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MORPHOLOGICAL PLASTICITY AND TAXONOMIC IMPLICATIONS OF *FAVITES* CORALS FROM SPERMONDE ARCHIPELAGO

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ABSTRACT

Morphologycal characterstic both descriptive and morphometric, like corralite diameter, corralite shape, the presence or absence of paliform lobe, colonies surface form, and septa teeth were the key for determining the Favites coral species characters, but these character are often influenced by environmental factors. In this studi will be try to reconstructed phylogeny tree of *Favites* coral"s (*Favites abdita*, *F. benattae*, *F. chinensis*, *F. flexuosa*, *F. halicora*, and *F. paraflexuosa*). The speciment collected from Spermonde Archipelago. Phylogeny tree was reconstructed based on the morphological characters (descriptive and morphometric) using UPGMA (Unweighted Pair Group Method with Arithmetic Mean) Methood on PAUP 4.0 software. The result showed the grouping of taxa for each species. However, if only using morphometric character in preparing the taxa group, it will not show the clear differences among species. This caused by the morphometric characters have the highest plasticity and influenced by environmental factors, if compared with the descriptive character.

Keywords: *Favites* coral, morphology variation, Spermonde Archipelago.

INTRODUCTION

Several morphological variations in corals have been reported, including variation in corallite shapes within the same colony, variation in different parts of a single colony, variation among colonies within the same biotope, variation between different environmental conditions, regional variation, and even variation not in the skeleton but in the polyps (Veron, 1995). These variations pose major challenges in coral identification. Another difficulty is that terminologies are not universally applicable to all coral taxa, as almost every family or even genus has its own specific terminologies (Suharsono, 2008). This makes coral taxonomy more complex compared to other taxa.

Environmental factors strongly contribute to the morphological variations observed in corals. Such phenomena have been widely documented. For instance, Pocillopora damicornis from different depths in the Great Barrier Reef exhibits distinct growth forms (Veron, 1995). Goniastrea pectinata at deeper waters develops wider calices to maximize light capture, whereas in shallow waters its calices are more compact to protect tissues from excessive radiation (Ow and Todd, 2010). Similarly, *Favia speciosa* transplanted to unusual depths undergoes changes in corallite structure (Todd, 2008). Growth forms of *Pocillopora damicornis* also vary under different current velocities and light intensities (Todd, 2008). Kramer et al. (2022) highlighted that the morphological architecture of *Stylophora pistillata* skeletons is a key determinant of photoadaptation, whereby mesophotic morphotypes enhance solar energy utilization under low-light conditions, whereas shallow-water morphotypes mitigate excess irradiance through self-shading skeletal features. There were significant differences between populations inhabit different depths and turbidity levels (Ghafari et al., 2024). In sub-optimal mangrove environments, *Pocillopora acuta* tends to develop thinner and more porous skeletons, whereas *Montipora cf. digitata* is able to maintain a more robust skeletal structure through larger and more dispersed corallite configurations, highlighting species-specific strategies to cope with environmental stressors (Chadda-Harmer et al., 2025).

Hybridization among coral species has also been reported. For example, *Montastrea annularis*, *M. franksi*, and *M. faveolata* are capable of cross-fertilization, producing fertile larvae (Szmant et al., 1997). This phenomenon is supported by synchronous mass spawning involving multiple coral species. Mass spawning events have been recorded in several regions, such as in Karimunjawa Islands (Permata et al., 2012). In the Spermonde Archipelago, several Acropora species were observed to spawn simultaneously during the full moon in March (Yusuf, 2012). More than 130 species spawn synchronously within days after the full moon in the Great Barrier Reef, with over 30 species spawning at the same hour and night in a single location (Babcock et al., 1986). Similar multi-species spawning has also been reported in Singapore (Guest et al., 2002). Such hybridization, supported by mass spawning, may produce coral individuals with novel morphological forms resulting from crossbreeding between two distinct species.

Another phenomenon observed in corals is the occurrence of sibling species-species that are morphologically identical but genetically, physiologically, ecologically, reproductively, and behaviorally distinct. For example, Montastrea annularis has been shown to consist of three sibling species (Knowlton et al., 1992).

Morphological variation influenced by environmental factors, hybridization facilitated by multi-species spawning, and the existence of sibling species collectively obscure species boundaries in corals. As highlighted by (Best et al., 1984), coral species descriptions continue to increase due to the high degree of morphological variation, which complicates accurate identification. Therefore, studies focusing on morphological approaches remain essential for improving coral taxonomy.

