

Comparison of shallow water soft coral (*Octocorallia*) diversity and distribution among three islands in Makassar Strait, Indonesia

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Abstract. Putra AW, Priawandiputra W, Litaay M, Atmowidi T. 2022. Comparison of shallow water soft coral (*Octocorallia*) diversity and distribution among three islands in Makassar Strait, Indonesia. *Biodiversitas* 23: 5951-5961. There are only a few soft coral research in Indonesia. In the last ten years, there has been only seven published research. On the other hand, there are still many areas that are still unexplored, and every unexplored location has a chance to find a new species, thus we did this research. This study aims to conduct biodiversity research in the selected areas where soft corals biodiversity papers have never been published before. The distribution of soft coral in three small islands in Makassar strait and close to Sulawesi main island is reported in this paper. We hope that there is a correlation between the soft coral community in each researched island. The research was done by using a modified visual census method with 50 meters transect in the shallow water area (approx. 5 meters in depth). The data was collected by diving, sampling, and capturing images of each species found. Identification was made by comparing morphological characteristics using the book *soft coral and Sea fans* by Fabricius and Alderslade and newest papers about soft coral. In total, there are 41 species belonging to 14 genera and eight families found in this research. There is not much correlation between these three islands' soft coral communities. Every island had its key species based on the characteristics of the underwater habitats. The genera *Acrossota* and *Dendronephthya* only occur in Barrang Caddi Island, while, *Cladiella*, *Clavularia* and *Xenia* were only found in Gusung Toraja Island, and *Anthellia* and *Heteroxenia* were only found in Pannikiang Island. The genera *Litophyton*, *Lobophyton*, *Sarcophyton*, and *Sinularia* were found in all three researched islands. The south side of every island has the highest species abundance compared to the North, West, and Eastside.

Keywords: Celebes, Cnidaria, Octocorallia, spermonde, sangkarrang

INTRODUCTION

Indonesia is an archipelago country on the equator line, with 62% of its area being the ocean (Nontji 2005). This condition thus makes Indonesian waters a suitable habitat for coral growth, especially in the middle and eastern parts of Indonesia. Indonesia, with five other countries, Timor Leste, Malaysia (Sabah), The Philippines, Papua New Guinea, and the Solomon Islands, are known as the Coral Triangle area (Coral Triangle Centre 2013). Veron (2009) used the word Coral Triangle to name 16 ecoregions with the highest corals diversity in the world. In this region, there are at least 605 species of zooxanthellate which are 76% of the world's corals (Veron et al. 2011). This coral is usually divided into hard coral (Sclerectinia) and soft coral (Octocorallia).

Diversity and distribution of soft corals in Indonesia are still rarely studied (Manuputty 2010). In the last ten years, there have been only seven publications about soft coral distribution in Indonesia. These include two studies in West Indonesia by Akbar (2016) and Nababan (2015), three studies in Middle Indonesia by Janes (2013), Wanda (2018), and Putra (2019), and two studies in East Indonesia

by Agustiadi (2017) and Manuputty (2016). Study of soft coral in the Makassar strait area is also very sparse, as stated by Akbar (2013), that conducted research at Lae-lae, Bonebatang, and Badi Island (Spermonde archipelago). Soft coral publications in Makassar strait focused on one species was also reported by such as Haris (2010) on *Sinularia flexibilis* reproduction, and Candri et al. (2016) on *Isis hippuris* reproduction.

At a larger scale, Ramvillas et al. (2019) state that the contributions of Asian soft coral researchers (from Japan, Iran, and Israel) in the past 40 years were very low and indicate there are only a few local soft coral experts in this region. Large-scale research about soft coral distributions should be executed soon before extinction occurs. The coral reef as the habitat of soft coral is rapidly declining worldwide. Sadly, coral reefs are rapidly disappearing all over the world. This is primarily due to the mass extinction of many foundation species brought on by disease outbreaks, frequent intense bleaching events, increasing storm frequency and intensity, and ocean acidification caused by global climate change (GCC). These factors are all made worse by local/regional anthropogenic stressors like pollution, coastal development, and overfishing (Bruno

et al. 2003; Harvell et al. 2004, 2009; Burge et al. 2014; Lafferty and Hoffman 2016, Hughes et al. 2017). Coral reef composition, structure, and function have changed as a result of significant losses in live coral cover, abundance, and diversity (Aronson and Precht 2001, Bruno et al. 2007; Ward and Lafferty 2004; Carpenter et al. 2008; Wilkinson and Souter 2008; Miller et al. 2009; Weil et al. 2009; Dubinsky and Stambler 2011; Jackson et al. 2014; Woodley et al. 2016). Soft corals are also negatively affected by environmental degradation and diseases (Weil et al. 2002, Rosenberd and Loya 2004, Raymundo et al. 2008, Etnoyer 2015, Kim and Rypien 2016, Lalas et al. 2021).

