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Morphological Differences between *Chaetodon auriga* and *Chaetodon vagabundus* based on Truss Morphometric Characters

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Abstract. *Chaetodon auriga* and *Chaetodon vagabundus* are popular marine aquaria fish from Cahetodontidae family. Both species show subtle morphological variations, especially in juvenile stages, which might lead to misidentification. Additional morphological characteristics, such as truss morphometric, are valuable characters for species identification in Chaetodontidae. This study aimed to evaluate morphological differences between *Chaetodon auriga* and *C. vagabundus* based on truss morphometric characters. The study is expected to provide new morphometric characters for *Chaetodon auriga* and *C. vagabundus* differentiation on the southern coast of West Java, Indonesia. Fish samples were collected from Ujunggenteng and Taman Manalusu Beach. The specimens were identified based on morphological characteristics and referred to the characters available in the literature. Truss morphometric characters were measured using callipers with an accuracy of 0.01mm and convert to ratio values to obtain constant value. The data were analyzed statistically using the Mann-Whitney test in SPSS software packages. The result showed that five truss morphometric characters were significantly different between *C. auriga* and *C.vagabundus*. This study concluded that *C. auriga* and *C. vagabundus* could be differentiated using truss morphometric character. This study provides five new morphometric characters for species differentiation in fish species, especially between *C. auriga* and *C. vagabundus*.

Key words: Chaetodon, meristic, morphology, truss morphometric

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INTRODUCTION

Indonesia’s marine waters reside between the Indian and Pacific Oceans. This strategic geographical position and high diversity of coral ecosystems lead Indonesia's waters to host various fish fauna, including marine ornamental fish (Wahyudin, 2011). According to Kusrini (2010), approximately 650 marine ornamental fish live in Indonesia marine waters, and 480 species has been identified.

Ornamental fish trading is a potential business started in 1930 (Wabnitz et al., 2003). In Indonesia, it was started in 1960 (Idris & Mardesyawati, 2012). Until the present time, Indonesia is among the biggest exporter of marine biota. Even Indonesia is the third leading exporter of marine ornamental fish (Prasetio & Kusrini, 2012).

Many marine ornamental fish market spots are identified across Indonesia (Akmal et al., 2020; Nuryanto et al., 2020). There are four market spots of marine ornamental fish in the coastal areas of southern West Java. i.e., Pelabuhan Ratu, Ujung Genteng, Taman manalusu, and Pangandaran (Nuryanto et al., 2020; Nuryanto et al., 2021). The potency of marine ornamental fish of the south coast of West Java, especially at those four areas was very high (Wahyudin, 2011).

Indonesia is among countries with a high diversity of Chaetodontidae (Froese & Pauly, 2021). Chaetodontidae is a dominant marine ornamental fish in coral reef ecosystems (Sugianti & Mujianto, 2013). The diversity of Chaetodontidae in Indonesia is different among the site to the others (Wibowo et al., 2013; Hastuty et al., 2014; Yuliana et al., 2017; Fadli et al., 2018; Sahetapy et al., 2018). A total of 65 species of Chaetodontidae has been described from Indonesia (Forese & Pauly, 2021). Nine species of Chaetodontidae or butterflyfish was reported from southern West Java, two of them were *C. auriga* and *C. vagabundus* (Nuryanto et al., 2020; Nuryanto et al., 2021).

Morphology becomes a strong character for fish identification (Rawat *et al*., 2017), including

Chaetodontidae (Naeem et al., 2011). Morphological characteristics commonly used in species identification are meristic, colour pattern, and standard morphometric (Putri et al., 2015; Ali et al., 2017; Nabila et al., 2019). Previous study had identified member of Chaetodontidae based on standard morphometrics (Ihya et al., 2020). However, limited morphological variations are observed between *C. auriga* and *C. vagabundus*, especially during early juvenile stages, which might lead to misidentification. Therefore, additional morphological characters are needed. Truss morphometric characters are among morphological characters that are useful as taxonomic characters for species identification (Muchilisn 2013; Mojekwu & Anumudu, 2015; Rawat et al., 2017) and also population differentiation (Putri et al., 2015; Asiah et al., 2019; Mustikasari et al., 2020). However, no study has been done to differentiate *C. auriga* and *C. vagabundus* based on truss morphometric characters. Hence, this study aimed to evaluate morphological differences between *Chaetodon auriga* and *C. vagabundus* based on truss morphometric character to add new morphometric characters for species differentiation on Chaetodontidae on the southern coast of the West Java region, Indonesia.

