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MORPHOMETRIC AND MERISTIC CHARACTERISTICS OF *Siganus virgatus* (Valenciennes, 1835) IN THE SPERMONDE WATERS, SOUTH SULAWESI

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ABSTRACT

Indonesia is recognized as a global center of marine biodiversity, including members of the family Siganidae. However, detailed data on species specific morphological characteristics remain limited in dynamic marine environments such as the Spermonde Archipelago. This study aimed to comprehensively describe the morphological characteristics of *Siganus virgatus* in the waters of the Spermonde Archipelago to establish a taxonomic baseline and support fisheries management. A total of 50 specimens were collected from Paotere Fish Landing Center between January and February 2026 and analyzed using morphometric and meristic approaches. The results revealed that *S. virgatus* in this region exhibits a characteristic oval body profile, with two dark brown diagonal bands serving as its primary diagnostic feature. Morphometric measurements indicated a mean total length of 158.8 mm, while caudal fin shape varied from emarginate to moderately forked with increasing individual age. Principal Component Analysis (PCA) revealed that the first three principal components accounted for 99.28% of the total data variance, with PC1 predominantly associated with body size (98.84%), whereas PC2 and PC3 represented body shape characteristics, particularly body depth proportions and caudal fin emargination. Overall, the morphological characteristics of specimens from the Spermonde Archipelago were consistent with standard taxonomic descriptions of the species in the western Indo-Pacific region. These findings strengthen the reliability of species identification and provide baseline morphological data to support the sustainable management of local fisheries resources.

Keywords: *Siganus virgatus*; Morphometrics; Meristics; Spermonde Archipelago; Paotere; Principal Component Analysis (PCA).

INTRODUCTION

Indonesia is recognized as a global center of marine biodiversity, including members of the family Siganidae. The waters surrounding Sulawesi support a particularly high species richness, with 17 species recorded (Burhanuddin *et al*., 2014; Burhanuddin *et al*., 2025). One species of considerable ecological and economic importance is *Siganus virgatus* (Achille Valenciennes, 1835), locally known as baronang kae-kae or baronang cura, and more commonly referred to internationally as the Barhead spinefoot (Nguyen *et al*., 2024). *S. virgatus* belongs to the family Siganidae, commonly known as rabbitfishes (Awaluddin & Nadiarti, 2024). The species is distributed throughout the coastal waters of India, Southeast Asia, and northern Australia (Carpenter & Niem, 2001; Nguyen *et al*., 2024). *S. virgatus* is a demersal herbivorous fish that typically inhabits seagrass beds and coral reef ecosystems (Muller *et al*., 2021).

As a demersal herbivore, *Siganus virgatus* plays an important role in maintaining the ecological balance of coral reef and seagrass ecosystems by regulating algal growth (Muller *et al*., 2021). Geographically, the species exhibits a broad distribution along coastal regions extending from India and Southeast Asia to northern Australia (Carpenter & Niem, 2001; Nguyen *et al*., 2024). Despite its extensive distribution, the morphological identification of *S. virgatus* can be challenging because of phenotypic variation associated with different growth stages (Zarco-Perollo *et al*., 2023). Its principal distinguishing characteristics include a non-tubular snout and continuity between the spinous and soft portions of the dorsal fin (Awaluddin & Nadiarti, 2024; Kim *et al*., 2025). Furthermore, ontogenetic changes in caudal fin morphology, from an emarginate shape in juveniles to a forked shape in adults, further complicate taxonomic identification (Burhanuddin *et al*., 2014; Kim *et al*., 2025).

Although the general morphological characteristics of *Siganus virgatus* have been documented, variations in physical traits among populations from different locations may occur in response to local environmental conditions (Suwarni *et al*., 2020). The Spermonde Archipelago in South Sulawesi represents one of

Indonesia's most dynamic and ecologically important coral reef systems. However, detailed information on the morphological characteristics of *S. virgatus* in this region remains limited. Therefore, a comprehensive understanding of the morphometric and meristic characteristics of this species in the Spermonde Archipelago is essential for accurate taxonomic identification and for establishing baseline data to support the sustainable management of fisheries resources (Molina & Malaya, 2025). Accordingly, this study aims to provide a comprehensive description of the morphological characteristics of *S. virgatus* in the waters of the Spermonde Archipelago, thereby addressing the existing knowledge gap regarding phenotypic variation in this species within the region.

