

Seasonal Variation of Megabenthos Abundance and Spatial Distribution in the GITA NADA Marine Protected Area, Sekotong, West Lombok

Raja Aditya Sahala Siagian¹, Relis Gabriel Sihaloho¹, Muhammad Farhan Anshory¹,
M. Gilang Aktia², Ruhul Anshori², Kara M A Majerus^{1*}

¹Sustainable Oceanic Research Conservation and Education, Sekotong, West Lombok, Indonesia

²Marine Science Study Program, Faculty of Agriculture, University of Mataram, Indonesia

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*Corresponding Author:

Kara M A Majerus,
Sustainable Oceanic Research
Conservation and Education,
West Lombok, Indonesia;
Email: k.majerus@sorce.org

Abstract: Megabenthos are organisms that inhabit the benthic zone and live on or within the substrate, including biota that attach, crawl, or burrow, and which function as important components of benthic food webs. This study aimed to determine the distribution patterns abundance and frequency of occurrence megabenthos during the dry and wet seasons in the GITA NADA Marine Protected Area (MPA), West Lombok. Megabenthos data were collected using the belt transect method. Results showed that megabenthos abundance at all locations within the GITA NADA MPA at depths of 3–5 m was 16,59 ind/m² in the dry season and 13,83 ind/m² in the wet season, while at depths of 8–10 m abundance was 39,74 ind/m² in the dry season and 38,25 ind/m² in the wet season. Independent t-tests indicated no significant differences in megabenthos abundance between the dry and wet seasons at either depth (3–5 m and 8–10 m). Frequency of occurrence megabenthos at depths of 3–5 m ranged from very rare to moderate in both the dry and wet seasons. At depths of 8–10 m, frequency of occurrence ranged from very rare to moderate in the dry season and from very rare to absolute in the wet season. The Morisita index values for megabenthos distribution in the GITA NADA MPA ranged from -0,0005 to 0,492, indicating both uniform and clumped distribution patterns.

Keywords: distribution pattern, megabentos, MPA GITA NADA, seasonal.

Introduction

Coral reefs function as essential habitats for a wide range of marine biota, including megabenthos (Quanita, 2018). Megabenthos are organisms that inhabit the benthic zone and live on or within the substrate, including biota that attach, crawl, or burrow. These organisms typically have body sizes greater than 10 mm (1 cm) and play an important role as food resources within benthic ecosystems (Arbi and Sihaloho, 2017). Due to their relatively large body size, long life cycles, and limited mobility, megabenthos are able to respond sensitively to changes in environmental and water quality conditions, making them useful indicators of ecosystem health (Mutaqin et al., 2020).

Megabenthos comprise a diverse group of taxa, including sea cucumbers (Holothuroidea), clams (Tridacninae), topshell snails (Trochidae), lobsters (Panuliridae), crown-of-thorns starfish (*Acanthaster* spp.), coral-feeding snails (*Drupella* spp.), sea urchins (Echinoidea), and blue sea stars (*Linckia laevigata*) (Arbi and Sihaloho, 2017). As integral components of aquatic food webs, megabenthos influence the structure and functioning of benthic ecosystems and serve as important prey resources for demersal fish and other higher trophic organisms (Sahidin and Wardiatno, 2016; Johannesen et al., 2017; Outrequin et al., 2025).

Gili Tangkong, Gili Nanggu, and Gili Sudak are within the GITA NADA Marine Protected Area which is located in Sekotong

District, West Lombok Regency, Indonesia. GITA NADA MPA was formally designated as a marine protected area under the Decree of the Minister of Maritime Affairs and Fisheries Number 93 of 2018 (Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia, 2018). According to this decree, the total area of the GITA NADA MPA is 21,132.82 ha. Previous reports by the West Lombok Department of Marine Affairs and Fisheries (Dinas Kelautan dan Perikanan, 2016) indicated average megabenthos abundances within the MPA of 19 ind/ha for clams, 7 ind/ha for sea cucumbers, and 239 ind/ha for sea urchins.

Previous megabenthos monitoring studies in West Lombok have shown variable trends. Satyawan *et al.* (2018) reported an overall increase in megabenthos abundance between 2016 and 2018, with the exception of sea cucumbers, which declined. Similarly, Ghafari *et al.* (2020) documented fluctuations in megabenthos abundance in Sekotong Bay during a five-year monitoring period from 2015 to 2019. However, studies specifically addressing the distribution patterns and frequency of occurrence of megabenthos within the GITA NADA MPA remain limited.