METHODS

The Sampling site and time

The Chaetodontidae samples were collected from two locations on the southern coast of West Java, namely Ujung Genteng in Sukabumi Regency and Taman Manalusu in Garut Regency (Figure 1). Fish specimens were collected during the field trips in February and March 2018.

Figure 1. Map of Java Island with West Java (blue colour) showing two sampling sites

Morphological characterization

Two morphospecies of Chaetodontidae were selected as the object of the study. The selection was based on the number of individuals of each morphospecies to have statistically reliable data and covers life stages (juvenile and adult stages). Morphological characterization was performed based on their general performance, meristic, standard and truss morphometric characters.

General performance includes body shape, colour, and colour pattern. The meristic characters consisted of rays and spines of all fins and scales in the lateral line. A total of six standards and 20 truss morphometric characters were measured (Figure 2). The detailed information about standard and truss morphometric distances is presented in Table 1. Standard and truss morphometric measurements were conducted using rope to be the easiest to follow fish's body shape. Afterwards, the results of measurements were re-measured using a calliper with an accuracy of 0.01 mm. Truss morphometric distances were divided by standard length for the truss distance in the main body and caudal parts. In contrast, the truss distances in the head part were divided by head length to have homogenously measured for all fish samples with different sizes. The comparison to standard and head length was conducted to obtain constant values while individual size varies (Pambudi et al., 2019; Almusyarofah et al., 2020)

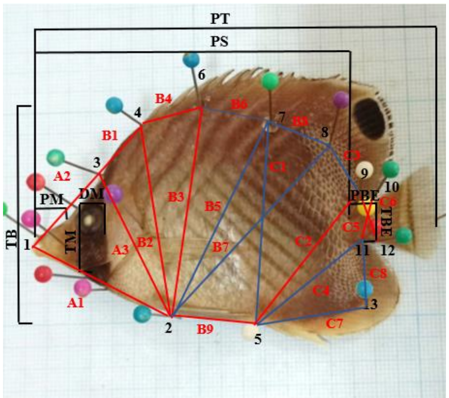

Figure 2. An illustration of truss and standard morphometric distances observed in the research object (Note: blue lines modification)

Table 1. Annotation of **s**tandard and truss morphometric characters codes observed in the research object

Standard morphometric following Ihya et al. (2020)		
Code		Annotation
PT		Total length
PS		Standard length
PK		Head length
TB		Body height
DM		Aye diameter
PM		Snout length
TM		Snout height
TBE		Caudal peduncle height
PBE		Caudal peduncle length
Truss Morphometric modified from Siliprandi et al. (2019)		
Body part	Code	Annotation
Head	A1 (1-2)	The distance between the snouts' tip and the anterior base of the pelvic fin
	A2 (1-3)	The distance between the snouts' tip and the nape
	A3 (2-3)	The distance between the anterior base of the pelvic fin and the boundary of the head and dorsal
Body	B1 (3-4)	The distance between the head and dorsal boundary and anterior base of dorsal fin
	B2 (2-4)	The distance between the anterior base of the pelvic fin and the anterior base of the dorsal fin
	B3 (2-6)	The distance between the anterior base of the pelvic fin and the highest point of the body
	B4 (4-6)	The distance between the anterior base of the dorsal fin and the highest point of the body (front-back)
	B5 (2-7)	The distance between the anterior base of the pelvic fin and the midpoint of the upper body part
	B6 (6-7)	The distance between the highest point of the body and the midpoint of the upper body part (middle back)
	B7 (2-8)	The distance between the anterior base of the pelvic fin and the posterior base of the dorsal fins
	B8 (7-8)	The distance between the midpoint of the upper body part and the posterior base of the dorsal fins (hind back)
	B9 (2-5)	The distance between the anterior base of the pelvic fin and the anterior base of the anal fin
Caudal	C1 (5-7)	The distance between the anterior base of the anal fin and the midpoint of the upper body part
	C2 (5-9)	The distance between the anterior base of the anal fin and the anterior base of the dorsal of caudal peduncle
	C3 (8-9)	The distance between the posterior base of the dorsal fins and the anterior base of the dorsal of caudal peduncle
	C4 (5-11)	The distance between the anterior base of the anal fin and the anterior base of the ventral caudal peduncle
	C5 (10-11)	Distance between the back base of the upper caudal peduncle and the leading base of the lower caudal peduncle
	C6 (9-12)	The distance between the leading base of the upper caudal peduncle and the rear base of the lower caudal peduncle
	C7 (5-13)	Distance between the anterior base of the anal fin and the base of the anal fin arch
	C8 (11-13)	Distance between the front base of the lower caudal peduncle and the base of the anal fin arch