MATERIALS AND METHODS

Sampling Period and Location

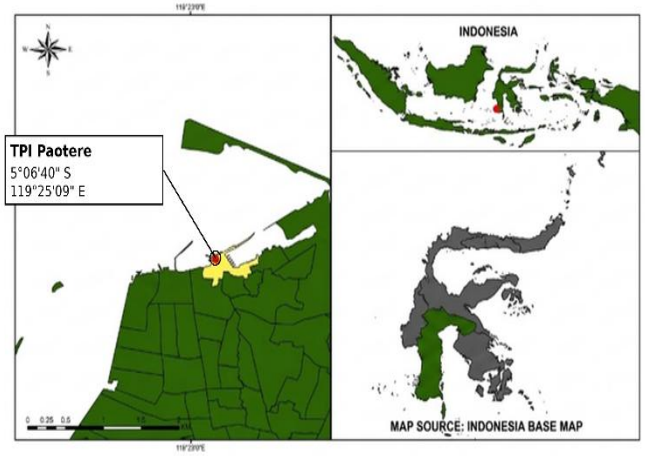


Figure 1. Study location for *Siganus virgatus* at the Paotere Fish Landing Center (TPI), Makassar, Indonesia

A total of 50 *Siganus virgatus* specimens were collected between January and February 2026 from the Paotere Fish Landing Center, located in Gusung District, Makassar, Indonesia. This site was selected because it serves as one of the major landing points for fish catches from the waters of the Spermonde Archipelago.



Figure 2. Conditions at the *Siganus virgatus* sampling site at Paotere Fish Market, Makassar, Indonesia.

Laboratory Procedures

Morphological analyses were conducted at the Marine Biology Laboratory, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia. Specimen identification was performed using morphometric and meristic approaches, beginning with sample preparation, which involved cleaning the specimens, spreading the fins, photographing, and labeling the samples. The specimens were subsequently immersed in a 7% formalin solution for five days, followed by rinsing under running water for three days to remove residual formalin from the tissues. The specimens were then immersed in 70% ethanol for seven days for preservation, ensuring that they remained in suitable condition for subsequent morphometric and meristic measurements.

Morphometric and Meristic Analyses

Morphometric measurements were obtained using a vernier caliper with a precision of 0.01 mm, following the protocol described by Randall and Kulbicki (2005). The parameters measured included body dimensions, namely standard length (SL), maximum body depth, body width, and caudal peduncle length and depth; head characteristics, including head length, snout length, orbital diameter, interorbital width, and cheek depth; and fin measurements, comprising caudal fin length and caudal fin fork depth. For meristic analysis, the numbers of fin spines and soft rays were counted for the dorsal, anal, pectoral, caudal, and pelvic fins. Additionally, the number of scales along the longitudinal row above the lateral line and the number of gill rakers on the first gill arch were recorded.

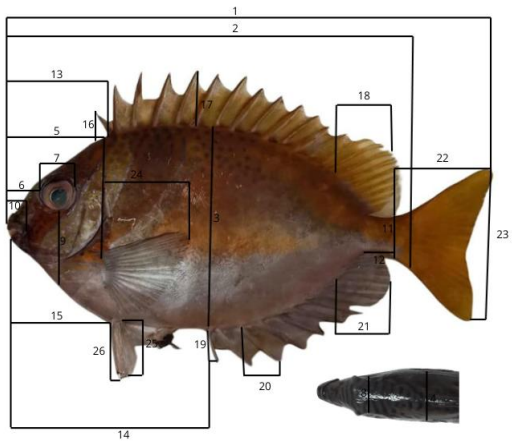


Figure 3. Morphometric and meristic measurements of *Siganus virgatus* 1. Total length, 2. Standard length, 3. Body depth, 4. Body width, 5. Head length, 6. Snout length, 7. Orbital diameter, 8. Interorbital width, 9. Cheek depth, 10. Upper jaw length, 11. Caudal peduncle depth, 12. Caudal peduncle length, 13. Predorsal length, 14. Preanal length, 15. Prepelvic length, 16. First dorsal-fin spine, 17. Longest dorsal-fin spine, 18. Longest dorsal-fin ray, 19. First anal-fin spine, 20. Longest anal-fin spine, 21. Longest anal-fin ray, 22. Caudal-fin length, 23. Caudal-fin emargination, 24. Pectoral-fin length, 25. First pelvic-fin spine, and 26. Longest pelvic-fin ray.