There are more than 100 genera of shallow-water soft coral from the Indo-Pacific that have been described (Fabricius and Alderslade 2001). All these genera are distributed in marine environments and are mainly diverse in shallow tropical reefs and deep-sea habitats like seamounts (Zapata-Guardiola 2012; Williams and Cairns 2013; Perez CD et al. 2016). This study will be focused on the shallow water soft coral.

Research on soft coral diversity in Indonesia is still very limited, considering that there are still many areas that have not been fully explored. This study aims to compare the diversity and composition of soft corals (Alcyoniina and Stoniferia) from three small islands (Barrang Caddi Island, Pannikiang Island, and Gusung Toraja Island) located in the Makassar Strait, Indonesia. There have been several underwater studies at this location, including studies on oceanography (Lanuru et al. 2018), tunicates (Litaay 2018), scleractinian corals (Arifin and Kepel 2013), foraminifera (Abas et al. 2022), sponges (Hardiono 2020), echinoderms (Omar et al. 2020) and seagrass (Parawansa et al. 2020). Reports on soft corals from these three islands have never been published before. This research is expected to add the species list and distribution map of Indonesian soft corals.

MATERIALS AND METHODS

Sampling sites

All samples were collected between August 2019-December 2020 on three selected islands across Makassar Strait, Indonesia (Figure 1). One island is in the West Sulawesi region and two islands are in the South Sulawesi region. These three islands are Gusung Toraja Island (GT), Pannikiang Island (PN), and Barrang Caddi Island (BC). On each island, four sites were selected by considering the direction and site condition. Each site is coded with the Island name and number 1-4 (1=North, 2=East, 3=South, 4=West). Gusung Toraja Island is the northernmost of these three islands ($5^{\circ} 5' 21.49''\text{S}$ $119^{\circ} 19' 2.1''\text{E}$) and is 3.2 km from mainland Sulawesi. This island is located in Polman, West Sulawesi. This island is known as a tourist destination (Parawansa 2020). West side of GT faces

straight to Makassar strait; thus this site has strong sea waves and higher tides compared to other islands. Pannikiang Island is located in the middle ($4^{\circ} 22' 6.33''\text{S}$ $119^{\circ} 35' 7.24''\text{E}$), exactly in Barru Regency, South Sulawesi, and is 1.78 km away from the mainland. This island is habited island as well as a mangrove tourism destination (Rusdi et al. 2020). This island is surrounded by mangroves and mostly has muddy substrates. There are two rivers from mainland that disembogue to the PN waters. Thus, the PN waters are more turbid than the two other islands. West side of PN facing straight to Makassar strait. The third island is Barrang Caddi which is the southernmost of the three research sites ($3^{\circ} 29' 48.15''\text{S}$ $119^{\circ} 23' 17.45''\text{E}$). This island is in the middle of the Spermonde archipelago, with a distance of 10.4 km from the mainland. Barrang Caddi Island is densely inhabited. The island's water was mostly clear due to less eutrophication, with relatively calm waves and tides. Unlike the two other islands, the west side of BC is not straightly facing the Makassar Strait. Observations and data processing was carried out at the Environmental and Marine Sciences Laboratory, Department of Biology, Hasanuddin University, and in the Animal Biosystematics and Ecology Laboratory, Department of Biology, IPB University, Bogor, Indonesia.

Field methods

The data were collected using a modified visual census method (Halford et al. 1994) with a sampling area of 50 meters in length and 5 meters in width (2.5m to the left and 2.5m to the right of the transect); sample collection in outside of the observation area was permitted for the inventory. The reefs were mostly reached by boat and carried out by scuba diving. Sampling was carried out at a depth of 5 meters. All soft corals in the observation area were recorded, photographed, and representative colony was collected for identification. Sample photos were taken using a Canon G16 camera with underwater housing.

Specimen identification

The identification process included the examination of colonies' morphology, texture, and color (Manuputty 2016). Observations of soft coral sclerites were carried out by taking tissue from the bottom, stems, and polyps (Soedharma et al. 2005). Sclerites were obtained by dissolving soft coral tissue using 10% sodium hypochlorite and then rinsed with fresh water (Samimi and van Ofwegen 2016). The sclerites obtained were then observed under a microscope, photographed, and stored based on the sample code to be identified based on Fabricius and Alderslade (2001), World Register of Marine Species (WoRMS), related articles, and direct communication with experts. The classification of families is already updated based on McFadden et al. (2022).