This study aims to identify morphological variations within the genus Favites and to investigate the extent of morphological plasticity in this group. The genus Favites, belonging to the family Faviidae, is grouped with 18 other genera. Faviidae represents the largest family in terms of the number of genera. According to Veron and Staffordsmith (2000) and Suharsono (2008), most members of this family form massive colonies resembling hemispherical heads. Key diagnostic features include the presence of septa, pali, columella, and corallite walls, which are often formed by fused septocostae. Colonies of Favites are typically large, rounded, and cerioid, with intratentacular budding, polygonal corallites, and the absence of a distinct central corallite. Septa are well developed with conspicuous septal teeth, and in some species, pali structures are prominent (Veron, 2000, Suharsono, 2008). High morphological variability in Favites, such as differences in the thickness of the thecae and septal dentition patterns, has been shown to be strongly influenced by environmental factors (Wijsman-Best, 1976).

MATERIALS AND METHODS

A total of six Favites species (*F. abdita*, *F. benattae*, *F. chinensis*, *F. flexuosa*, *F. halicora*, and *F. paraflexuosa*) were collected from several islands within the Spermonde Archipelago, South Sulawesi, Indonesia, namely Barrang Lompo, Dewakkang Lompo, Doangdoangan Lompo, and Marasende (Table 1; Fig. 1).

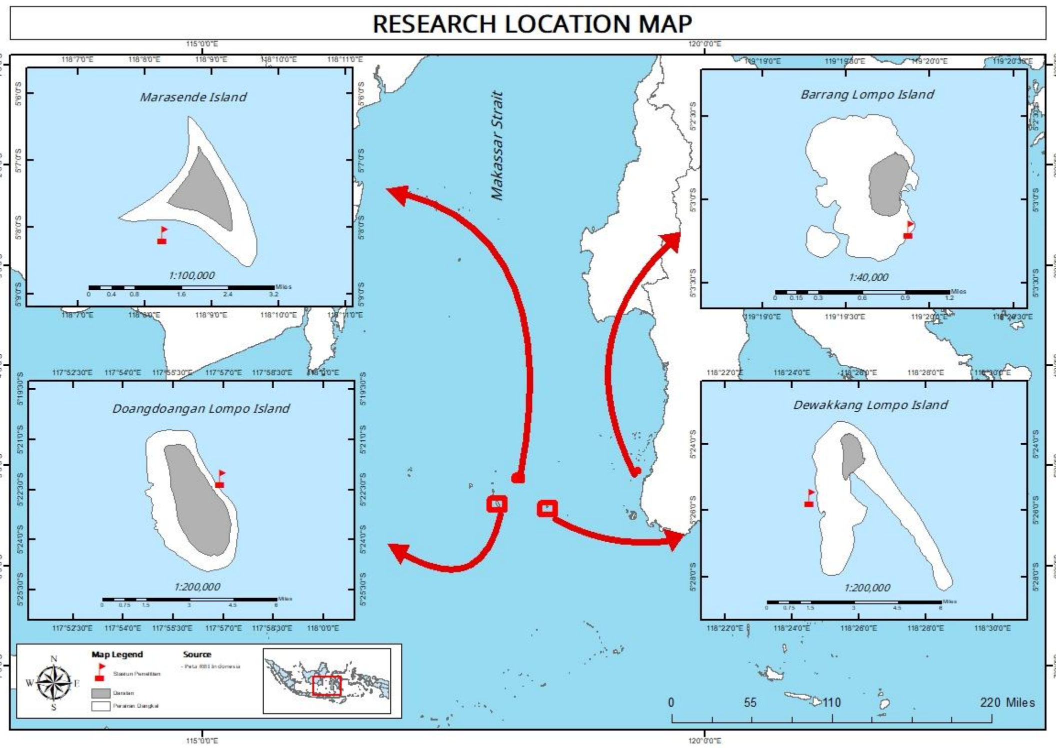

Figure 1. Map of the sampling location of Favites coral specimens

Table 1. List of Specimens

No	Taxa	Collection Site Island	Specimen Code
1	*Favites abdita*	Barrang Lompo	AH009, AH011
		Dewakkang Lompo	AH039, AH051
		Doangdoangan Lompo	AH081, AH085
		Marasende	AH116
2	*Favites chinensis*	Barrang Lompo	AH014, AH021
		Dewakkang Lompo	AH053
3	*Favites flexuosa*	Doangdoangan Lompo	AH086, AH090
4	*Favites halicora*	Barrang Lompo	AH015
5	*Favites paraflexuosa*	Barrang Lompo	AH036
6	*Favites bennattae*	Doangdoangan Lompo	AH083

Data Collection Techniques

Colonies were sampled randomly regardless of depth using scuba diving or snorkeling. Each colony was first photographed in situ with an underwater camera before collection. Coral fragments (approximately 10 × 10 cm) were obtained using a hammer and chisel.