Statistical Analysis

All morphometric characters were expressed as proportions of standard length (SL) to minimize the influence of differences in body size among individuals, using the following formula: Proportion (%) = (character measurement / SL) × 100 (Randall & Kulbicki, 2005). SL was measured from the tip of the upper lip to the base of the caudal fin. The resulting proportional data were subsequently analyzed using Principal Component Analysis (PCA) in PAST version 4.03, based on a [correlation/covariance] matrix. PCA was employed to reduce the number of morphometric variables into a smaller set of principal components and identify the characters contributing most substantially to morphological variation in *Siganus virgatus*. The principal components retained for interpretation were selected based on their eigenvalues and cumulative percentage of variance explained.

RESULTS AND DISCUSSION

Description

The examined specimens of *Siganus virgatus* exhibited a laterally compressed body with an oval profile (Figure 4; Table 1), a characteristic feature of the family Siganidae. The snout was non-tubular, and the mouth was subterminal, equipped with rows of fine teeth adapted to its herbivorous feeding habits. Visual examination revealed a continuous dorsal fin without a distinct notch separating the spinous and soft-rayed portions, comprising 13 spines (XIII) and 10 soft rays. The principal diagnostic feature distinguishing this species was the presence of two dark brown diagonal bands. The first band crossed the eye, extending from the nape to the chin, whereas the second, broader band extended from the base of the fourth dorsal-fin spine toward the base of the pectoral fin. The orbital diameter appeared proportionate to head length, while the cheek region exhibited a distribution of fine scales that was generally concentrated in the posterior portion. The caudal fin displayed variation in shape, ranging from slightly emarginate to moderately forked,

potentially reflecting differences in ontogenetic development and proximity to maturity. The pelvic fin exhibited the characteristic structure of Siganidae, consisting of two robust spines flanking three soft rays. Overall, the external morphology of the examined specimens was consistent with standard taxonomic descriptions of populations in the western Indo-Pacific, particularly with respect to body proportions and the characteristic paired pigmented bands on the anterior body.



Figure 4. Lateral view of *Siganus virgatus* (family Siganidae) collected from the Spermonde Archipelago, South Sulawesi, Indonesia

Body proportions were characterized by a relatively large body depth (Table 1), ranging from 50.0 to 72.1 mm, while head length had a median value of 30.8 mm. In the anterior region, snout length ranged from 10.3 to 19.2 mm, whereas orbital diameter was relatively small, with a median value of 11.3 mm. These morphometric proportions indicate a characteristic body structure in this species.

Table 1. Morphometric measurements of *Siganus virgatus* from the Spermonde Archipelago

Character	***Siganus virgatus*** **N=50** **Range (Mean)**
Morphometric	
Total length	158,8±10,8 (126,7–177,1)
Standard Length	132,1±9,3 (107,1–153,2)
%SL	
Body depth	64,4±4,6 (50,0–72,1)
Body width	18,5±2,0 (12,3–21,6)
Head length	38,1±2,9 (30,8–43,6)
Snout length	15,5±1,9 (10,3–19,2)
Orbital diameter	11,3±1,0 (9,1–13,4)
Interorbital width	12,5±1,6 (8,7–16,1)
Cheek depth	26,9±2,8 (18,4–30,7)
Upper-jaw length	8,9±0,8 (6,3–10,2)
Caudal peduncle depth	10,4±1,6 (7,3–15,5)
Caudal peduncle length	6,7±1,6 (4,4–12,4)
Predorsal length	38,2±3,5 (28,8–44,7)
Preanal length	72,3±5,9 (56,5–82,2)
Prepelvic length	42,0±4,1 (30,2–50,1)
First dorsal spine	9,3±1,7 (6,5–16,4)