Megabenthos distribution are strongly influenced by seasonal variability, particularly in tropical regions where there is a clear distinction between the dry and rainy seasons (Mwaijengo *et al.*, 2020; Feng *et al.*, 2025). Wet season is generally characterized by increased rainfall, land runoff, nutrient and sediment influx, and water quality (Alkhadher *et al.*, 2025). Dry season is typically characterized by reduced rainfall, lower terrestrial runoff, and increased water clarity (Croteau *et al.*, 2023; Alkhadher *et al.*, 2025). Reduced sediment and freshwater input during the dry season generally leads to improved substrate stability and higher light penetration, which may enhance benthic primary production and biofilm development—important food sources for many detritivorous and grazing benthic communities (Díez-Minguito *et al.*, 2020; Lønborg *et al.*, 2021; Perez-Rodriguez *et al.*, 2024; Girard *et al.*, 2025).

Despite increasing interest in monitoring megabenthos as ecological

indicators, studies examining seasonal variation in megabenthos communities within marine protected areas remain limited, particularly in Lombok. Most previous research has primarily focused on monitoring megabenthos abundance or assessing coral reef health indicators without integrating distribution patterns, abundance and frequency of occurrence in wet and dry season in Lombok (Satyawan *et al.*, 2018; Ghafari *et al.*, 2020; Ghafari *et al.*, 2021). Therefore, this study aimed to analyze the seasonal variation dry and wet in abundance, frequency of occurrence, and distribution patterns of megabenthos in the GITA NADA Marine Protected Area, Sekotong, West Lombok.

Material and Methods

Time and location

The study was conducted from October 2023 to August 2024. The dry season was observed from August to October 2023 and from May to August 2024, while the wet season occurred from November 2023 to April 2024. Megabenthos monitoring was carried out across two depth categories: shallow (3–5 m) and deep (8–10 m). A total of 44 observation stations were surveyed at shallow depths, and 39 observation stations were surveyed at deep depths. Observation stations were assigned distinct numbering labels according to depth category. The spatial distribution and labeling of observation stations are presented in Figure 1.

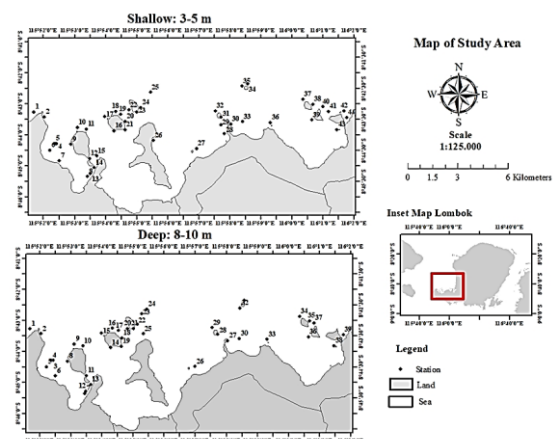


Figure 1. Map of Study Location

Data Collection

Megabenthos monitoring was conducted using the belt transect method, following the *Megabenthos Monitoring Guide, 2nd Edition* developed by COREMAP-CTI, Indonesian Institute of Sciences (LIPI) (Arbi and Sihaloho, 2017). Observations and counts of megabenthos and individual abundance were recorded along transect lines measuring 150 m in length, with an observation width of 1 m on each side of the

transect line (Figure 2). This resulted in a total survey area of 300 m² per transect (2 × 150 m). The megabenthos groups recorded during the survey included sea cucumbers (Holothuroidea), clams (Tridacninae), topshell snails (Trochidae), lobsters (Panuliridae), crown-of-thorns starfish (*Acanthasteridae*), coral-feeding snails (*Drupella* spp.), sea urchins (Echinoidea), and blue sea stars (*Linckia laevigata*).



Figure 2. Transect Illustration data collecting.

Data analysis

Megabenthos Abundance

Megabenthos abundance was defined as the number of individuals per unit area and calculated following Harvey (2008) using the formula:

$$\text{Abundance (ind/m}^2\text{)} = N / A$$

where:

N = total number of individuals of a given megabenthos taxon recorded within a transect
 A = area of the belt transect (300 m²; 2 × 150 m)

Abundance values were expressed as individuals per square meter (ind/m²).