Data analysis

The taxonomic status of *C. auriga* and *C. vagabundus* were obtained from morphological identification according to Allen & Erdmann (2012), Tiralongo et al. (2018), and Lee & Kim (2021). Identification is an obligate step in taxonomic study to ensure that the study is done in the correct species. The truss morphometric data were analyzed statistically using the Mann-Whitney test for two-group data. The test was selected because the data are nonparametric ratio data.

RESULTS AND DISCUSSION

Taxonomic status of Chaetodontidae specimens

A total of 37 individuals from two morphospecies of Chaetodontidae has been examined and identified during the study. Both morphospecies is characterized by a compressed body, terminal mouth with short to long snout, and small teeth. They have a curved lateral line (linea lateralis) starting from the posterior of the operculum to the anterior part of the caudal peduncle. Another prominent character of Chaetodontidae is bright and beautiful colouration. The observed characters were similar to the characters of Chaetodontidae as previously described by Rahardjo *et al*. (2011), Pyle & Kosaki (2016), Tiralongo et al. (2018) and Lee & Kim (2021), such as compressed body, curved lateral line, terminal mouth, and bright colorations. Based on those characters comparisons, we were determined that both morphotypes are belonging to Chaetodontidae.

A detailed examination of the samples proved that the specimens could be divided into two different morphotypes, namely Morphotype A and Morphotype B. A complete description of the two morphotypes is as follow.

Morphospecies A

Description

Morphospecies A has a compressed body with a terminal mouth. It has white, brownish body colour with the posterior body part to caudal has a yellow colour. There are opposite diagonal stripes on the body, with a black patch on the back part of the dorsal fin and thick vertical black lines on the head through the eyes (Figure 3A). The fin formula was D. XI-XIII. 20-24, P. 13-17, V. I-II. 3-5, A. III. 18-22, C. 15-18. Ctenoid scales cover the body. The number of scales in the *linea lateralis* ranged between 30 and 36. The caudal fin is rounded.

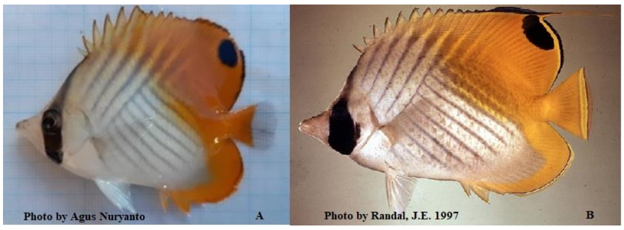

Figure 3. Morphospecies A (A) and diagnostic species *Chaetodon auriga* (B)

Diagnosis

Chaetodon auriga had opposite direction of diagonal lines on both body sides. This species has yellow colour in the posterior part of the body up to the caudal with black patches in the rear part of the dorsal fin (Figure 3B). *C. auriga* has fin formula as follow: D.XIII.22-25, A.III.19-22, P.15-17, V.I.5, and C.16-18, and has 31 to 40 scale on linea lateralis (Allen & Erdmann, 2012; Trialongo *et al*., 2018). It has rounded caudal fin (Weinheimer, 2021). *Chaetodon auriga* has a maximum body size of 23 cm (Allen & Erdmann, 2012). The scales are ctenoid (Alwany, 2012).

Chaetodon auriga has geographic distribution in the Indo-Pacific coral reef ecosystems spanning west Read Sea and East Africa to east region Hawaii, Marquesan, and Ducie. The latitudinal distribution of this species is from Northern Japan to the south area in Lord Howe and Rapa (Froese & Pauly, 2021). The southern coast of West Java belongs to the Indo-Pacific region. Based on the examinations, Morphospecies A shared similar characters with *C. auriga*. In this report, we identified Morphospecies A belongs to *C. auriga*.

Morphospecies B

Description

The specimens of morphospecies B had typical chaetodontid fish that is a compressed body. It has white, brownish colour in half anterior and yellow in the posterior part of the body to the caudal fin. There are opposite diagonal lines on both sides of the body. There are thick vertical lines on both sides of the head through the eyes. A black line spans the dorsal fin to the anal fin and the posterior part of the caudal fin. Fin formula is D. VIII-XIII. 22-25, P. 13-16, V. I. 4-6, A. II-III. 17-22, C. 15-18 (Figure 4A). Morphotype 2 has a terminal mouth, rounded caudal fin, and ctenoid scales. There are 30-36 scales in *linea lateralis*.