To remove live tissue, fragments were soaked in diluted sodium hypochlorite solution (1:20), rinsed with freshwater, and air-dried prior to analysis.

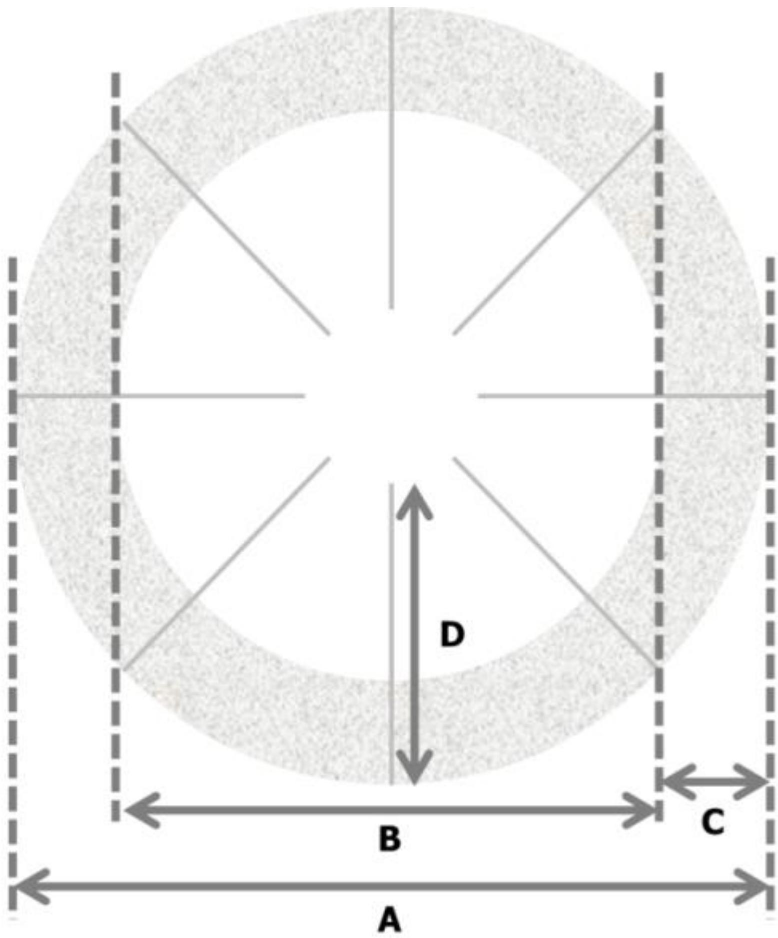

Figure 2. Illustration of corallite parts used as morphometric characters: (A) corallite diameter, (B) calice diameter, (C) corallite wall thickness, and (D) septa length

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Table 2. Morphological characters, including descriptive and morphometric traits

No	Character	Character Status	Character Status Value
1	Corallite diameter (Figure 2A)	Small to Medium (<14 mm)	0
		Large (≥14 mm)	1
2	Type of corallite angle (Figure 3)	Angular	0
		Rounded	1
3	Paliform lobe (Figure 4)	Not developed	0
		Developed	1
4	Colony surface (Figure 5)	Rugose (hill-like)	0
		Not rugose	1
5	Septal teeth (Figure 6)	Very distinct	0
		Indistinct	1
6	Calice diameter (Figure 2B)	< 0,9 cm	0
		≥ 0,9 cm	1
7	Corallite wall thickness (Figure 2C)	< 0,3 cm	0
		≥ 0,3 cm	1
8	Septal length (Figure 2D)	< 0,7 cm	0
		≥ 0,7 cm	1
9	Corallite depth	< 0,6 cm	0
		≥ 0,6 cm	1
10	Number of septa	< 48	0
		≥ 48	1
11	Number of corallite angles	< 5	0
		≥ 5	1

Coral Identification

Specimens were identified to the species level using the taxonomic keys provided by Veron and Pichon (1997), Veron and Staffordsmith (2000), and Suharsono (2008). Diagnostic morphological features such as colony form, corallite structure, septa arrangement, columella, and paliform lobe were examined under a stereo microscope (Olympus SZ61). Close-up images were documented using an Optilab digital camera connected to a computer, as well as a Sony DSC-W320 camera.