Frequency of occurrence

Frequency of occurrence was used to determine the proportion of sampling stations at which each megabenthos taxon was present within the GITA NADA MPA. This metric provides an indication of the spatial distribution of species within an ecosystem (Suin, 2002). Frequency of occurrence was calculated following Krebs (1985) using the formula:

$$\text{Frequency of occurrence (\%)} = (n_i / N) \times 100$$

where:

n_i = number of stations where species i was recorded

N = total number of observation stations

Frequency of occurrence was categorised as follows:

0–25% : very rare occurrence

25–50% : rare occurrence

50–75% : common occurrence

75–100% : absolute occurrence

Distribution Pattern Megabentos

The Distribution pattern of megabenthos was analysed using the Morisita index (Id). Calculations of Id, along with the uniform (Mu) and clumped (Mc) distribution indices, followed Jongjitvimolet *et al.* (2005). The Morisita index (Id) was calculated using the formula:

$$Id = n \frac{\sum \chi^2 - \sum \chi_i}{(\sum \chi_i)^2 - \sum \chi_i}$$

where:

Id = Morisita index

n = number of observation stations

χ_i = number of individuals at station i

The values of Mu and Mc were calculated as follows:

$$Mu = \frac{\chi_{0.975}^2 - n + \sum x_i}{(\sum x_i) - 1}$$

$$Mc = \frac{\chi_{0.025}^2 - n + \sum x_i}{(\sum x_i) - 1}$$

where:

Mu = Morisita index for uniform distribution

Mc = Morisita index for clumped distribution

$\chi_{0.975}^2$ = chi-square value with $n-1$ degrees of freedom at 97,5% confidence level

$\chi_{0.025}^2$ = chi-square value with $n-1$ degrees of freedom at 2,5% confidence level

To standardise the Morisita index, the Morisita degree (Ip) was calculated using the following criteria:

If $Id \geq Mc > 1$, then:

$$Ip = 0,5 + 0,5 \left(\frac{Id - Mc}{n - Mc} \right)$$

If $Mc > Id \geq 1$, then:

$$Ip = 0,5 + 0,5 \left(\frac{Id - 1}{Mc - 1} \right)$$

If $1 > Id > Mu$, then:

$$Ip = -0,5 \left(\frac{Id - 1}{Mu - 1} \right)$$

If $1 > Mu > Id$, then:

$$Ip = -0,5 + 0,5 \left(\frac{Id - Mu}{Mu} \right)$$

Based on the resulting Ip value, distribution patterns were classified as follows:

- $Ip < 0$: uniform distribution
- $Ip = 0$: random distribution
- $Ip > 0$: clumped distribution

Independent T-test Statistic

An independent *t*-test was used to compare the mean abundance of megabenthos between the dry and wet seasons. This test compares the means of two independent groups to determine whether a statistically significant difference exists (Hartono, 2008). Independent *t*-tests were applied to total megabenthos abundance as well as to individual megabenthos. Statistical analyses were conducted using SPSS version 16.

Decision criteria followed Hartono (2008) and were based on significance (Sig.) values:

Sig, > 0,05 : not significant (H_0 accepted)

Sig, < 0,05* : significant (H_1 accepted)

Sig, < 0,01** : highly significant

The hypotheses tested in this study were:

H_0 : There is no difference in megabenthos abundance between the dry and wet seasons.

H_1 : There is a difference in megabenthos abundance between the dry and wet seasons.

Results And Discussion

Megabenthos Abundance at 3-5m Depth

The total number of megabenthos individuals recorded at depths of 3–5 m across all stations during the dry season was 1.536 individuals, while 1.269 individuals were recorded during the wet season. As shown in Figure 3, the mean megabenthos abundance during the dry season was 0,3495 ind/m², whereas the mean abundance during the wet season was 0,2884 ind/m². Although mean megabenthos abundance was higher in the dry season than in the wet season, an independent *t*-test indicated that this difference was not statistically significant ($P > 0,05$).

The blue sea star exhibited the highest mean abundance among all megabenthos in both the dry season (0,155 ind/m²) and the wet season (0,147 ind/m²). This finding is consistent with the study by Nursakinah et al. (2023), who reported that blue sea stars had the highest abundance in shallow waters of Pandanan Hamlet, West Sekotong. The highest abundance of blue sea stars during the dry season was recorded at station 20 (1,21 ind/m²) (Figure 4), while the highest abundance during the wet season was observed at station 41 (0,86 ind/m²) (Figure 5). Based on visual observations, station 20 was dominated by rubble substrate, whereas station 41 was dominated by live coral. This agrees with Siburian et al. (2023), who reported that blue sea stars tend to inhabit hard and rocky substrates such as coral reefs and rubble in Kri Raja Ampat.