Character	*Siganus virgatus* N=50 Range (Mean)
Longest dorsal spine	19,7±1,6 (15,6–22,7)
Longest dorsal ray	23,0±2,0 (18,8–27,5)
First anal spine	12,8±1,2 (10,5–15,8)
Longest anal spine	19,7±1,6 (15,9–22,9)
Longest anal ray	19,5±1,8 (14,8–25,4)
Caudal fin length	32,2±2,9 (25,9–37,5)
Caudal concavity	2,6±1,5 (1,1–6,0)
Pectoral fin length	31,5±3,5 (24,1–47,8)
First pelvic spine	20,0±2,0 (14,9–25,5)
Longest pelvic ray	21,2±3,1 (15,3–28,7)

Table 2. Meristic measurements of *Siganus virgatus* from the Spermonde Archipelago

Character	*Siganus virgatus* N=50
Dorsal fin	XIII,10
Anal fin	VII,9
Pelvic fin	II,3
Pectoral fin	XV
Caudal fin	17–18

Regarding the fins and locomotor structures (Table 1), the longest dorsal-fin spine had a mean length of 15.6 mm, identical to the mean length recorded for the longest anal-fin spine. Fin measurements indicated that the caudal fin had a mean length of 32.2 mm, with caudal-fin emargination ranging from 1.5 to 2.6 mm. In addition, pectoral-fin length exhibited a relatively broad range, varying from 24.1 to 47.8 mm, reflecting the specific morphological characteristics of the locomotor structures in the examined *Siganus virgatus* specimens.

Coloration

Based on observations of the specimens (Figure 3), *Siganus virgatus* exhibited a characteristic coloration gradient between the dorsal and ventral regions. The upper body was predominantly yellowish-brown, gradually transitioning to silvery white toward the abdomen. One of the most prominent taxonomic features was the presence of two dark brown diagonal bands. The first band crossed the eye, extending from the nape to the chin, whereas the second, broader band extended from the base of the anterior dorsal-fin spines toward the pectoral-fin region. Small, pale blue or white spots were irregularly distributed across the head and upper dorsal surface. Fin coloration also exhibited distinctive characteristics: the dorsal and anal fins were predominantly translucent yellow, whereas the caudal fin displayed a more intense and uniform yellow coloration than the other fins. In contrast, the pectoral fins appeared more transparent or hyaline. This distinctive pattern of two dark diagonal bands represents a key visual diagnostic feature for distinguishing *S. virgatus* from closely related species.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) of the morphometric variables revealed a distinctive distribution of variation across the principal components (Table 3). The first principal component (PC1) exhibited highly uniform and consistently positive loadings across all variables (approximately 0.14). This pattern suggests that PC1 represents a general size factor, with the variation captured primarily reflecting overall differences in linear body dimensions among individuals.

Table 3. Eigenvalues and Percentage of Variance Explained by Principal Component Analysis (PCA) of the Morphometric Characteristics of *Siganus virgatus* from the Spermonde Archipelago.

PC	Eigen value	Variance (%)
1	49.4238	98.848
2	0.124616	0.24923
3	0.0910247	0.18205

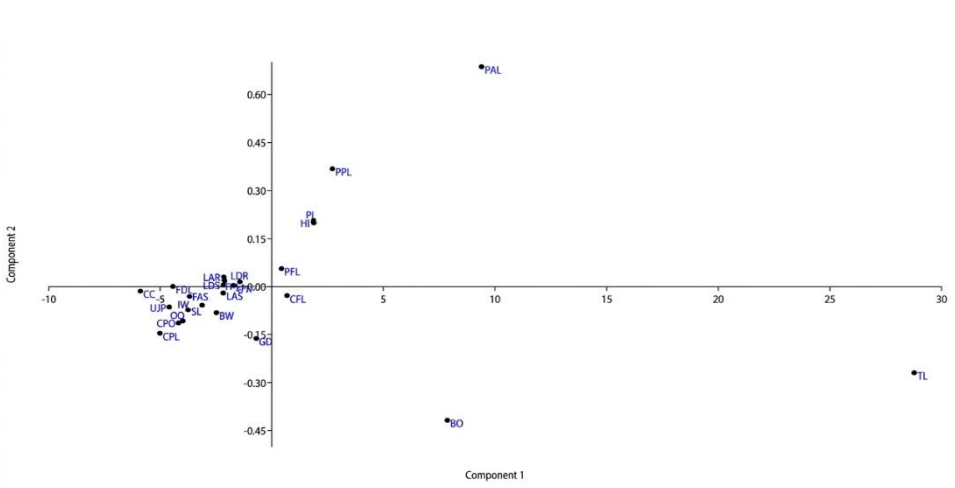


Figure 5. Loading Plot of the Principal Component Analysis (PCA) of the Morphometric Characteristics of *Siganus virgatus*.