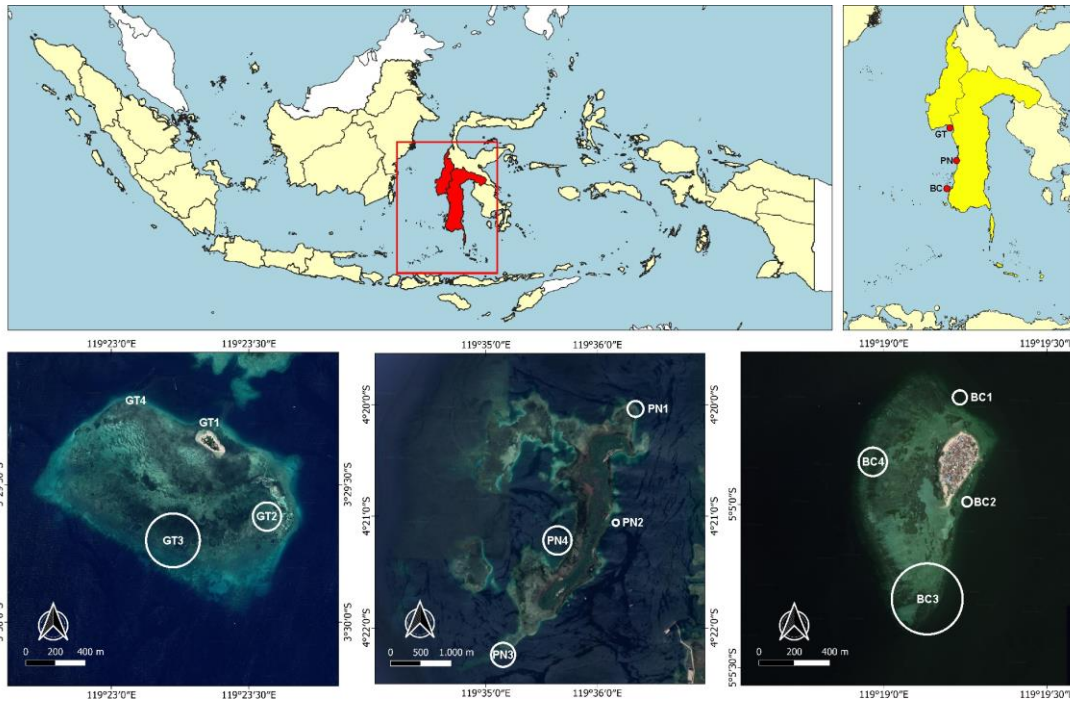


Figure 1. Map of sampling sites in Gusung Toraja Island (GT), Pannikiang Island (PN), and Barrang Caddi Island (BC) of Makassar Strait, Indonesia. The circle size represents the number of soft coral species in each site

Data analysis

We used Chao-1 estimation and rarefaction to estimate the number of species. We analyzed diversity index, which consists of Shannon-Wiener diversity index (H'), evenness (e), and dominance (D) species. Similarity of species composition between each island was analyzed using non-dimensional matrix scaling (nMDS), t-test analysis, and analysis of similarity ANOSIM. All analyses were conducted by using PAST 4.03 software (Hammer et al. 2001)

Genus and species occurrence were counted based on Chanmethakul et al. (2010):

$$O = \frac{n}{N} \times 100$$

Where:

O : occurrence

n : number of sites with the species/genus

N : total sampled sites

RESULTS AND DISCUSSION

Soft coral biodiversity

The results of the chou-1 estimation score analysis showed 54.2, which indicates there may still be around 12 species that have not been recorded in this study. However, the rarefaction curve (Figure 2) shows that the peak of the curve has approached the stationary line, which means the number of recorded specimens is considered sufficient for this study.

There are eight families, 14 genera, and 41 species found in this research (Table 1). In Gusung Toraja (GT), 15 species belonging to 8 genera were found; in Pannikiang

(PN) island, there were 13 species belonging to 8 genera, and in Barrang Caddi (BC), 25 species belonging to 8 genera were found. The 14 genera found in this research were *Acrossota*, *Anthelia*, *Cladiella*, *Clavularia*, *Dendronephthya*, *Heteroxenia*, *Litophyton*, *Lobophytum*, *Sarcophyton*, *Sinularia*, *Scleronephthya*, *Stereonephthya*, *Tubipora*, and *Xenia*. The genera *Litophyton*, *Lobophytum*, *Sarcophyton*, and *Sinularia* can be found on every island. The genera *Acrossota*, *Anthelia*, and *Clavularia*, were newly recorded genera from Makassar Strait. Of 41 species found, 21 morphospecies could be identified to genus only, while others can be identified by their species name. Unidentified but distinct morphospecies was coded as "Genus name" sp1, sp2, sp3, etc. Mostly, the genera with more than one unknown species are *Sarcophyton*, *Sinularia*, *Lobophytum*, *Stereonephthya*, and *Litophyton*.