Trochus spp. exhibited the lowest mean abundance across all stations in both the dry season (0,0005 ind/m²) and the wet season (0,001 ind/m²), followed by lobsters, which showed a mean abundance of 0,001 ind/m² in both seasons (Figures 4 and 5). The low abundance of *Trochus* spp. may be related to their nocturnal feeding behaviour, making them difficult to detect during daytime

surveys. Juliet et al. (2015) reported that *Trochus* species are gastropods that actively forage at night. Similarly, the low abundance of lobsters may be attributed to harvesting pressure by local communities. Cappenberg and Mahulette (2019) stated that lobsters are becoming increasingly scarce due to fishing activities targeting these species for commercial purposes.

The mean abundance of crown-of-thorns (*Acanthaster* spp.) at 3–5 m depth was 0,002 ind/m², indicating a relatively low population density within the GITA NADA MPA. According to Luthfi and Iliani (2019), low abundances of crown-of-thorns do not pose a significant threat to coral reef health. Independent t-test analysis showed a significant difference ($P < 0.05$) in the mean abundance of *Drupella* spp. between the dry and wet seasons, whereas no significant seasonal differences were observed for other megabenthos. As shown in Figure 3, the mean abundance of *Drupella* spp. was higher during the dry season than during the wet season. This pattern may be related to increased food availability during the dry season. *Drupella* spp. are obligate corallivorous gastropods that feed directly on live coral tissue, and their abundance is strongly associated with the availability of coral

prey and reef habitat conditions (Hoeksema et al., 2018). Seasonal environmental conditions such as water clarity and reduced sediment input during the dry season may enhance coral health and productivity, potentially increasing food resources for corallivorous organisms such as *Drupella* spp. (Hoeksema et al., 2018). Consequently, higher coral prey availability during the dry season may contribute to the increased abundance of *Drupella* spp. observed in this study.

Station 21 exhibited the highest megabenthos abundance during the dry season (1,95 ind/m²), while station 6 recorded the highest abundance during the wet season (1,79 ind/m²) (Figure 4). The high abundances observed at station 21 in the dry season and station 6 in the wet season were primarily influenced by sea urchin abundance, which reached 1,89 ind/m² and 1,79 ind/m², respectively. Visual observations indicated that station 6 was dominated by rubble substrate, whereas station 21 was dominated by sandy substrate. This finding aligns with Suryanti (2020), who reported that sea urchins preferentially inhabit rubble and sandy substrates. Additionally, Ghafari et al. (2020) suggested that increases in sea urchin populations may be associated with water pollution.