Morphological and Morphometric Characters

Both descriptive and morphometric characters were assessed following Wallace (1999) and Wolstenholme et al. (2003). A total of 11 characters were examined, consisting of four descriptive characters (Nos. 2–5) and seven morphometric characters (Nos. 1, 6–11) (Table 2). Each character state was coded into a binary data matrix, with the primitive state coded as "0" and the derived state as "1". Primitive characters were defined as ancestral traits, while derived characters were considered more advanced conditions. The character states were compiled into a morphological character matrix (Table 3) for phylogenetic reconstruction.

Phylogenetic Analysis

Phylogenetic relationships among Favites species were reconstructed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) implemented in PAUP* version 4.0 (Swofford, 2002). The analysis was based on the binary-coded morphological and morphometric data matrix.

Data Analysis

The phylogenetic tree based on morphological characters was reconstructed using the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) method in PAUP 4.0b10 (Swofford, 2002). A total of 11 morphological characters, consisting of both descriptive and morphometric traits, were analyzed. The resulting phylogenetic tree was visualized using FigTree version 1.4 (tree.bio.ed.ac.uk).

In addition, to examine the grouping patterns of Favites species based on morphometric characters, Principal Component Analysis (PCA) and Agglomerative Hierarchical Clustering (AHC) were performed. These analyses were carried out using XLSTAT 2014 (xlstat.com).

RESULTS AND DISCUSSION

Taxonomic Description of *Favites* Species from the Spermonde Archipelago

Six species of the genus Favites were identified from the collected specimens: *F. abdita*, *F. benattae*, *F. chinensis*, *F. flexuosa*, *F. halicora*, and *F. paraflexuosa*. Morphological characters observed for each species are summarized below. *Favites abdita* (Ellis & Solander, 1786) Colonies are typically massive, with cerioid corallites that are slightly hillocky. Septa are vertical with sharp septal teeth. Corallites are generally rounded with prominent septal spines. Colonies are usually brown to yellowish, with a green oral disc. Distribution: reef flats to reef slopes. Widely distributed throughout Indonesian waters. This species was the most frequently encountered during this study.

Favites chinensis (Verrill, 1866) Colonies are massive and rounded. Corallites are shallow, angular to rounded, with thin walls. Septa are straight and paliform lobes are absent. Colony color ranges from yellowish to brown. Commonly found on reef slopes and widely distributed across Indonesian waters.

Favites flexuosa (Dana, 1846) Colonies are hemispherical or occasionally flat. Corallites are angular and deep. Septa are prominent with large, well-defined septal teeth. Paliform lobes are sometimes present. This species is generally found in subtropical regions.

Favites halicora (Ehrenberg, 1834) Colonies are massive, often with irregularly folded surfaces, and occasionally forming short, irregular branches. Corallite walls are thick, sometimes with well-developed pali, which may lead to confusion with Goniastrea. Colonies are light brown to yellow, often with a greenish surface. Typically inhabits shallow reef flats and reef edges. Distribution: widely across Indonesian waters.

Favites paraflexuosa (Veron, 2000) Colonies are massive, dome-shaped. Corallites are cerioid, angular, and deep. Septa are evenly toothed, and paliform lobes are poorly developed. Colony color is brown to yellowish. Rare species in Indonesian waters.

Favites benattae (Veron & Pichon, 1977) Colonies are massive to encrusting, with cerioid corallites. Mature corallite diameter may reach up to 10 mm. Septa consist of three orders, with distinct paliform lobes. Septal ends are prominent. Columella is compact, and the theca is thick. Distribution: throughout Indonesian waters, though less common.