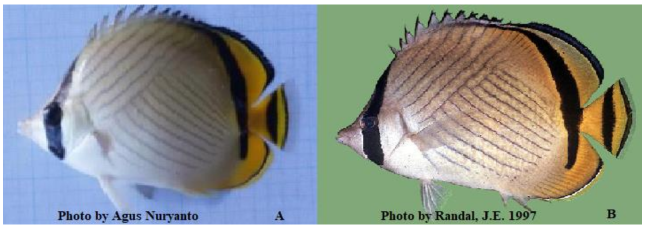

Figure 4. Morphospecies B (A) and diagnostic species *Chaetodon vagabundus* (B)

Diagnosis

Chaetodon vagabundus is characterized by having opposite diagonal lines on both sides of the body (Figure 4B). Another characteristic is thick black lines spanning the dorsal fin to the anal fin (Allen & Erdmann, 2012). Fin formula is as follow D.XIII.23-25, A.III.19-22, P.14-15, V.I.5, and C.16-18. According to Lee & Kim (2021), fin formula of *C. vagabundus* is D.XIII, 24, A.III, 21, P.14, V.I,5 and C.20. The body is covered by ctenoid scales (Alwany, 2012). Scale number on linea lateralis ranges from 34 to 40 (Allen & Erdmann, 2012). The caudal fin is rounded (Weinheimer, 2021). The maximum body length of *C. vagabundus* might reach 23 cm (Allen & Erdmann, 2012).

The geographic distribution of *C. vagabundus* is in the Indo-Pasifik regions. It can be found from East Africa to Line and Tuamoto Islands. Latitudinal distribution of this species from south Japan to Lord Howe and Austral Islands (Froese & Pauly, 2021).

According to the description and diagnostic characters, both Morphospecies B and *C. vagabundus* shared many characters. Therefore, we determined that Morphotype B was taxonomically identified as *C. vagabundus*.

Truss Morphometric Characterization

The specimen of the presumed *C. aruriga* and *C. vagabundus* were then subjected to truss morphometric comparisons. The truss morphometric characters were analyzed to ensure that the identification steps had similar result. The truss distances of the two presumed species were analyzed statistically using the Mann-Whitney test (Table 2).

It can be observed in Table 2 that five truss distances were significantly different between *C. auriga* and *C. vagabundus*. These truss characters were A2, B4, B6, B8, and C8. Detail observation of the data in Table 2 indicated that *C. auriga* has truss distance with a ratio of 0.99, while *C. vagabundus* was 0.89 (asymptote significance 0.003) for A2. The average value of the B4 truss distance of *C. auriga* was 0.21 and 0.18 for *C. vagabundus* (asymptote significance 0.003). Those two truss distances indicated that *C. auriga* has a larger size than *C. vagabundus*. This data means that *C. auriga* has a longer nape distance (A2) than *C. vagabundus*. That result was congruent with Froese and Pauly (2021) that *C. auriga* has a longer head and pre-dorsal than *C. vagabundus*. A similar phenomenon was also reported by Ihya *et al*. (2020) that *C. auriga* has a longer head than *C. vagabundus* with a length of 35.5% of standard length, while *C. vagabundus* has a shorter length with the size of 31.6% of standard length.

Table 2. Significance test of *Truss distances between C. auriga* dan *C. vagabundus* using Mann-Whitney U-test

Truss distance	Min-Max (X means ± Standard Deviation)		Asymp. Sig	Mann-Whitney U-test
	C. auriga	*C. vagabundus*		
A1	0.93-1.41 (1.22±0.140)	1.11-1.40 (1.27±0.068)	0.330	NS
A2	0.76-1.09 (0.99±0.090)	0.73-1.02 (0.89±0.092)	0.003	*
A3	1.20-1.58 (1.39±0.110)	1.24-1.65 (1.42±0.103)	0.637	NS
B1	0.11-0.25 (0.18±0.042)	0.12-0.28 (0.19±0.037)	0.342	NS
B2	0.57-0.68 (0.63±0.030)	0.62-0.70 (0.65±0.022)	0.22	NS
B3	0.62-0.71 (0.66±0.028)	0.43-0.74 (0.66±0.055)	0.252	NS
B4	0.17-0.28 (0.21±0.029)	0.15-0.22 (0.18±0.023)	0.003	*
B5	0.64-0.76 (0.69±0.034)	0.61-0.74 (0.67±0.028)	0.351	NS
B6	0.16-0.25	0.17-0.25	0.027	*