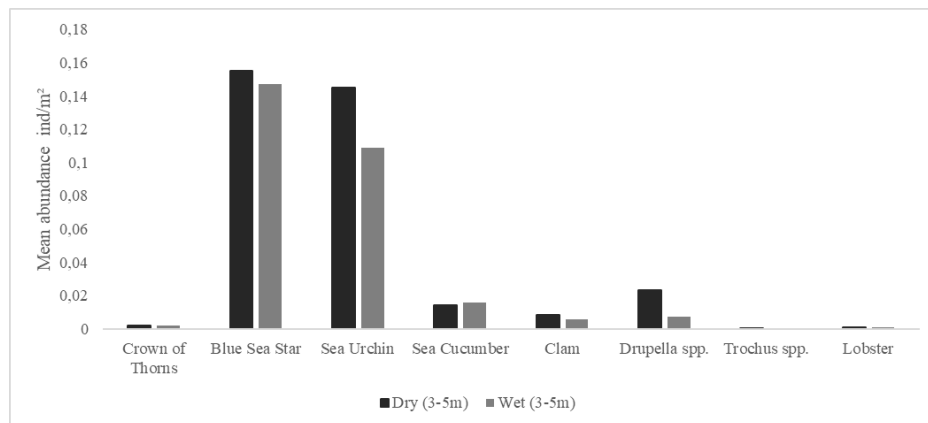


Figure 3. Mean megabenthos abundance at 3-5m

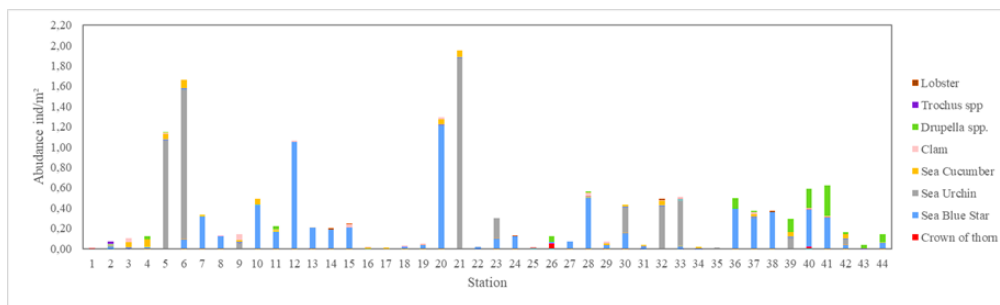


Figure 4. Megabenthos abundance at 3-5m during dry season.

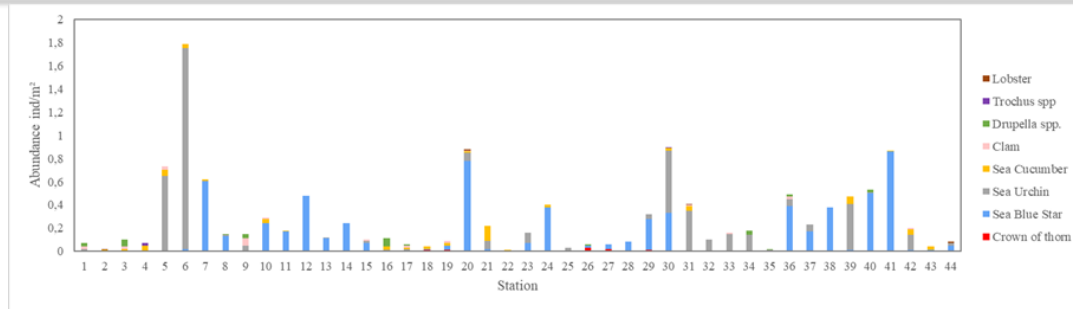


Figure 5. Megabenthos abundance at 3-5m during wet season.

Megabenthos Abundance at 8-10m Depth

The total number of megabenthos individuals recorded at depths of 8–10 m across all stations during the dry season was 3,828 individuals, while 3,625 individuals were recorded during the wet season. Mean megabenthos abundance during the dry season was 0,9303 ind/m², compared with 0,9295 ind/m² during the wet season. Although mean megabenthos abundance was slightly higher in the dry season, independent *t*-test analysis indicated no significant difference between dry and wet seasons ($P > 0.05$).

Sea cucumbers exhibited the highest mean abundance among all megabenthos in both the

dry season (0,740 ind/m²) and the wet season (0,776 ind/m²) (Figure 6). This pattern was strongly influenced by station 17, which showed exceptionally high sea cucumber abundance in both the dry season (27,95 ind/m²) and the wet season (29,25 ind/m²) (Figures 7 and 8). The sea cucumbers recorded at station 17 were predominantly yellow sea cucumbers (*Colochirus* sp.), characterised by a yellow body and tentacles and body sizes exceeding 1 cm (Figure 12). According to Du *et al.* (2017), *Colochirus* spp. contain high levels of vitamins, minerals, and other bioactive compounds that are beneficial to human health.

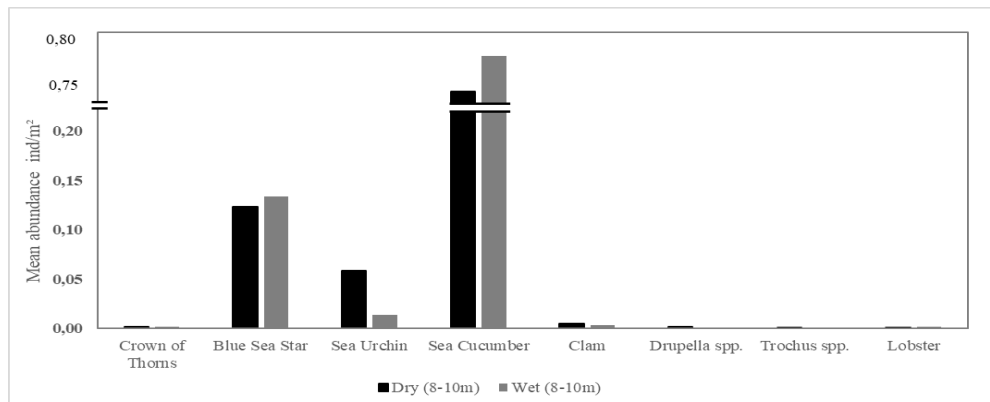


Figure 6. Mean megabenthos abundance at depth 8-10m.