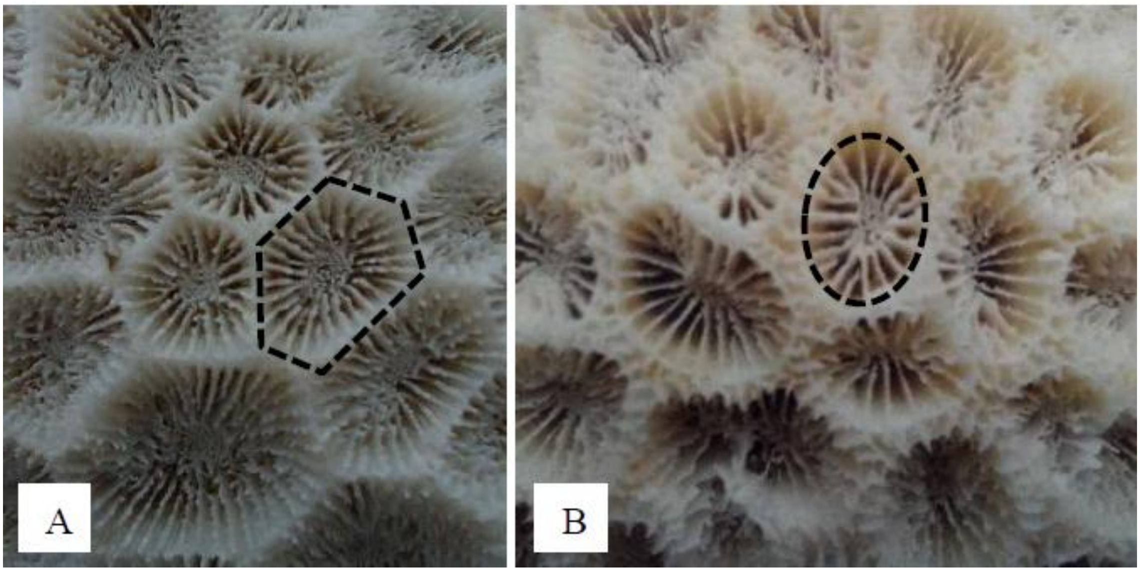


Figure 3. Types of corallite angles: (A) angular and (B) rounded.

Figure 4. Well-developed paliform lobes nearly forming a crown.

