Morphometric characteristics of rabbit fish (*Siganus canaliculatus* Park, 1797) in Makassar Strait, Flores Sea, and Bone Gulf

Suwarni, Joeharnani Tresnati, Ambo Tuwo, Sharifuddin Bin Andy Omar

Aquatic Resources Management, Faculty of Marine Science and Fisheries, Hasanuddin University, Tamalanrea, 90245, Makassar, Indonesia. Corresponding author: Suwarni, suwarniliger17@gmail.com

Abstract. Rabit fish (*Siganus canaliculatus)* is one of the fishery commodities in Indonesian coastal area. These fishes have an economical value, support the coastal community and and are an important protein resource. This study aimed to examine and compare the morphometric characteristics of rabbit fisht that cought from Makassar Strait, Flores Sea, and Bone Gulf waters. 29 morphometric characteristics of rabbit fish were determined from a total of 300 fish samples, from 3 locations, which were 50 male and 50 female fish from each location. Results showed that for the three locations male fish were longer in body length than female fish. In general, there were five morphometric differences of male rabbit fish in the three locations, namely interorbital length, the longest anal soft ray length, orbital width, standard length, and maxilla length. We found that there were seven morphometric characteristics different amongst the female fish from the three locations, such as interorbital length, the longest dorsal spine length, the longest anal spine length, eye width, mouth opening width, and pre-dorsal fin length. The discriminant test showed that there was a high similarity of morphometric characteristics between rabbit fish from Makassar Strait and Flores Sea and a significant difference between the morphometric characteristics of rabbit fish from Bone Gulf and the other two locations.
Key Words: *Siganus canaliculatus*, morphometric characteristics, Makassar Strait, Flores Sea, Bone Gulf.

Introduction. Rabbit fishes or siganids are generally littoral to sublittoral fishes and inhabit coral reefs, seaweed and sea grass beds, mangrove swamps, estuaries, river mouths and lagoons up to a depth of 6 meters (Gorospe & Demayo 2013). The Siganidae family is represented by 27 species, 15 of which are schooling species and the rest occur in pairs and are coral dwellers. These coral dwelling species are brightly colored, fragile, and sensitive to physico-chemical changes and usually show interspecific aggressive behavior. The schooling species of siganids, colored gray or drab, are sturdy and apparently resistant to considerable variations in salinity and temperature. These schooling species are an important food resource and currently the subject of mariculture studies for species such as *Siganus canaliculatus*, *S. argenteus*, *S. rivulatus*, *S. vermiculatus* and *S. guttatus*. *S. vermiculatus* and *S. guttatus* grow faster compared to *S. canaliculatus* in ponds and cages (Gorospe & Demayo 2013).

Siganus canaliculatus, is a member of the Siganidae family, commonly known as rabbitfish and is widely distributed in the warm seas of the world. This fish inhabits the Indo-Pacific in the Arabic Gulf, Hong Kong, Taiwan, Indonesia and Eastern Mediterania Waters (Al-qishawe et al 2014). Gundermann et al (1983) found that the fish of the Siganidae family occupy a wide habitat distribution in tropical to subtropical coastal areas in the Indian Ocean and the West Pacific and in Indonesia, the rabbit fish is abundant in the waters of the Makassar Strait, Flores Sea and Bone Gulf. According to Woodland and Anderson (2014), siganids are generally regarded as good food in spite of their relatively small size. Some species have been cultured because of their herbivorous food habits, rapid growth, and economic value (Randall et al 2005). They are widely distributed in shallow coastal habitats throughout the Indo-Pacific Ocean and eastern Mediterranean Sea (Woodland 1995). Siganids are of economic importance for fishery production and aquaculture (Lam 1974; Soliman et al 2009). Knowledge of the wild population dynamics is vital for their management as an important fishery resource (Bell et al 2008; Lipcius et al 2008).

Rabbit fishes belong to the genus Siganus of the family Siganidae. Siganid species are all remarkably like each other in most of the features. All species possess thirteen dorsal fin spines, and seven anal fin spines. The genus Siganus is also unique among marine fish for having two pectoral spines on each side which are separated by three soft rays. Along with the twenty-four spines, one procumbent spine is found in front of the first dorsal spine which is part of the proximal pterygiophore. It is completely embedded or sometime protrudes from a small groove and makes up the main defense for the fish. The spines are poisonous (Jaikumar 2012). The teeth are also remarkably similar to each other, with a single row on top and one on the bottom jaw. They are very compressed and incisiform in shape. The teeth also overlap and are individually spade-like and pointed (Jaikumar 2012).

Siganus canaliculatus has a compressed body, is fairly slender, the head is concave above the eyes, the snout is blunt, the anterior nostril is with a long flap in juveniles (shortening with age, absent in old fish) and the tip of the flap is reaching less than halfway to the posterior nostril in specimens larger than 12 cm in standard length. A forward-directed spine is present in front of the dorsal fin; the last dorsal spine is the shortest, being 0.5 to 0.6 times out of the longest dorsal spine; the last anal spine is 1.2 to 1.5 times out of the longest anal spine (usually the third). Caudal fin is almost emarginated in specimens under 10 cm standard length and is forked in larger fish (but median rays are never less than half the length of the longest rays). 21 to 27 scale rows between lateral line and the base of leading dorsal spines. Colour in live fish is highly variable from greenish grey on dorsal side to silver on ventral side; numerous pearly blue match-head size spots on the sides, arranged in aproximately horizontal rows. The caudal fin is plain grey or irregularly barred with pale and dark grey; pectoral fins have a hyaline appearance; dorsal, anal and pelvic spines and rays have the same colour as the adjacent areas of the sides; fin membranes are grey; after death fins usually turn pale and dark grey, and the dorsal fin rays are banded (Woodland 1995).