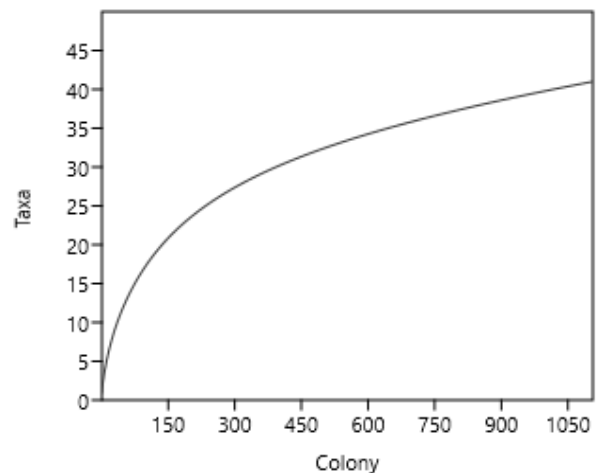


Figure 2. Rarefaction curve of every researched island

Table 1. Soft corals found at each site (colony)

Family	Genera	Species	Barrang Caddi	Pannikiang	Gusung Toraja	Colony total	
Sarcophytidae	<i>Sarcophyton</i>	<i>S. ehrenbergi</i>	8	0	3	11	
		<i>S. infundibuliforme</i>	5	0	0	5	
		<i>S. crassocaule</i>	1	0	1	2	
		<i>S. glaucum</i>	0	21	0	21	
		<i>S. trocheliphorum</i>	0	615	0	615	
		<i>Sarcophyton</i> sp.1	0	0	6	6	
		<i>Sarcophyton</i> sp.2	0	0	5	5	
		<i>Sarcophyton</i> sp.3	0	0	1	1	
		<i>Sarcophyton</i> sp.4	0	2	3	5	
		<i>Lobophytum</i>	<i>L. compactum</i>	51	15	8	74
			<i>L. crassum</i>	0	1	0	1
			<i>Lobophytum</i> sp.1	1	0	0	1
			<i>Lobophytum</i> sp.2	1	0	0	1
		Sinulariidae	<i>Sinularia</i>	<i>S. flexibilis</i>	3	0	0
<i>S. pavida</i>	1			0	0	1	
<i>S. peculiaris</i>	2			1	0	3	
<i>S. digitata</i>	0			0	1	1	
<i>Sinularia</i> sp.1	7			0	0	7	
<i>Sinularia</i> sp.2	7			0	0	7	
<i>Sinularia</i> sp.3	1			0	0	1	
<i>Sinularia</i> sp.4	1			0	0	1	
<i>Sinularia</i> sp.5	9			0	0	9	
<i>Sinularia</i> sp.6	4			0	0	4	
<i>Sinularia</i> sp.7	1			0	1	1	
<i>Sinularia</i> sp.8	44			74	8	126	
Cladiellidae	<i>Cladiella</i>			<i>Cladiella</i> sp.	0	0	1
Nephtheidae	<i>Stereonephthya</i>	<i>Stereonephthya</i> sp.1	1	0	0	1	
		<i>Stereonephthya</i> sp.2	2	0	0	2	
		<i>Stereonephthya</i> sp.3	0	2	0	2	
	<i>Litophyton</i>	<i>Litophyton</i> sp.1	2	0	10	12	
		<i>Litophyton</i> sp.2	47	7	0	54	
		<i>Litophyton</i> sp.3	0	2	0	2	
		<i>Litophyton</i> sp.4	3	0	3	6	
	<i>Scleronephthya</i>	<i>Scleronephthya</i> sp.	10	0	0	10	
	<i>Dendronephthya</i>	<i>Dendronephthya</i> sp.	1	0	0	1	
	Xeniidae	<i>Heteroxenia</i>	<i>Heteroxenia</i> sp.	0	23	0	23
<i>Anthelia</i>			0	19	0	19	
<i>Xenia</i>			0	0	3	3	
Acrossotidae	<i>Acrossota</i>	<i>Acrossota</i> sp.	12	0	0	12	
Tubiporidae	<i>Tubipora</i>	<i>Tubipora</i> sp.	0	28	2	30	
Clavulariidae	<i>Clavularia</i>	<i>Clavularia</i> sp.	0	0	16	16	
	Total colony		225	810	71	1106	
	Total species		25	13	15	41	
Diversity indices	Dominance (D)		0.14	0.59	0.11	-	
	Diversity (H')		2.35	1.00	2.37	-	
	Evenness (e)		0.42	0.20	0.71	-	

The *Sarcophyton trocheliphorum* species has the highest colony number, with 615 colonies in only one site on Pannikiang Island. These species dominate the site. The second-highest colony number was *Sinularia* sp8, with 126 colonies, and was collected from 7 different sites. There are also 11 species with only one colony found from all sites, and some of them were juvenile stage, which is shown by their small size.

The total colonies found in this research is 1.106 colonies that are recorded from 10 out of 12 sites. Two

research sites, GT1 and GT4, are known to not have a single colony of soft coral because of their environmental condition. The PN2 site was recorded to have the highest number of the colony, with 693 colonies found. In comparison, BC2 followed in the second position with 127 colonies. There is no other site with more than 100 colonies. While if we exclude GT1 and GT4, the site with the lowest colony number is PN2, with only two colonies that come from only one species.