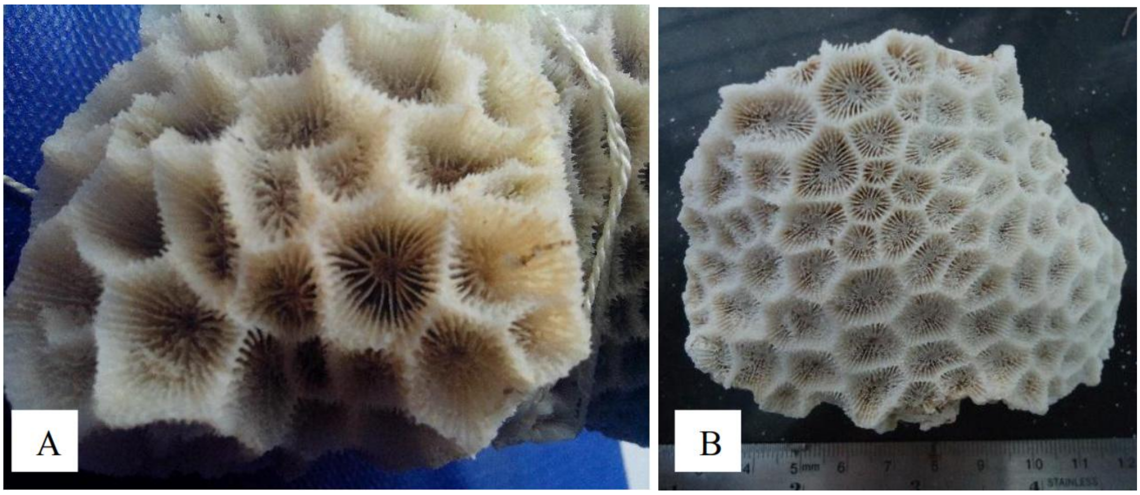


Figure 5. Colony surface: (A) hillocky and (B) non-hillocky

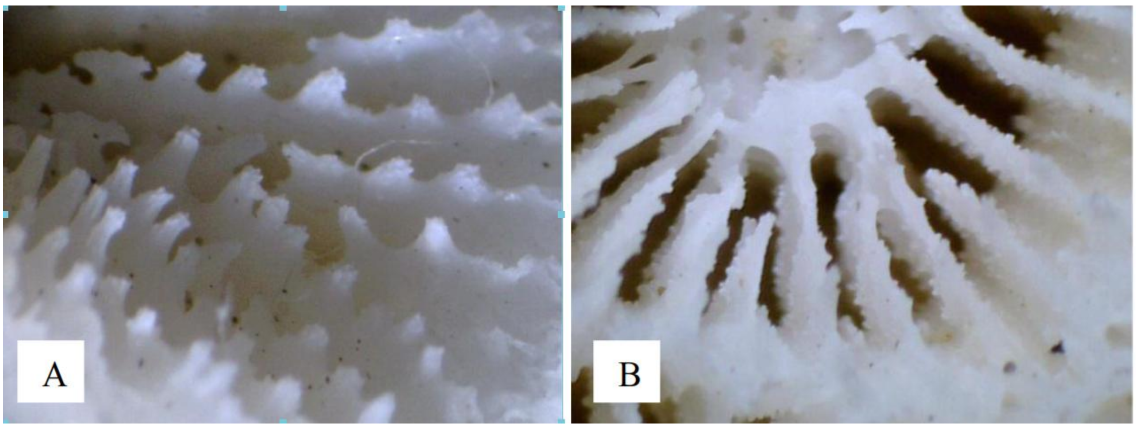


Figure 6. Septal teeth: (A) very distinct and (B) less distinct.

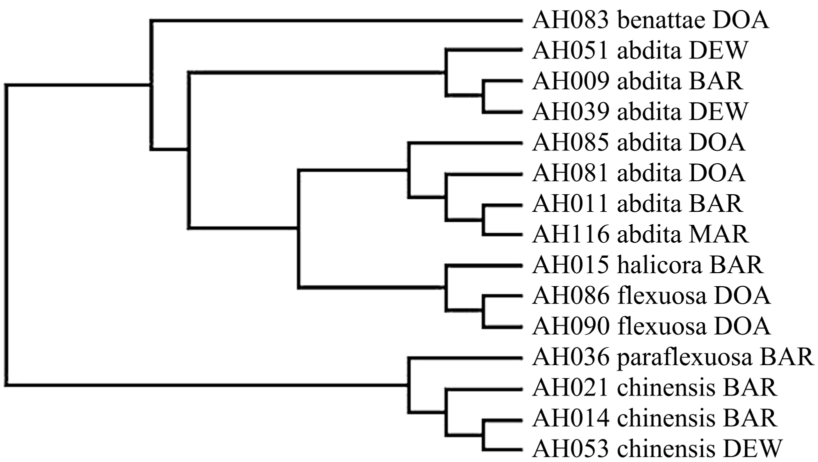
Phylogenetic and Morphometric Analyses

The phylogenetic tree of Favites corals (Figure 7) was reconstructed from a morphological character matrix (Table 3) using the UPGMA method. The resulting tree showed clustering of taxa based on species. The first cluster consisted of F. benattae, F. abdita, F. halicora, and F. flexuosa. According to Veron (2000), F. abdita, F. halicora, and F. flexuosa are considered similar species. The second cluster comprised F. paraflexuosa and F. chinensis. F. abdita was the most abundant species, collected from all study sites, and consistently grouped within the same cluster. In contrast, F. benattae, F. halicora, and F. flexuosa were each represented by a single specimen, resulting in relatively weak statistical support for their clustering.

PCA analysis of morphometric characters (Figure 8) revealed no clear separation among specimens. This finding highlights that descriptive characters play a more decisive role in species clustering within the phylogenetic tree compared to morphometric traits. Morphometric characters tend to be highly plastic and strongly influenced by environmental conditions. Nevertheless, Veron (2000) emphasized that traits such as corallite diameter are important diagnostic characters in Favites identification.

Table 3. Morphological character matrix of Favites corals

No	Taxa	Specimen Code	Characters
1	*F. abdita*	AH009	00110001111
		AH011	00110000011
		AH039	10110101110
		AH051	10110111111
		AH081	10110100010
		AH085	10110010010
		AH116	00110000010
2	*F. chinensis*	AH014	10011100011
		AH021	01011000000
		AH053	00011010010
3	*F. flexuosa*	AH086	10100101011
		AH090	10100110011
4	*F. halicora*	AH015	10000000011
5	*F. paraflexuosa*	AH036	01100100000
6	*F. benattae*	AH083	10000010110



Notes: Dewakkang Lompo Island (DEW), Barrang Lompo Island (BAR), Marasende Island (MAR), and Doangdoangan Lompo Island (DOA).

Figure 7. Phylogenetic tree of Favites corals from Spermonde Archipelago waters based on morphological characters, constructed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA).