Siganus canaliculatus is a commercially important species which is caught with a variety of fishing methods, including bottom trawls and traps, in coastal waters throughout its range (Woodland & Anderson 2014). It is estimated that there are 19 species of rabbit fish found in Indonesian waters, or about 70.4% of the total species of rabbit fish in the world. Carpenter (2001) found that there are 12 species of the genus Siganidae in Indonesia, while Burhanudin et al (2014) documents 17 species from the family Siganidae and Yunus (2005) documents 13 species in Spermonde waters.

Morphological studies have long been useful to delimit marine fish stocks and describe their spatial distribution (Palma and Andrade 2002). This knowledge is important to elaborate management strategies for a better exploitation of fish resources (Bailey 1997). Morphological variations between fish populations may be induced by several environmental factors. Several works have demonstrated morphological divergence on different regions of the fish body in several marine fish species (Hammami et al 2013; Mejri et al 2012; Turan 2004).

Morphometric studies are based on a set of measurements which are continuous data, revealing the size and shape variation (Turan 1999). The development of image analysis systems has facilitated progress and diversification of morphometric study methods (Cadrin & Friedland 1999). Morphometric analysis is an important tool used to differentiate closely related species of organisms having huge similarity indices of various parameters or characters (Fagbuaro et al 2015). Assessment of these parameters are essential in fish studies, particularly to understand the taxonomy and differences within a population. While the shapes and structures are unique to each fish species, the variations between groups of the same species can be related to habitat location and genetic impurity among the stocks (Fagbuaro et al 2015; Iswanto et al 2015).

The Directorate General of Capture Fisheries, Ministry of Marine and Fisheries Affair, Republic of Indonesia recorded that in 2014 fisheries production was able to contribute to the second largest fish production in Indonesia (12.43%) of the total national production

(6,037,654 tons). Reef fish resources are ranked 4th after small pelagic fish, large pelagic fish, demersal fish. The potential for reef fish in 2011 was 34.10 thousand tons/year (Minister of Marine Affairs and Fisheries Decree Number KEP.45/MEN/2011) and an increasing in 2016 to 365.40 thousand tons/year (Minister of Marine Affairs and Fisheries Decree Number 47/KEPMEN-KP/2016) (Koeshendrajana et al 2019). The most exploited reef fishes were from the family Siganidae. One of the most commonly caught was white-spotted spinefoot fish (*Siganus canaliculatus*).

Rabbit fish is locally called as kea-kea (Seribu Islands), biawas (Central Java), samadar (Maluku), biawasa (Takalar), malaja (Luwu), and biahasa (Selayar) (Sahabuddin et al 2015). Umar et al (2018) stated that the catching yield of rabbit fish in the South Sulawesi waters reached 81% of MSY (Maximum Sustainable Yield) or passing the precautionary approach from the code of conduct for responsible fisheries from the Food and Agriculture Organization of the United Nations, which suggested that the catching yield should not pass 80% of Maximum Sustainable Yield (MSY) to maintain the fish resources.

One of the important informations for the resource management of white-spotted spinefoot fish in the South Sulawesi is the biological aspect containing the morphometric characteristics of the fish in Makassar Strait, Flores Sea, and Gulf of Bone. However, there was a lack of studies related to morphometric characteristics of this fish from Makassar Strait, Flores Sea and Bone Gulf. The aim of the study was to examine and compare the morphometric characteristics of rabbit fish caught at Makassar Strait, Flores Sea, and Bone Gulf waters.

Material and Method. This study was conducted from February 2017 until January 2018 in Pangkajene Islands in the Makassar Strait, Jeneponto in the Flores Sea, and Luwu in the Gulf of Bone. Fish samples analysis was performed in the Laboratory of Fish Biology and Physiology, Faculty of Marine Science and Fisheries, Hasanuddin University. Fish sampling locations were obtained based on the location where the fishermen installed the catching devices (set nets) (Table 1 and Figure 1).

Table 1

The coordinates of fish sampling points

No	Location	Location Coordinates	
		Latitude	Longitude
1	Makassar Strait	4°40'30,861" - 4°44'35,54"	119°24'21,626" - 119°28'45,879"
2	Flores Sea	5°37'48,751" - 5°40'57,3"	119°35'24,821" - 119°38'23,234"
3	Gulf of Bone	2°58'22,14" - 3°3'4,393"	120°15'19,574" - 120°22'6,177"

Fish samples were taken from the fishermen and put into the cool box with ice blocks to be preserved before being analyzed in the laboratory. Fish were observed on the sample board and labeled as the marker. The fish fins were stretched with needles and smeared with formaline 40% for 15 minutes until the fins became rigid. The morphometric characteristics were measured using a digital caliper with 0.01 mm accuracy. The morphometric characteristic analysis components were referred to Allen et al (2000). We used abbreviation for each parameter to easily conduct the comparison analysis (Table 2).