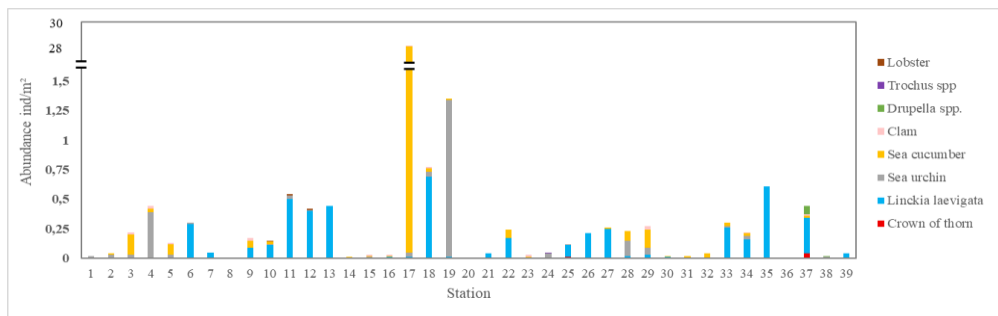


Figure 7. Megabenthos abundance all station at 8-10m dry season.

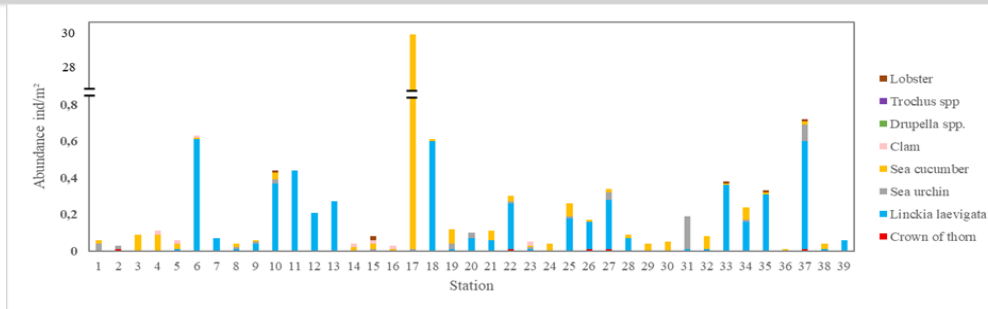


Figure 8. Megabenthos abundance all station at 8-10m wet season

Blue sea stars and sea cucumbers exhibited higher abundances during the wet season compared with the dry season, whereas most other megabenthos showed higher abundances during the dry season. Independent *t*-test analysis revealed significant seasonal differences ($P < 0,05$) in the abundance of *Drupella* spp., *Trochus* spp., and sea urchins, while no significant seasonal differences were detected for other megabenthos. *Drupella* spp. and *Trochus* spp. were recorded during the dry season but were not observed during the wet season.

Megabenthos frequency of occurrence at 3-5m Depth

Figure 9 shows that the frequency of occurrence of megabenthos in the GITA NADA MPA at depths of 3–5 m ranged from 2,27% to 70,45% during the dry season and from 4,55% to 65,91% during the wet season. Based on these values, frequency of occurrence during both seasons was categorised from very rare to common occurrence. The blue sea star exhibited the highest frequency of occurrence in both the dry season (70,45%) and the wet season (65,91%), followed by sea urchins, which showed frequencies of 56,82% in the dry season and 61,36% in the wet season. These results indicate that blue sea stars and sea urchins fall within the common occurrence category at this depth.

Other megabenthos, including *Trochus* spp., lobsters, and crown-of-thorns, exhibited very rare occurrence (<25%). The low occurrence of *Trochus* spp. and lobsters may be related to their nocturnal behaviour, which reduces detectability during daytime surveys. Cappenberg et al. (2019) reported that both lobsters and *Trochus* spp. are primarily nocturnal species. Crown-of-thorns also showed very rare

occurrence (<25%), indicating that their population density at depths 3–5 m in the GITA NADA MPA is low. This suggests that Crown-of-thorns are not currently a threat to coral reef ecosystems at this depth. Consistent with this finding, Ghafari et al. (2020) reported that crown-of-thorns were not observed in 2019 and that their abundance remained well below thresholds associated with coral reef degradation in West Sekotong.