Truss distance	Min-Max (X means ± Standard Deviation)		Asymp. Sig	Mann-Whitney U-test
	C. auriga	C. vagabundus		
	(0.19±0.027)	(0.21±0.022)		
B7	0.67-0.79 (0.72±0.033)	0.61-0.73 (0.65±0.032)	0.395	NS
B8	0.15-0.26 (0.20±0.031)	0.22-0.29 (0.25±0.021)	0.000	*
B9	0.25-0.31 (0.29±0.018)	0.23-0.35 (0.28±0.031)	0.252	NS
C1	0.59-0.70 (0.65±0.032)	0.61-0.73 (0.65±0.032)	0.732	NS
C2	0.44-0.58 (0.51±0.032)	0.41-0.58 (0.51±0.039)	0.793	NS
C3	0.17-0.27 (0.21±0.033)	0.18-0.30 (0.22±0.028)	0.369	NS
C4	0.33-0.49 (0.42±0.039)	0.38-0.52 (0.44±0.034)	0.234	NS
C5	0.16-0.20 (0.18±0.011)	0.15-0.21 (0.17±0.016)	0.079	NS
C6	0.14-0.19 (0.17±0.016)	0.14-0.20 (0.17±0.017)	0.531	NS
C7	0.27-0.37 (0.32±0.033)	0.25-0.45 (0.34±0.053)	0.336	NS
C8	0.13-0.19 (0.17±0.018)	0.15-0.21 (0.19±0.017)	0.010	*

Note: NS= Non-significant, *= Significant

It is also observed from Table 2 that *C. auriga* has a longer front back (B4) distance than *C. vagabundus*. According to Froese & Pauly (2021), C.auriga has a deeper (higher) body than *C. vagabundus*. Therefore, it is reasonable if *C. auriga* has a longer distance than *C. vagabundus* in the distance between the front base of dorsal fins and the body's highest point (B4).

Unlike previous significant characters (A2 and B4), *C. vagabundus* has higher truss distances in the remaining three characters (B6, B8, and C8) than *C. auriga*. The average value of B6 truss distance was 0.19 in *C. auriga* versus 0.21 in *C. vagabundus*, with an asymptote significance value of 0.027. The B8 character of *C. auriga* has an average value of 0.20, while in *C. vagabundus* was 0.25 with the asymptote significance value of 0.000. Those characters proved that *C. vagabundus* has longer middle and posterior parts of the dorsal areas than *C. auriga*. The results were quite logical because *C. vagabundus* has a more elongated body than *C. auriga*. According to Froese & Pauly (2021), *C. auriga* has a deeper body than *C.vagabundus*. This character means *C. vagabundus* has a more elongated body than *C. auriga*.

This study found that *C. vagabundus* has a more rounded anal fin base than *C. auriga*, a triangular base of anal fins. According to the morphology of both species available in Forese & Pauly (2021), *C. vagabundus* has a more rounded caudal fin base than *C. auriga*. Additionally, *C. vagabundus* has a longer distance than *C. auriga* in the distance between the front base of the caudal peduncle and the base of the anal fin arch (C8) with an average ratio value of 0.19, while in C. auriga was 0.17. Therefore, it was not surprising that both species have different sizes on the distance between the front base of the caudal peduncle and the base of the anal fin arch (C8).

Previous studies reported the importance of truss morphometric character in species differentiation (Muchilisn 2013; Mojekwu & Anumudu, 2015; Rawat et al., 2017). Moreover, the truss characters could also be utilized for population differentiation (Asiah et al., 2019; Mustikasari et al., 2020). However, this study could not make a congruent comparison to those previous studies because these studies and the studies by Muchilisn (2013), Mojekwu & Anumudu (2015), and Rawat et al. (2017) used different fish species. Nevertheless, the present study has a similar result to Muchlisin (2013), who also discovered that the head part could differentiate among *Rasbora* species. This study provided five new morphometric data, which determine *C. auriga* and *C. vagabundus*.

CONCLUSION

This study concluded that *C. auriga* and *C. vagabundus* could be differentiated using truss morphometric characters. This study provides five new morphometric data for species differentiation between *C. auriga* and *C. vagabundus*.

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