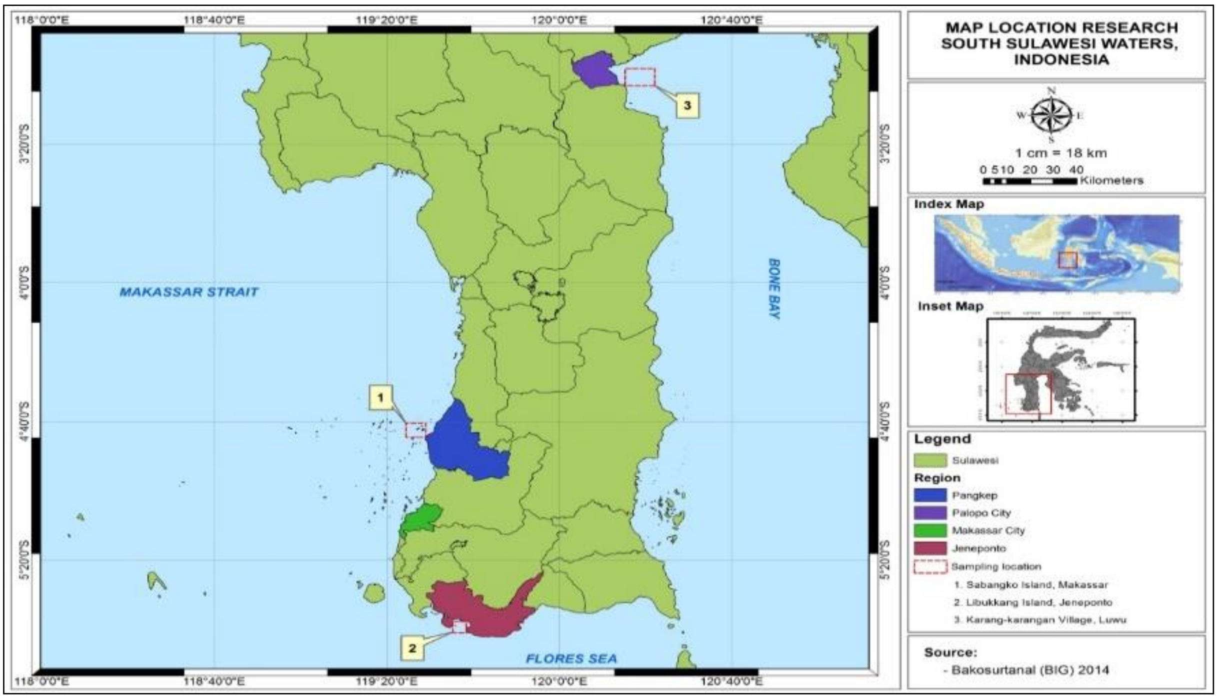

Figure 1. Map of study sites.

Table 2

The measured morphometric characteristics of *Siganus canaliculatus* fish samples

	Variable	*Information*
1	Total Length (TL)	The distance between the front of the head and end of caudal fin.
2	Standard Length (SL)	The distance between the front of the head and the base of the caudal fin.
3	Dorsal Fin Length (DFL)	The distance between the insertion of the first and last fin ray of the dorsal fin.
4	Pectoral Fin Length (PFL)	The distance between the first front fin ray and the last fin ray.
5	Pelvic Fin Length (VFL)	The distance between the first front fin ray and the thin membrane at the back of the last fin ray.
6	Anal Fin Length (AFL)	The distance between the first front ray and thin membrane at the back where the last ray inserts.
7	Pre-dorsal Fin Length (PdFL)	The distance between the front of the head and first front dorsal fin.
8	Caudal Peduncle Length (CPL)	The slope distance between the base end of anal fin and middle caudal fin ray.
9	Post-orbital Length (PoL)	The distance between the back side of orbital cavity and back edge of the operculum membrane.
10	Body Height (BH)	Measured from the highest position between the dorsal and ventral sides of the body.
11	The Longest Pectoral Fin Ray Length (LPcFRL)	Measured from the longest tip until the end of pectoral fin ray.
12	The Longest Pelvic Fin Ray Length (LPeFRL)	Measured from the longest tip until the end of pelvic fin ray.
13	The Longest Dorsal Fin Spine Length (LDSL)	Measured from the longest tip until the end of dorsal fin spine.

14	The Longest Dorsal Soft Fin Ray Length (LDSFRL)	Measured from the longest tip until the end of dorsal soft fin ray.
15	The Longest Anal Fin Spine Length (LASL)	Measured from the longest tip until the end of anal fin spine.
16	The Longest Anal Soft Fin Ray Length (LASFRL)	Measured from the longest tip until the end of anal soft fin ray.
17	Caudal Peduncle Height (CPH)	Measured on the lowest caudal peduncle height.
18	Head Length (HL)	The distance between the front of the head and back of operculum.
19	Snout Length (SnL)	The distance between the front of the snout and orbital cavity.
20	Length between Orbital and Operculum Angle (LOOA)	The distance between the orbital cavity and operculum angle.
21	Maxilla Length (MaL)	The upper jaw length measured from the front until the end of the upper jaw bone.
22	Mandibule Length (MnL)	The lower jaw length measured from the front until the back edge of the folded jaw.
23	Interorbital Length (IL)	The distance between the two upper edges of orbital cavities.
24	Head Height (HH)	The distance between the top and bottom of the head.
25	Cheek Height (CH)	The distance between the lower side of the orbital cavity and preoperculum front.
26	Lower Orbital Height (LOH)	The distance between the lower side of the orbital cavity and upper jaw.
27	Orbital Width (OW)	The diameter of the orbital cavity.
28	Head Width (HW)	The distance between the two operculums on both sides of the head.
29	Mouth-Opening Width (MOW)	The distance between both mouth angles, when the mouth is open wide.