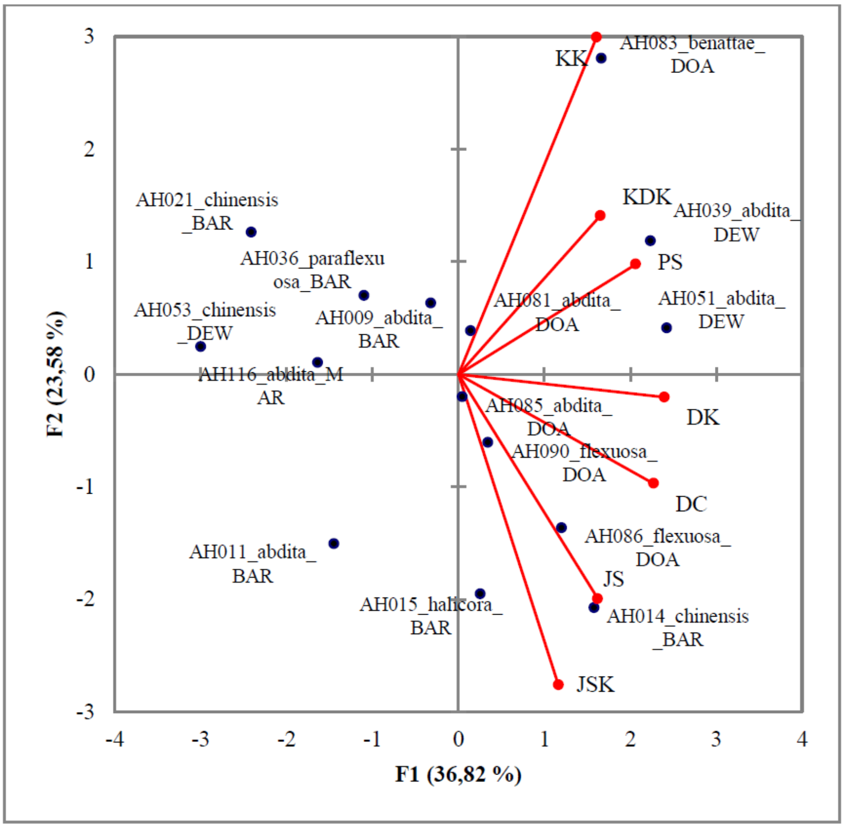


Figure 8. Grouping of Favites corals based on morphometric characters, analyzed using Principal component Analysis (PCA).

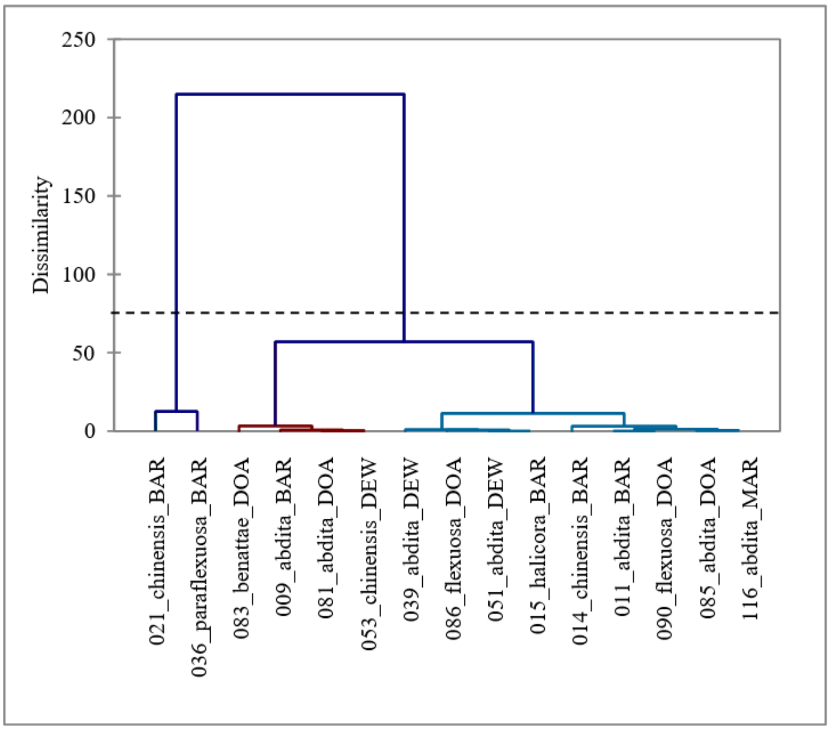


Figure 9. Dendrogram of Favites corals based on morphometric characters, analyzed using Agglomerative Hierarchical Clustering (AHC).