Table 2. Soft coral diversity indices from each site

Indices	BC1	BC2	BC3	BC4	PN1	PN2	PN3	PN4	GT1	GT2	GT3	GT4
Dominance (D)	0.5	0.2598	0.1177	0.179	0.6067	1	0.7957	0.2437	-	0.1811	0.1985	-
Diversity (H')	1.037	1.55	2.417	1.875	0.795	0	0.427	1.526	-	1.855	1.974	-
Evenness (e)	0.5644	0.5236	0.6598	0.8152	0.5536	0	0.2554	0.6571	-	0.7991	0.6002	-

Diversity indices

There are several diversity indices taken in this research. These indices show the soft coral ecological condition in each site. These indices are dominance indices, evenness indices, and Shannon-Wiener diversity indices. Table 2 shows that the dominant species in PN2 and PN3 were categorized as a high dominance with indices value of more than 0,75. PN1 and BC1 were categorized as moderate dominant.

Shannon-wiener diversity indices of all sites show that there are none of the sites categorized as high diversity sites. The BC3 has the highest diversity value (H'=2.41) and is categorized as a moderate diversity site with sites of BC1, BC2, BC4, PN4, GT2, and GT3. Both PN1 and PN3 has the lowest diversity score, with 0.795 and 0.427 (H'<1.0). Evenness shows that the BC4, PN2, and GT2 were categorized as a site with stable communities, and the other sites were categorized as labile communities. The GT2 and GT3 were not formulated because there is no soft coral found in these sites. Based on the t-test of each island (Table 3) indicates there is significant difference between BC and PN, and GT and PN.

Shannon-Wiener diversity indices from all sites show that there are no of the sites categorized as high diversity index. The BC3 has the highest diversity index (H'=2.41) and is categorized as a moderate diversity together with BC1, BC2, BC4, PN4, GT2, and GT3. Both PN1 and PN3 has the lowest diversity value, with 0.795 and 0.427 (H'<1.0). Evenness shows that the BC4, PN2, and GT2 were categorized as a site with stable communities, and the other sites were categorized as labile communities. The GT2 and GT3 were not formulated because there is no soft coral found in these sites. The t-test of each island (Table 3) indicates there are significant differences between BC and PN and GT and PN.

Non-metric Multidimensional Scaling (nMDS) analysis was used to determine the grouping of each site by looking at the species composition similarity. The nMDS is preferred over MDS because the data is not normally distributed. The pattern is influenced by the number of colonies of each species found in each site. There are no pattern interceptions between each site, meaning there is no similarity between each island (GT 1 and GT 4 were excluded due to 0 individuals of soft coral in this site). On the other hand, The ANOSIM global test result of these three island species compositions reveals no similarity between study sites (R=0.12 p=0.22) (Figure 3).

Occurrence

There are five species with the highest species occurrence in this research (Table 4). *Sinularia* sp8 and

Litophyton sp2 have the highest occurrence (58.3% of sites), then *Lobophytum compactum* with 50% occurrence, and *Sarcophyton ehrenbergi* with 41.67% occurrence. Other species' percentages ranged between 8.33% and 25%. Overall, the genera occurrence from this research is shown in Table 5. There are only three genera with occurrence above 50%. Based on Table 5, Arcophyton and *Litophyton* have the highest occurrence (66.67% of sites), and there are 6 genera with the low occurrence (8.33%), i.e., *Anthelia*, *Cladiella*, *Dendronephthya*, *Heteroxenia*, *Scleronephthya*, and *Xenia*. Based on percent occurrence, the highest to lowest occurrence were *Sarcophyton*, *Litophyton*, *Sinularia*, *Lobophytum*, *Stereonephthya*, *Acrossota*, *Clavularia*, *Tubipora*, *Anthelia*, *Claidella*, *Dendronephthya*, *Heteroxenia*, and *Xenia*, respectively.

The occurrence of genera on each island shows that there are several absent genera on each island. *Litophyton*, *Lobophytum*, *Sarcophyton*, and *Sinularia* occur on every island. *Stereonephthya* and *Tubipora* occur on two islands, and the rest only occur on one island (Figure 4).