Results and Discussion

Morphometric characteristics of Siganus canaliculatus. The total of white-spotted spinefoot fish samples were 100 samples (50 female and 50 male fishes) for each study site/sampling location. The most varied morphometric characteristics of male white-spotted spinefoot fish were found in Makassar Strait based on the standard length (SL) (111 – 177 mm) compared to Flores Sea and Gulf of Bone, as well as mentioned by Sahabuddin et al (2015) in Makassar Strait and Gulf of Bone. Meanwhile, the longest pectoral fin ray length (LPcFRL) of the fish found in Flores Sea was the most varied characteristic compared to Makassar Strait and Gulf of Bone (0.81 – 10.6 mm), as well as lower than Sahabuddin et al (2015) who observed the fish from Makassar Strait and Gulf of Bone. The white-spotted spinefoot fish found in the Gulf of Bone also showed the most varied total length (TL) (97 – 190 mm), compared to Makassar Strait, Flores Sea, and Sahabuddin et al (2015) in Makassar Strait and Gulf of Bone.

Based on the results obtained, the most varied morphometric characteristic of female white-spotted spinefoot fish based on the total length (TL) (145 – 225 mm) was obtained from Makassar Strait, compared to Flores Sea, Gulf of Bone, and the results obtained by Jumriani (2017) in Makassar Strait and Gulf of Bone. Meanwhile, the most varied characteristic based on the head height (HH) was obtained from Flores Sea (11.5 – 21.9 mm), compared to Makassar Strait and Gulf of Bone, but lower than the results obtained by Saripah (2009) in Binuang water area. The Gulf of Bone obtained the most varied caudal peduncle height (CPH) (1.00 – 9.10 mm), compared to Makassar Strait and Flores Sea.

Morphometric characteristics of male Siganus canaliculatus. The total of white-spotted spinefoot male fish measured were 150 fish, comprising of 50 fish from Makassar Strait, 50 fish from Flores Sea, and 50 fish from Gulf of Bone water area. The discriminant analysis result on the morphometrics of white-spotted spinefoot fish group in Makassar Strait, Flores Sea, and Gulf of Bone indicated that 11 out of 29 variables showed high significant differences ($P<0.01$), namely: Standard length (SL), caudal peduncle length (CPL), anal fin length (AFL), post-orbital length (PoL), the longest pelvic fin ray length (LPeFRL), the longest anal fin spine length (LASL), maxilla length (MaL), interorbital length (IL), head height (HH), cheek height (CH), and lower orbital height (LOH).

Stepwise test was performed to determine the discriminated variables. This stepwise test presented which variables from the 29 input variables could be entered in the discriminant. The entering process in the stepwise analysis was started from the highest parameter value. The stepwise test result against the morphometric differences of white-spotted spinefoot fish group in Makassar Strait, Flores Sea, and Gulf of Bone indicated that 6 out of 11 input variables entered the discriminant function as having higher F value and significant differences ($P<0.01$) were: Head height (HH), interorbital length (IL), the longest anal fin spine length (LASL), lower orbital height (LOH), standard length (SL), and maxilla length (MaL). These 6 variables were included in the canonical discriminant function (Z score). Each function is presented on the following equations:

Z Score 1 = - 6.861 + (5.931 SL) – (22.869 PoL) – (10.316 AFL) + (1.936 MaL) – (20.724 CH) – (45.381 LPeFRL) + (135.416 HH) + (102.724 LASL) – (77.860 CPL) + (129.021 IL) + (41.695 LOH)

Z Score 2 = - 26.711 + (17.644 SL) + (12.503 PoL) + (24.657 AFL) - (0.743 MaL) – (15.544 CH) + (129.935 LPeFRL) + (46.149 HH) - (147.478 LASL) – (17.726 CPL) + (17.366 IL) + (80.019 LOH)

The centroid average is presented to observe the distribution pattern among the white-spotted spinefoot fish groups on each water area location. The fish discriminant groups on Makassar Strait, Flores Sea, and Gulf of Bone had different centroid points for each group.

Some morphometric variables of male white-spotted spinefoot fish in Makassar Strait, Flores Sea, and Gulf of Bone were similar as there was a centroid mixture between Makassar Strait and Flores Sea, while male white-spotted spinefoot fish in Gulf of Bone was different as the centroid tended to spread, though some centroids seemed touching the centroid of Flores Sea and Makassar Strait.

Table 4

The classification results of male *Siganus canaliculatus* in Makassar Strait, Flores Sea, and Gulf of Bone

		Location	*Group Member Prediction*			
			Makassar Strait	*Flores Sea*	*Gulf of Bone*	*Total*
Origin	Result Σ(%)	Makassar Strait	45 (90)	5(10)	0(0)	50(100)
		Flores Sea	7(14)	40(80)	3(6)	50(100)
		Gulf of Bone	0(0)	5(10)	45(90)	50(100)
Validation	ResultΣ(%)	Makassar Strait	45(90)	5(10)	0(0)	50(100)
		Flores Sea	7(14)	37(74)	6(12)	50(100)
		Gulf of Bone	1(2)	5(10)	44(88)	50(100)

The classification results of Table 4 indicates that the results obtained can explain the feasible discriminant function to differentiate the fish groups from Makassar Strait, Flores Sea, and Gulf of Bone. The observation results elaborates that the original classification of 45 fish (90%) from Makassar Strait did not have the similar characteristics with the other fish groups, while 5 fish (10%) had the similar characteristics with the male fish from Flores sea. However, 0% fish from Flores Sea showed similarity with the fish from Gulf of Bone.