Total length (TL), standard length (SL), body depth (BD), body width (BW), head length (HL), snout length (SnL), orbital diameter (OD), interorbital width (IW), cheek depth (CD), upper jaw length (UL), caudal peduncle depth (CBD), caudal peduncle length (CBL), predorsal length (PDL), preanal length (PAL), prepelvic length (PPL), first dorsal-fin spine (FDS), longest dorsal-fin spine (LDS), longest dorsal-fin ray (LDR), first anal-fin spine (FAS), longest anal-fin spine (LAS), longest anal-fin ray (LAR), caudal-fin length (CFL), caudal-fin emargination (CN), pectoral-fin length (PFL), first pelvic-fin spine (FPS), and longest pelvic-fin ray (LPR).

As shown in Table 4, more specific variation in body shape, representing shape-related factors, emerged in the subsequent principal components. The second principal component (PC2) was most strongly influenced by postorbital distance, with a loading value of 0.517. This indicates that morphological variation along this component was primarily associated with the proportional length of the posterior region of the head. The third principal component (PC3) was dominated by dorsal-fin base length, with a loading value of 0.532. Notably, the same character was also the primary contributor to PC4, with a loading value of 0.357, further highlighting dorsal-fin dimensions as an important source of morphological variation in this population. The fifth principal component (PC5) was strongly influenced by body depth at the anal-fin region, which exhibited the highest loading among the reported components, at 0.657. This suggests substantial variation in body depth in the ventral region. The eighth principal component (PC8), characterized by snout length with a loading value of 0.491, indicated morphological variation in the anterior region of the head.

Table 4. Dominant Morphometric Characters Across Principal Components (PCs) of *Siganus virgatus* from the Spermonde Archipelago

Character	PC	Loading
Orbital Distance	PC2	0.517
Dorsal-fin base length	PC3	0.532
Dorsal-fin base length	PC4	0.357
Body depth at the anal-fin region	PC5	0.657
Orbital Distance	PC8	0.476

The morphological identification results indicated that the *Siganus virgatus* specimens collected from the Spermonde Archipelago exhibited physical characteristics consistent with standard descriptions of the family Siganidae, particularly their laterally compressed bodies and oval profiles. The most prominent

diagnostic feature was the presence of two dark brown diagonal bands. The first band crossed the eye, extending from the upper head region toward the chin, while the second extended from the base of the fourth dorsal-fin spine toward the base of the pectoral fin (Hoey *et al*., 2025). This distinctive double-band pigmentation pattern, together with pale blue spots on the head, represents an important taxonomic feature for distinguishing this species from closely related taxa in the western Indo-Pacific (Kim *et al*., 2025). Furthermore, the subterminal mouth position and fine tooth structure support its ecological adaptation as a demersal herbivore, which plays an important role in regulating algal growth within coral reef ecosystems (Fox & Bellwood, 2007).

The observed morphometric variation in the head region provides insights into individual developmental patterns within the population. Head shape and its proportions relative to standard length are characteristic features of *Siganus* species and reflect adaptations commonly observed in herbivorous fishes (Sahabuddin *et al*., 2015). Gaffar *et al*. (2022) reported that *Siganus virgatus* exhibits more pronounced morphometric changes in the head region as individuals grow, with these changes correlated with total length. These findings are supported by the Principal Component Analysis (PCA), particularly PC2, which was reported to be dominated by anterior body characteristics, with the highest loading value reaching 0.24. This result suggests that head morphology represents an important source of variation among the individuals examined (Wambiji, 2020).

