorsal fin to the crease of the gills) and N (the distance from the curve of the upper tail stem to the indentation of the lower tail stem), while the other morphometric characters contribute to the second function.

The scatter plot of traditional and truss morphometrics was successfully grouping the three fish populations into three groups based on each eel population (Figure 3), where the Singkil population closely to Tibang population, and the Kajhu population was distinguished separately. Therefore, the results of the DFA analysis confirmed that the A. bicolor SKL and A. bicolor TB were more similar than A. bicolor KJU populations. These results confirmed that truss morphometric analysis is more reliable and sensitive compared to traditional morphometric analysis. Similar result was also reported by Muchlisin et al. [21, 22] in the Rasbora group at the Lake Kaut Tawar, Aceh Province, Indonesia.

An intra-species variation on the morphology of fish species can be influenced by environments condition and populations, as detected in naleh fish (Barbonymus sp.) [23] and mullets [24]. Similar findings were also found in several species such as morphometric variations in two populations of Sander lucioperca at fragmented areas, Rhone River, France [25], morphometric variation among Sardina pilchardus populations from the Northeastern Atlantic and the Western Mediterranean [26], and morphometric variation between Pomatomus saltatrix in the Black, Marmara, Aegean, and Northeastern Mediterranean Seas [27].

4. Conclusion
The morphometric of the three populations of eel in Aceh waters are highly similar or identical, however, A. bicolor SKL and A. bicolor TB has closely related to A. bicolor KJU populations.

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