The original classification of male white-spotted spinefoot fish from Flores Sea resulted that 40 fish (80%) fish had no similar characteristics with other fish groups, 7 fish (14%) were similar to the male fish found in Makassar Strait, and 3 fish (6%) were similar to the fish found in Gulf of Bone.

The original classification of male white-spotted spinefoot fish from Gulf of Bone showed that 45 fish (90%) did not have the similar characteristics with the other fish groups, 5 fish (10%) were similar to the male fish found in Flores Sea, and 0% similar to the male fish from Makassar Strait.

The male fish group classification and prediction determines the discriminant function feasibility to differ the three male fish groups. The group classification of male white-spotted spinefoot presented that 86.7% of 150 fish were correctly grouped following the original data and 84% of the data had been correctly classified based on the cross-validation among groups. As the validation value of each group was above 50%, then the discriminant function formed was feasible to differ the fish groups among Makassar Strait, Flores Sea, and Gulf of Bone.

Based on the cross-validation value, the Makassar Strait had the highest validation value with 90%, compared to the Gulf of Bone (88%) and the Flores Sea (74%). Based on the morphometric similarity level in each group and characteristics given to the other groups, the male white-spotted spinefoot fish from Gulf of Bone had a high similarity level (90%) or relatively homogeneous with lower morphometric diversity of 10% characterized from Flores Sea and 0% from Gulf of Bone, while the fish group in Makassar Strait was 90% and the one from the Flores Sea was 80%, showing more diverse characteristics than the male fish group from the Gulf of Bone. The individual characteristic similarity to the male fish even in an insignificant percentage shows that the three groups of the male fish are 100% inseparable.

***Morphometric characteristics of female Siganus canaliculatus**.* The total number of female white-spotted spinefoot fish for the morphometric measurements were 150 fish, containing 50 fish from Makassar Strait, 50 fish from Flores Sea, and 50 from Gulf of Bone. The discriminant result on the morphometric differences in the female fish groups of Makassar Strait, Flores Sea, and Gulf of Bone Gulf indicated that 13 out of 29 morphometric variables were tested to be significantly different ($P < 0.01$), namely: Interorbital length (IL), the longest dorsal fin spine length (LDSL), the longest anal fin spine length (LASL), mouth-opening width (MOW), orbital width (OW), pre-dorsal fin length (PdFL), the longest anal soft fin ray length (LASFRL), maxilla length (MaL), the longest pelvic fin ray length (LPeFRL), lower orbital height (LOH), the longest dorsal soft fin ray length (LDSFRL), caudal peduncle length (CPL), and head width (HW).

Stepwise test was performed to determine the discriminated variables. This stepwise test presented which variables from 13 input variables could be entered in the discriminant. The entering process in the stepwise analysis was started from the highest parameter value. The stepwise test result against the morphometric differences of white-spotted spinefoot fish group in Makassar Strait, Flores Sea, and Gulf of Bone indicated that 7 out of 13 input variables entered the discriminant function as having higher F value and significant differences ($P<0.01$) were: Interorbital length (IL), the longest dorsal fin spine length (LDSL), the longest anal fin spine length (LASL), mouth-opening width (MOW), the longest dorsal soft fin ray length (LDSFRL), the longest anal soft fin ray length (LASFRL), and pre-dorsal fin length (PdFL). These 7 variables were included in the canonical discriminant function (Z score). Each function is presented in the following equations:

Score 1 = – 5.955 + (9.442 PdFL) – (62.720 CPL) – (18.351 OW) – (17.363 LPeFRL) + (114.827 LDSL) + (68.708 LASL) + (215.286 IL) – (45.943 HW) + (60.257 MOW) + (114.827 LDSFRL) + (68.708 LASFRL) – (12.560 MaL) – (30.175 LOH)

Z Score 2 = – 3.824 – (38.197 PdFL) + (79.044 CPL) – (3.732 OW) + (78.890 LPeFRL) + (84.965 LDSL) + (40.661 LASL) – (66.883 IL) – (12.034 HW) – (18.907 MOW) + (84.965 LDSFRL) + (40.661 LAFSRL) – (4.320 MaL) + (60.635 LOH)

This discriminant function is useful for classifying any individual fish who include on the white-spotted spinefoot fish in Makassar Strait, Flores Sea, and Gulf of Bone.

Based on the analysis result, the centroid point was mutually separated on the three locations, which showed significant differences among the female fish in the Makassar Strait, Flores Sea, and Gulf of Bone based on the morphometrics. However, there were some individuals who had the same morphometric variables on all three locations, specifically the female fish in Makassar Strait and Flores Sea, as there were some similarities presented from some individual mixing points with closed centroid distance between both locations. Meanwhile, the morphometric characteristics of female white-spotted spinefoot fish from Gulf of Bone had different characteristics, showing the further distance from the two other centroid points, although some individuals from both locations were seen in contact around the Gulf of Bone centroid. The female fish individual classification in Makassar Strait, Flores Sea, and Gulf of Bone is presented on Table 5.