Furthermore, the PCA loading plot indicated that morphometric variation among specimens was influenced by both body size and shape. The first principal component (PC1), which explained 98.8% of the total variance, represented a general size factor, with most variables, including total length (TL), exhibiting relatively uniform and positive loadings. This pattern indicates that differences in linear body dimensions were the primary source of variation among specimens collected from the Paotere Fish Landing Center (TPI Paotere). Meanwhile, the second (PC2) and third (PC3) principal components were interpreted as representing shape-related variation, particularly differences in caudal peduncle proportions and caudal fin morphology. Overall, these comprehensive morphological data provide a basis for reliable taxonomic identification and contribute valuable baseline information to support the sustainable management of fisheries resources in the Spermonde Archipelago (Muller *et al*., 2021).

Distribution

Geographically, *Siganus virgatus* has a broad distribution throughout the western Indo-Pacific. The species has been reported in the coastal waters of India, Southeast Asia, and northern Australia, as well as in various tropical marine environments, including the Philippines, Vietnam, and Indonesia (Awaluddin & Nadiarti, 2024; Nguyen *et al*., 2024). Its extensive distribution suggests a strong capacity to adapt to diverse tropical coastal environments, particularly habitats characterized by high primary productivity (Zarco-Perollo *et al*., 2023).

Ecologically, *Siganus virgatus* is commonly found in shallow waters associated with seagrass beds, lagoons, and coral reefs. These habitats provide its primary food resources, particularly benthic algae, which constitute an important component of the diet of herbivorous fishes in the family Siganidae (Mantyka & Bellwood, 2007). The grazing activities of rabbitfishes play a crucial ecological role in maintaining coral reef balance by controlling algal growth, which may otherwise become dominant on coral substrates (Mantyka & Bellwood, 2007; Fox & Bellwood, 2013).

In Indonesia, this species has been recorded in various coastal regions with well developed coral reef ecosystems, including the waters of South Sulawesi. The Spermonde Archipelago is one such region, characterized by complex coral reef habitats that support diverse reef fish communities, including rabbitfishes of the family Siganidae (Burhanuddin *et al*., 2014). The combination of seagrass beds, coral reefs, and sandy substrates provides potentially suitable habitats for herbivorous species such as *Siganus virgatus*. The specimens examined in this study were obtained from the Paotere Fish Landing Center (TPI) in Makassar, which serves as a major landing and trading point for fish caught by fishers operating around the Spermonde Archipelago. The presence of *S. virgatus* among the landed catches suggests that the species occurs in the surrounding region, potentially across a range of coral reef and seagrass habitats. However, confirming its distribution and habitat associations throughout the archipelago requires targeted ecological surveys. The occurrence of this species in catches from the Spermonde Archipelago further highlights the ecological importance of the region for herbivorous reef fishes that contribute to the maintenance of tropical coastal ecosystem stability (Burhanuddin *et al*., 2014; Fox & Bellwood, 2013).

CONCLUSION

Based on the findings of this study, *Siganus virgatus* specimens from the waters of the Spermonde Archipelago exhibited characteristic morphological features consistent with standard taxonomic descriptions of the species in the western Indo-Pacific. The fish displayed a laterally compressed body with an oval profile and could be visually identified by two dark brown diagonal bands on the anterior region of the body. The examined specimens had a mean total length of 158.8 mm, while caudal fin morphology varied from slightly emarginate in smaller individuals to moderately forked in larger specimens. The identified meristic formulae were XIII,10 for the dorsal fin, VII,9 for the anal fin, and II,3 for the pelvic fin. Principal Component Analysis (PCA) revealed that the first three principal components accounted for 99.28% of the total morphometric variance. This variation was dominated by body size in PC1 (98.85%), whereas PC2 and PC3 represented shape-related variation, particularly in caudal peduncle proportions, caudal fin emargination, and dorsal fin dimensions. A limitation of this study was the absence of sex determination and gonadal maturity assessment, which prevented the separate evaluation of potential sexual dimorphism in morphometric variation. Overall, the morphometric and meristic data provide a taxonomic basis for characterizing phenotypic variation in *S. virgatus* from the Spermonde Archipelago and establish valuable baseline information to support the sustainable management and conservation of local fisheries resources.

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