Table 3. T-test analysis of soft corals among islands

	BC	GT	PN
BC	-		
GT	t: -0.16407; df: 171.01; p: 0.86987	-	
PN	t: 14.74; df: 412.7; p: 7.5238 (e-40)	t: 12.725; df: 110.18; p: 2.2931 (e-23)	-

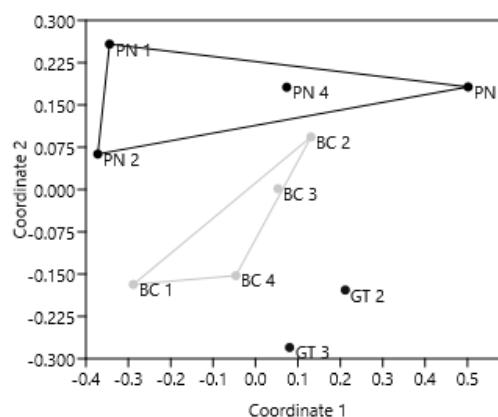


Figure 3. NMDS species composition of soft coral in each station with stress level 0.19

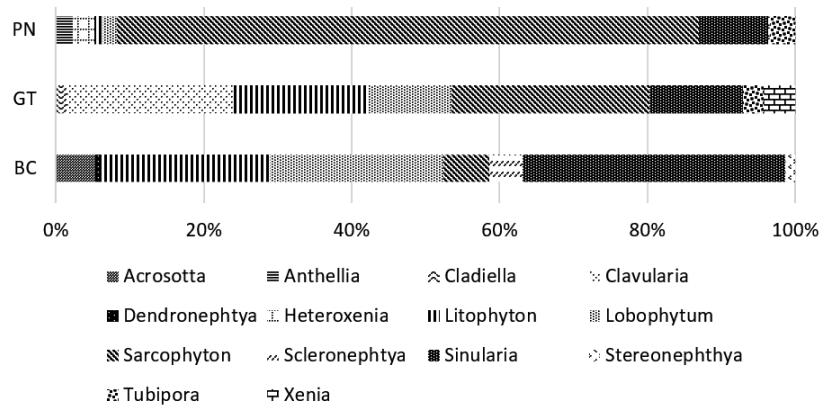


Figure 4. Soft coral composition in study sites

Table 4. Species occurrence of soft coral in percentage (%) in all study sites.

Species	%
<i>Anthelia glauca</i>	8.33
<i>Acrossota</i> sp.	16.67
<i>Cladiella</i> sp.	8.33
<i>Clavularia</i> sp.	16.67
<i>Dendronephthya</i> sp.	8.33
<i>Heteroxenia</i> sp.	8.33
<i>Litophyton</i> sp.1	16.67
<i>Litophyton</i> sp.2	58.33
<i>Litophyton</i> sp.3	8.33
<i>Litophyton</i> sp.4	16.67
<i>Lobophytum compactum</i>	50.00
<i>Lobophytum crassum</i>	8.33
<i>Lobophytum</i> sp.1	8.33
<i>Lobophytum</i> sp.2	8.33
<i>Sinularia digitata</i>	8.33
<i>Sinularia flexibilis</i>	16.67
<i>Sinularia pavida</i>	8.33
<i>Sinularia Peculiaris</i>	16.67
<i>Sinularia polydactyla</i>	58.33
<i>Sinularia</i> sp.1	16.67
<i>Sinularia</i> sp.2	8.33
<i>Sinularia</i> sp.3	8.33
<i>Sinularia</i> sp.4	8.33
<i>Sinularia</i> sp.5	8.33
<i>Sinularia</i> sp.6	8.33
<i>Sinularia</i> sp.7	8.33
<i>Sarcophyton crassocaule</i>	16.67
<i>Sarcophyton ehrenbergi</i>	41.67
<i>Sarcophyton glaucum</i>	8.33
<i>Sarcophyton infundibuliforme</i>	16.67
<i>Sarcophyton</i> sp.1	16.67
<i>Sarcophyton</i> sp.2	16.67
<i>Sarcophyton</i> sp.3	8.33
<i>Sarcophyton</i> sp.4	25.00
<i>Sarcophyton trocheliophorum</i>	8.33
<i>Scleronephthya</i> sp.	8.33
<i>Stereonephthya</i> sp.1	8.33
<i>Stereonephthya</i> sp.2	8.33
<i>Stereonephthya</i> sp.3	8.33
<i>Tubipora</i> sp.	16.67
<i>Xenia</i> sp.	8.33

Table 5. Genus occurrence of soft corals in percentage (%) in study sites.

Genus	%
<i>Acrossota</i>	16.67
<i>Anthelia</i>	8.33
<i>Cladiella</i>	8.33
<i>Clavularia</i>	16.67
<i>Dendronephthya</i>	8.33
<i>Heteroxenia</i>	8.33
<i>Litophyton</i>	66.67
<i>Lobophytum</i>	41.67
<i>Sarcophyton</i>	66.67
<i>Scleronephthya</i>	8.33
<i>Sinularia</i>	58.33
<i>Stereonephthya</i>	25.00
<i>Tubipora</i>	16.67
<i>Xenia</i>	8.33

Table 6. Genus occurrence of soft corals in Barrang Caddi Island (BC), Gusung Toraja Island (GT), and Pannikiang Island (PN) (%)