Table 5

The classification results of female *Siganus canaliculatus* in Makassar Strait, Flores Sea, and Gulf of Bone

			Group Member Prediction			
		Location	*Makassar Strait*	*Flores Sea*	*Gulf of Bone*	*Total*
Origin	Result Σ(%)	Makassar Strait	44(88)	5(10)	1(2)	50(100)
		Flores Sea	7(14)	40(80)	3(6)	50(100)
		Gulf of Bone	1(2)	2(4)	47(94)	50(100)
Validation	Result Σ(%)	Makassar Strait	42(84)	6(12)	2(4)	50(100)
		Flores Sea	8(16)	39(78)	3(6)	50(100)
		Gulf of Bone	1(2)	5(10)	44(88)	50(100)

The individual classification results explained that the function was very feasible to differentiate the female fish groups from Makassar Strait, Flores Sea, and Gulf of Bone. The original classification of 44 fish (88%) from Makassar Strait did not have any similar characteristics to other both locations, 5 fish (10%) were similar to the female fish from Flores Sea, and 1 fish (2%) from Gulf of Bone.

The original classification of female fish group from the Flores Sea resulted 40 fish (80%) had no similar characteristics to the female fish groups from the other locations, 7 fish (14%) were similar to the female fish group from Makassar Strait, and 3 fish (6%) were similar to Gulf of Bone.

The original classification of female fish group from the Gulf of Bone resulted 47 fish (94%) had no similar characteristics to the female fish groups from the other locations, 2 fish (4%) were similar to the female fish group from Flores Sea, and 1 fish (2%) was similar to Makassar Strait.

The female fish group classification and prediction determines the discriminant function feasibility to differentiate the three female fish groups. The group classification of female white-spotted spinefoot presented that 87% of 150 fish were correctly grouped following the original data and 83% of the data had been correctly classified based on the cross-validation among groups. As the validation value of each group was above 50%, then the discriminant function formed was feasible to differentiate the fish groups among Makassar Strait, Flores Sea, and Gulf of Bone.

Based on the cross-validation value, the female white-spotted spinefoot fish from Gulf of Boner had the highest validation value with 88%, compared to Makassar Strait (84%) and Flores Sea (78%). Based on the morphometric similarity level in each group and characteristics given to the other groups, the female white-spotted spinefoot fish from Gulf of Bone had a high similarity level (94%) or relatively homogeneous with lower morphometric diversity of 4% characterized from Flores Sea and 2% from Makassar Strait, while the fish group in Makassar Strait was 88% and Flores Sea was 80%, showing more diverse characteristics than the male fish group from Gulf of Bone. The individual characteristic similarity to the female fish even in an insignificant percentage shows that the three groups of the male fish are 100% inseparable as there are possible chances of genetic crosses due to the environmental influences.

The study results of Sahabuddin et al (2015) discovered that the specific characteristics of white-spotted spinefoot found in the Gulf of Bone are the maxilla length (MaL), caudal peduncle height (CPH), and orbital width (OW), while the specific characteristics of the fish found in Pare-Pare are body height (BH), snout length (SnL), and the longest anal fin spine length (LASL), and the specific characteristics found in Takalar are standard length (SL) and mouth-opening width (MOW). Jumriani (2017) discovered the specific characteristic of the white-spotted spinefoot fish in Makassar Strait is the caudal peduncle height (CPH) and for the Gulf of Bone is the longest anal fin spine length (LASL).

Discussion. Based on the analysis results, 10 characters distinguish between male and female fish in the waters of the Makassar Strait, namely the length of the anal fin base, the length of the longest pectoral fin ray, the length of the longest dorsal fin ray, the length of the longest hard ray of the anal fin, length of the longest weak ray of the anal fin, head length, length between eyes, angle of operculum, head height, and eye width indicate that female are longer in body length than males.

In the waters of the Flores Sea, the results of the analysis for 14 characters distinguish between male and female fish in the Makassar Strait waters, namely the length of the base of the pelvic fins, length base of anal fin, length of tail, length of head and back of eyes, length of pectoral fin the longest, the length of the longest hard rays on the dorsal fin, the length of the longest dorsal fin, the length of the longest hard ray of the anal fin, the length of the longest ray of the anal fin, the length between the eyes and the angle of the operculum, the length of the space between eyes (interorbital), cheek height, eye width and head width.

For the waters of Bone Bay 24 characters, namely total length, standard length, base length of dorsal fin, base length of pectoral fins, basic length of abdominal fin, basic length of anal fin, length of front of dorsal fin, length of tail, body height, ray length longest pectoral fin, longest abdominal fingers, longest dorsal fin longest hard fingers, dorsal fin lengths, longest weak fingers, length of head, length of nose, length between eyes with operculum angle, upper jaw length (maxilla length) and jaw length.

Sahabuddin et al (2015) found that out of 31 measured characters, there were 9 characters that distinguished male and female *Siganus canaliculatus* fish in the waters of Binuang District, West Sulawesi, namely the length of the longest dorsal fin, longest dorsal fin ray, and the length of the weak rays, longest anal fin, tail tail height, upper jaw length (maxilla length), head height, cheek height and eye width. Meanwhile, 17 characters were found that distinguish male and female *Siganus canaliculatus* fish in Sinjai waters, South Sulawesi, namely total length, fork length, dorsal fin base length, pectoral fin base length, pelvic fin base length, anal fin base length, dorsal fin length, length of the head back of the eyes, height of longest weak rays of dorsal fins, length of longest weak rays of anal fin, length of longest hard rays of anal fins, height of tail, length of upper jaw (maxilla length), head height, cheek height, head width, and body width indicate that female *Siganus canaliculatus* were longer in body length than males.