AHC analysis of morphometric data (Figure 9) revealed two major clusters: the first included *F. chinensis* and *F. paraflexuosa*, while the second comprised *F. benattae*, *F. chinensis*, and *F. abdita*. This clustering pattern differed from the phylogenetic tree constructed from combined descriptive and morphometric data, indicating that morphometric traits alone are insufficient to clearly separate Favites species.

Morphological Variation and Environmental Influence

The morphometric traits analyzed (such as corallite diameter, calice diameter, wall thickness, septal length and depth, septal number, and corallite corner count) are highly susceptible to environmental influence. Consequently, morphometric traits are less reliable for distinguishing species due to their high phenotypic plasticity. Similar phenomena have been reported in other corals, such as Pocillopora damicornis in the Great Barrier Reef, which shows growth form variation at different depths (Veron, 1995); *Goniastrea pectinata*, where calice morphology is influenced by light intensity (Ow and Todd, 2010) ; and *Favia speciosa*, which exhibits larger calices and thinner walls in shallow waters (Todd, 2008).

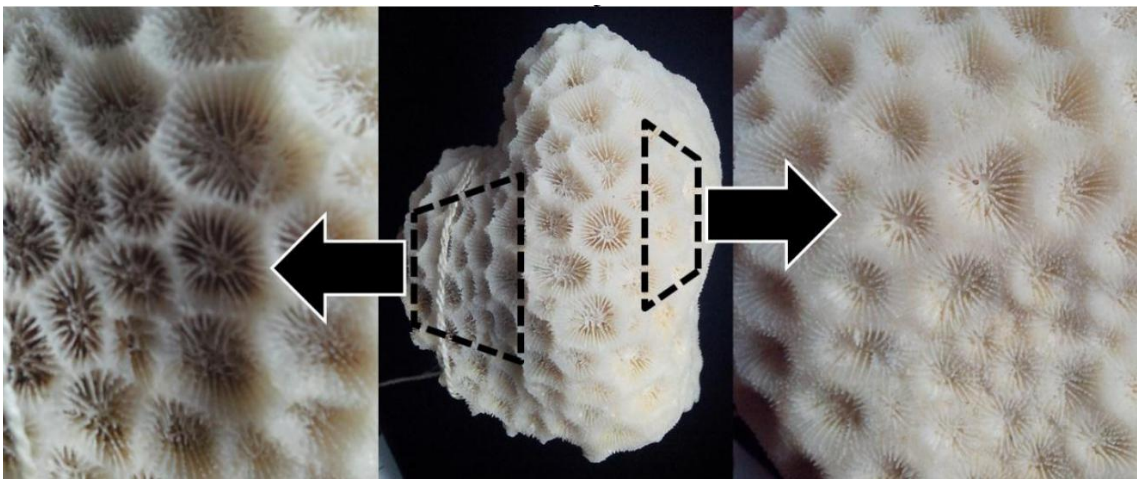


Figure 10. Variation in corallite forms of *Favites halicora* in this study.

In addition to interspecific variation, this study also identified intra-colony variation. For instance, *F. halicora* (Figure 10) exhibited different corallite shapes within the same colony. Similar phenomena have been reported in *Favia pallida* and *Favia rotumana* (Arrigoni et al., 2012). Such intra-colony variation can confound species identification and weaken the reliability of morphology-based taxonomy.

Environmental differences among study sites may also have contributed to the observed morphological variation. Barrang Lompo Island, located near Makassar's mainland, is more exposed to anthropogenic pollution compared to the offshore islands of the Makassar Strait (e.g., Dewakkang Lompo, Marasende, and Doangdoangan Lompo). Meanwhile, islands in the Strait experience stronger currents. These contrasting environmental conditions likely influenced the morphometric clustering of *Favites* corals.

Overall, the findings of this study suggest that descriptive characters are more reliable for distinguishing *Favites* species than morphometric traits, which are highly plastic. This underscores the importance of integrative approaches in coral systematics, combining morphological, ecological, and ideally molecular data to achieve a more robust taxonomic resolution.

CONCLUSION

This study concludes that the phylogenetic tree of *Favites* corals from the Spermonde Archipelago, reconstructed based on morphological characters (both descriptive and morphometric), showed clustering of taxa according to species. However, analysis using only morphometric characters did not reveal clear separation among species. This confirms that morphometric traits are highly plastic and strongly influenced by environmental factors. For future research, it is recommended to: Include additional morphological characters, particularly descriptive traits, to strengthen taxonomic resolution. Incorporate molecular characters as complementary data for more accurate identification. Compare specimens collected from similar environmental conditions, especially depth, to minimize the influence of environmental variability.

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