Genus	Site		
	BC	GT	PN
<i>Acrossota</i>	50	0	0
<i>Anthelia</i>	0	0	25
<i>Cladiella</i>	0	25	0
<i>Clavularia</i>	0	50	0
<i>Dendronephthya</i>	25	0	0
<i>Heteroxenia</i>	0	0	25
<i>Litophyton</i>	100	25	75
<i>Lobophytum</i>	75	25	50
<i>Sarcophyton</i>	100	50	50
<i>Scleronephthya</i>	25	0	0
<i>Sinularia</i>	75	50	50
<i>Stereonephthya</i>	50	0	25
<i>Tubipora</i>	0	25	25
<i>Xenia</i>	0	25	0

In Barrang Caddi, *Litophyton* and *Sarcophyton* had the highest occurrence (100%) (Table 6). In Gusung Toraja, we found *Clavularia*, *Sarcophyton*, and *Sinularia* with 50% occurrence. *Litophyton* had the highest occurrence in Pannikiang, with 75% occurrence. *Stereonephthya* was found in BC with 50% occurrence and PN with only 25%.

The pipe-soft coral, *Tubipora*, was found in PN and GT with 25% occurrence in both islands, and the rest genera can be only found in one of the islands with varied occurrence between 0%-25%.

Discussion

Soft coral diversity in every area differs based on environmental conditions. Therefore, all three islands in this study also have different environments. In general, the diversity of soft corals in this area was categorized as moderate diversity, with 41 species from 14 genera found. The number of genera found is less than that reported in the Andaman Sea (Chanmethakul et al. 2010), with 19 genera, but more than 12 genera found in the Gulf of Thailand (Chanmethakul et al. 2010). In Singapore, Goh (2009) found seven genera from 10 sites, and 16 morphotypes in 2015 (Seah et al. 2015). Mohammad et al. (2016) recorded 15 genera, 8 families of soft corals from North Malacca straits. Ben and Quang (2019) recorded 45 species, 12 genera, and seven families of soft corals from Cu Lao Cham Marine Protected Area (MPA), Vietnam. Lalas et al. (2022) reported approximately 10 families from West Philippine Sea. Twenty-two genera (69 species) were recorded from southern Taiwan by Benayahu (2004) and most of them are new zoogeographical records. There are also 34 species belonging to 6 genera found in Penghu Archipelago in 2012 using classical taxonomy (Benayahu et al. 2012), and 51 species from 20 genera recorded using combination of classical taxonomy and molecular barcode identification in 2018 (Benayahu et al. 2018).

Results showed that four genera were found in this study, i.e., *Litophyton*, *Lobophytum*, *Sarcophyton*, and *Sinularia*. All these genera are widespread (Fabricius and Alderslade 2001). *Lobophytum* and *Sarcophyton* are also found in previous research studies (Chanmethakul et al. 2010, Goh et al. 2009, Benayahu et al. 2004, Benayahu et al. 2012). *Lobophytum* is also found in India (Radhika et al. 2005), China (Chupu et al. 1984, Benayahu et al. 2012), and Maldives (Prat et al. 1903), and Australia (Bryce et al. 2014). *Sarcophyton* is also found in Egypt (Ismail 2017), India (Ajaneyulu et al. 2008, Rajendra et al. 2017), China (Chupu 1984, Benayahu and van Ofwegen 2009), Japan (Aratake 2012), Australia (Bryce et al. 29). It shows that *Lobophytum* and *Sarcophyton* were distributed in different geographical and environmental conditions. Fabricius and Alderslade (2001) also reported both *Lobophytum* and *Sarcophyton* are common genera found in shallow water.

Sarcophyton trocleiphorum shows an invasive species in PN3 with 615 colony numbers recorded inside the sampling area, and covers almost half of the observed area (20x5m²). The colonies that spread outside the sampling area are estimated to occupy a two- or three-times larger area than in the observed area. Most of the colonies consist of juveniles. This genus has a fast growth rate and asexual reproduction; thus, it is common to find extensive clones consisting of hundreds of colonies, especially in the turbid area (Fabricius and Alderslade 2001). The genus

Sarcophyton itself already makes up more than half of the total colonies found in this study (693 of 1.106 colonies).

Although the PN3 had the highest colony, but the Island (PN) is considered as a low-diversity area. While other islands, even though they had lower colony numbers than PN, such as BC and GT were categorized as having high diversity. The environmental condition may influence this condition. The PN is located near the main island, and there are two rivers found on this island, so the water is more turbid than on other islands. On the other hand, although the GT is located near the main island, no river is found, so the waters are clearer than in PN.