Jumriani (2017) found that there is one-character difference between males and females of *Siganus canaliculatus* landed at TPI Paotere (Makassar Strait), namely the height of the tail trunk (females have it longer than males). While the difference between male and female *Siganus canaliculatus* fish landed at TPI Lappa, Sinjai has 1 character, namely the longest hard rays of the anal fin (females have it longer than males).

Bone Gulf waters are semi-closed waters compared to the waters of the Makassar Strait and the Flores Sea, because geographically it is located in the east of South Sulawesi and west of Southeast Sulawesi. Based on this geographical location, the conditions from the Bone Gulf are relatively different from the conditions in the Makassar Strait and Flores Sea (Jamal 2007). Based on the results of image analysis of sea surface temperature (SST), the highest surface temperature of the Makassar Strait in December 2017 - February 2017 ranged from 31.2 - 31.7°C, and the lowest in June 2017 - August 2017 ranged from 29.2 – 29.7°C. The highest Flores Sea surface temperature in December 2017 - February 2017 ranged between 31.2°C - 31.7°C, and the lowest in June 2017 - August 2017 ranged from 27.1°C - 19.2°C. The highest surface temperature of Bone Gulf in December 2017 - February 2017 ranged from 31.7°C – 34.9°C, and the lowest in June 2017 - August 2017 ranged from 27.1°C - 27.2°C. The current velocity of the Makassar Strait and Bone Bay in December 2017 - November 2017 ranged from 0.0069 (m/s) - 0.1385 (m/s) while in the Flores Sea it ranged from 0.13888 (m/s) - 0.27 (m/s). Sahabuddin et al (2015) found that the characteristic of white-spotted spinefoot fish in the waters of Bone Gulf (the length of the upper jaw, the height of the tail and the width of the eyes) were higher than those of Pare-Pare waters.

According to Effendie (2002) differences in aquatic environmental conditions can have an impact on adaptation patterns, including adaptation in body shape and size or number of body parts. Other factors that can also affect morphometric characteristics were temperature, dissolved oxygen content, salinity, or the availability of food sources that affect the growth of fish larvae (Burhanuddin et al 2014). Based on the results of image analysis from February 2017 - November 2017, the chlorophyll-a content in the Makassar Strait waters ranged from 0.7464 to 0.9214 (mg/m^3), the Flores Sea ranged from 0.3451 - 0.4342 (mg/m^3), and Bone Gulf ranged from 0.1094 - 0.1922 (mg/m^3). The chlorophyll-a content can be used as a measure of the number of phytoplankton in certain waters so that it can be used as a parameter or an indication of the fertility or productivity of a water area. We assumed that the chlorophyll-a contents in the water indicated the areas natural productivity, and therefore the chlorophyll-a content affected indirectly the morphometric characteristic of fish.

Conclusion. The male white-spotted spinefoot fish from Makassar Strait, Flores Sea, and Gulf of Bone presented 6 different morphometric characteristics, i.e head height, interorbital length, the longest anal soft fin ray length, orbital width, standard length, and maxilla length, while 7 morphometric differences of female white-spotted spinefoot fish found in the three locations were interorbital length, the longest dorsal spine length, the longest anal soft ray length, mouth-opening width, the longest dorsal soft ray, the longest anal soft ray, and pre-dorsal fin length. There is a large difference on the morphophometrical characteristics from Makassar Strait and Flores Sea. The morphometric similarities are suspected to be related to the condition of the fish habitat between study sites. We further suggest a genetic analysis of the three populations, to accurately determine the differences between them (Makassar Strait, Flores Sea and Bone Gulf).

Acknowledgements. We would like to thank to the Head of Fisheries Biology Laboratory who facilitated the samples anlaysis. We also thank to Moh. Tauhid Umar who helped us with the data analysis. We would gladly thank as well to Nita Rukminasari who helped us with the editing and revising of our manuscript, Mr. Tallo and Mr. Arif as well as all fishermen and people around the sampling area who had facilitated and assisted during sampling.

References

Allen G., Swainston R., Ruse J., 2000 Marine Fishes of South-Eash Asia. Periplus Editions (HK) Ltd, Singapore.

Al-qishawe M. M. S., Ali T. S., Abahussain A. A., 2014 Stock assessment of white spotted rabbitfish (*Siganus canaliculatus* Park , 1797) in Jubail marine wildlife sanctuary, Saudi Arabia. Int. J. Fish. Aquat. Stud. 1, 48–54.

Bailey K. M., 1997 Structural dynamics and ecology of flatfish populations. J. Sea Res. 37, 269–280.

Bell J. D., Leber K. M., Blankenship H. L., Loneragan N. R., Masuda R., 2008 A new era for restocking, stock enhancement and sea ranching of coastal fisheries resources. Rev. Fish. Sci. 16, 1–9.

Burhanudin, Budimawan, Sahabuddin, 2014 International Journal of Plant, Animal and Environmental Sciences. Int. J. Plant, Anim. Environ. Sci. 95–102.

Cadrin S. X., Friedland K. D., 1999 The utility of image processing techniques for morphometric analysis and stock identification. Fish. Res. 43, 129–139.

Carpenter K. E., 2001 The Living Marine Resources of The Western Central Pacific. Vol. 6. pp. 3627-3650. FAO. Roma.

Effendie M. I., 2002 [Fisheries Biology]. Yayasan Pustaka Nusatama, Yogyakarta [in Indonesian].

Fagbuaro O., Oso J., Olurotimi M., Akinyemi O., 2015 Morphometric and Meristic Characteristics of *Clarias gariepinus* from Controlled and Uncontrolled Population from Southwestern Nigeria. J. Agric. Ecol. Res. Int. 2, 39–45.

Gorospe J. G., Demayo C. G., 2013 Population variability of the Golden rabbitfish (*Siganus guttatus* Bloch) (Pisces: Siganidae) in Northern Mindanao, Philippines. AACL Bioflux 6, 188–201.

Gundermann N., Popper D. M., Lichatowich T., 1983 Biology and life cycle of *Siganus vermiculatus* (Siganidae, Pisces). Pacific Sci. 37, 165–180.

Hammami I., Bahri-Sfar L., Kaoueche M., Grenouillet G., Lek S., Kara M. H., Ben Hassine O. K., 2013 Morphological characterization of striped seabream (*Lithognathus mormyrus*, Sparidae) in some Mediterranean lagoons. Cybium 37, 127–139.

Iswanto B., Imron I., Suprapto R., Marnis H., 2015 Morphological Characterization Of The African Catfish (*Clarias gariepinus* Burchell, 1822) Strains Introduced To Indonesia. Indones. Aquac. J. 10, 91.

Jaikumar M., 2012 A Review On Biology And Aquaculture Potential Of Rabbit Fish In Tamilnadu (*Siganus canaliculatus*). Int. J. Plant, Anim. Environ. Sci. 2, 57–64.

Jamal M., 2007 [Tuna (*Katsuwonus pelamis*) fisheries analysis at Bone Gulf: The correlation between biological and environmental aspects]. Thesis. Institut Pertanian Bogor [in Indonesian].

Jumriani J., 2017 [Morphometric and meristic of rabbit fish (*Siganus canaliculatus*) from Makassar Strait]. Thesis. Universitas Hasanuddin [in Indonesian].

Koeshendrajana S., Rusastra I. W., Martosubroto P., 2019 [Marine and fisheries resources potential] [in Indonesian].

Lam T. J., 1974 Siganids: Their biology and mariculture potential. Aquaculture 3, 325–354.

Lipcius R. N., Eggleston D. B., Schreiber S. J., Seitz R. D., Shen J., Sisson M., Stockhausen W. T., Wang H. V., 2008 Importance of metapopulation connectivity to restocking and restoration of marine species. Rev. Fish. Sci. 16, 101–110.

Mejri R., Lo Brutto S., Hassine N., Arculeo M., Hassine O. K., Ben, 2012 Overlapping patterns of morphometric and genetic differentiation in the Mediterranean goby *Pomatoschistus tortonesei* Miller, 1968 (Perciformes, Gobiidae) in Tunisian lagoons. Zoology 115, 239–244.

Palma J., Andrade J. P., 2002 Morphological study of *Diplodus sargus*, *Diplodus puntazzo*, and *Lithognathus mormyrus* (Sparidae) in the Eastern Atlantic and Mediterranean Sea. Fish. Res. 57, 1–8.

Randall J. E, Kulbicki M., 2005 *Siganus woodlandi,* new species of rabbitfish (Siganidae) from New Caledonia. Cybium, 29(2), 185 - 189.

Sahabuddin S., Burhanuddin I., Malina A. C., Nurhapsa N., 2015 [Morphometric and

meristic of rabbit fish (*Siganus canaliculatus* PARK, 1797) from Bone Gulf and Makassar Strait]. Torani (Journal of Marine Science and Fisheries) 25, 44–52 [in Indonesian].
Saripah, 2009 Study of rabbit fish (*Siganus canaliculatus*) morphometric and meristic characteristics from Binuang and Sinjai Waters. Thesis. Universitas Hasanuddin. Makassar.
Soliman V. S., Bobiles R. U., Yamaoka K., 2009 Overfishing of Three Siganid Species (Family : Siganidae) in Lagonoy Gulf , Philippines. Kuroshio Sci. 145–150.
Turan C., 1999 A note on the examination of morphometric differentiation among fish populations: The Truss System. Turkish J. Zool. 23, 259–263.
Turan C., 2004 Stock identification of Mediterranean horse mackerel (*Trachurus mediterraneus*) using morphometric and meristic characters. ICES J. Mar. Sci. 61, 774–781.
Umar M. T., Omar S. B. A. O., Suwarni S., 2018 [Baronang fish stock status (Siganidae) at Makassar Waters, South Sulawesi]. Makassar [in Indonesian].
Woodland D. J., 1995 Rabbitfishes (spinefoots). pp. 3627–3641.
Woodland D. J., Anderson R. C., 2014 Description of a new species of rabbitfish (Perciformes: Siganidae) from southern India, Sri Lanka and the Maldives. Zootaxa 3811, 129–136.
Yunus M., 2005 [The difference morphometric and meristic characteristic of Siganidae family]. Thesis. Universitas Hasanuddin [in Indonesian].

Received: 12 April 2020. Accepted: 13 May 2020. Published online: 30 August 2020.
Authors:
Suwarni, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, e-mail: suwarniliger17@gmail.com
Joeharnai Tresnati, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, e-mail: naniethardjoeno@gmail.com
Ambo Tuwo, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, e-mail: ambotuwo62@gmail.com
Sharifuddin Bin Andy Omar, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, e-mail: sbandyomar@gmail.com

How to cite this article:
Suwarni, Tresnati J., Tuwo A., Omar S. B. A., 2020 Morphometric characteristics of rabbit fish (*Siganus canaliculatus* Park, 1797) in Makassar Strait, Flores Sea, and Bone Gulf. AACL Bioflux 13(4):2343-2354.