The number of species found at each station in the three islands varied. The highest number of species in the southern station of Barrang Caddi Island (BC3) with 18 species, followed by the southern station on Gusung Toraja Island (GT3) with 12 species. Although the southern station of Barrang Caddi Island (BC3) has fewer species than other sites, this area has the highest number of colonies. The abundance of soft coral in the south of the island in this study is also influenced by the shape of the Spermonde area, which generally stretches from north to south (Klerk 1982). The shape of this reef is probably influenced by currents in the Makassar Strait (Imran et al. 2013). Research by Hasanuddin University's Coral Study Center (2002) also revealed that the reef area in the southern and western parts of the island would tend to be wider. This condition causes the research point in the west to have more species than the north and east areas. The number of species at stations BC 4 (west) and PN 4 (west) found 7 species, while BC 1 (north) found 2 species, PN 1 (north) found 4 species, BC 2 (east) found 3 species, and PN 2 (east) found one species. At stations GT 1 (north) and GT 4 (west) on the island of Gusung Toraja, no soft corals were found, while at GT 2 (E), seven soft coral were found. Based on this research, soft coral is very abundant on the island's south side in the Makassar Strait area. This condition can be influenced by the Makassar strait current, which generally flows from north to south yearly. Thus, it affects the position of the reef on each island.

In this study, several genera were found only on one island. The genus *Acrossota* and *Dendronephthya* are only found on the island of Barrang Caddi (BC). So far, the genus *Acrossota* consists of only one species (WoRMS 2022), and the species found have different characteristics compared to the previously recorded species. The genus *Acrossota* in Indonesia was first reported in 1902 by Burchard in Ambon with the species *Acrossota amboniensis* (originally *Clavularia amboniensis*). *Acrossota* species found in this study have different characters from those found in Ambon. This species has small polyp with a banana-shaped tentacle (narrow base) and smooth side with no pinnules. The mouth of polyp has a white-colored mouth, pale-colored area around the mouth, and dark-colored around the base (Figure 5d). The tentacle is unretractable (it shows no reaction when touched). The polyps are connected by flat stolon, which is rooted to the hard substrate. Most colonies are found in low current areas between or hanging under hard substrates.

Figure 5. Soft coral found in sampling sites. A. *Anthelia glauca*; B. *Dendronephthya* sp.; C. *Heteroxenia* sp. with retracted tentacle from Pannikiang island; D. *Acrossota* sp. from Barrang Caddi Island; E. *Sinularia flexibilis*; F. *Tubipora* sp.; G. *Litophyton* sp.; H. *Sarcophyton*

The genus *Dendronephthya* in Indonesia has been recorded previously, such as Manuputty (2016) in Biak, Akbar (2013) in Spermonde, and Wanda (2018) in Woworoha. The genera *Cladiella*, *Clavularia*, and *Xenia* were found only on this island. *Clavularia* and *Xenia* are commonly found in clear waters with areas affected by waves or swept away by currents (Fabricius and Alderslade 2001). Report of Chanmethakul et al. (2010) in the Thai peninsula showed the genus *Xenia* was found in flat coral areas with a depth of 2-10 meters. The condition of Gusung Toraja faced the open waters of the Makassar Strait, so the current in the south of the island is quite strong compared to other islands. The water conditions on the south and east sides are clearer than on the other two sides. The genus *Cladiella*, *Clavularia*, and *Xenia* in Indonesia have been recorded previously, such as Manuputty (2016), found three genera in Biak, Janes (2013) and McFadden et al. (2014) studied Xenidiidae in Lembah, Putra et al. (2019) in Gonda, Akbar (2013) in Spermonde, and Nababan (2015) in Karimun Jawa. The genera only found in Pannikiang Island (PN) were *Anthellia* and *Heteroxenia*. Both genera belong to the family Xenidae and can be found in reef areas (Fabricius and Alderslade 2001). *Heteroxenia* can also be found in offshore areas (Chanmethakul et al. 2010). This genus has previously been reported in other waters in Indonesia by Janes (2013), Akbar (2013), Manuputty (2016), and Putra et al. (2019).

We realize that this research cannot represent the soft coral biogeography on the east side of Makassar strait, but at least it shows a small part of the biogeography. There are still hundreds of islands that remain unexplored and uncharacterized until now. Through this research, without much eutrophication effect, the soft corals will be in high abundance on the south side of the island. This condition may be affected by the current of the Makassar Strait, which usually flows from north to south annually. Thus, it affects the position of the reef flat on each island. So, we hope there will be more research or exploration in this location in the future. The species of *Acrossota* found in this research is suspected as a new species, but it still needs further examination, especially for molecular identification.

In conclusion, this research shows there is a varied distribution and diversity of soft corals on every island studied. A total of 41 species, belonging to 14 genera, and eight families were found, with *Litophyton*, *Lobophytum*, *Sarcophyton*, and *Sinularia* found in all studied islands. *Sarcophyton trocheliophorum* is the species with the highest colony number (615); *Sinularia* sp8 and *Litophyton*

sp2 are the species with the highest occurrence (58.33%). The genera with the highest occurrence are *Litophyton* and *Sarcophyton*, with 66.67% occurrence. There is less similarity between studied islands that is caused by the environmental condition.

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