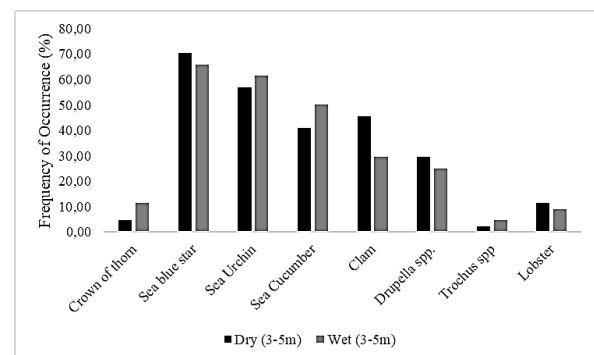


Figure 9. Megabenthos frequency of occurrence at 3-5m

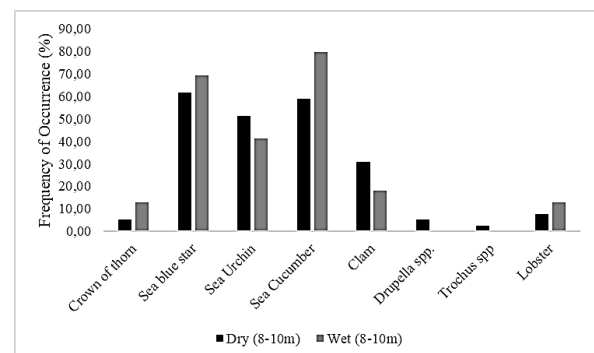


Figure 10. Megabenthos frequency of occurrence at 8-10m

Figure 10 shows that the frequency of occurrence of megabenthos in the GITA NADA

MPA at depths of 8–10 m ranged from 2,56% to 61,54% during the dry season and from 0% to 79,49% during the wet season. Based on these values, megabenthos frequency of occurrence in both seasons ranged from very rare to absolute occurrence. Sea cucumbers exhibited the highest frequency of occurrence during the wet season, reaching 79,49%, which falls within the absolute occurrence category. This pattern may be related to reproductive activity, as Ali. (2024), reported that the availability of organic matter and sediment nutrients increases during the rainy season and affects the growth and activity of sea cucumbers. *Drupella* spp. and *Trochus* spp. showed the lowest frequency of occurrence during the wet season, with values of 0%, indicating very rare occurrence at this depth. In contrast, blue sea stars exhibited a high frequency of occurrence (69,23%), categorised as common occurrence.

Megabenthos distribution pattern

Based on Table 1, Morisita's degree (I_p) values across all observations ranged from -0,0005 to 0,492. The distribution patterns of megabenthos across all sampling locations were classified as either clumped or uniform. Crown-of-thorns (*Acanthaster* spp.), blue sea stars, sea urchins, clams, and *Drupella* spp. exhibited clumped distribution patterns in both the dry and

wet seasons and at both depth categories (3–5 m and 8–10 m). Lobsters exhibited a clumped distribution pattern only during the wet season at depths of 8–10 m, while *Trochus* spp. showed a clumped distribution pattern at depths of 3–5 m during both the dry and wet seasons. According to Fitriyani *et al.* (2022), clumped distribution patterns may result from similar species abundances among locations, as well as shared environmental conditions, substrate types, and food availability.

In contrast, *Trochus* spp. at depths of 8–10 m exhibited a uniform distribution pattern. Lobsters also showed a uniform distribution pattern during the dry season at both depths (3–5 m and 8–10 m) and during the wet season at 3–5 m depth. These uniform distribution patterns are likely related to the low abundance of *Trochus* spp. and lobsters across observation locations (Figures 3 and 6). Wahab *et al.* (2019) reported that uniform distribution patterns can arise when species occur at low densities and when large habitat areas promote spatial separation as individuals seek food or suitable habitat. Uniform distribution may also occur when competition among individuals is evenly distributed or when antagonistic interactions influence spatial spacing, resulting in regular dispersion patterns (Riyanti, 2023).

Table 1. Distribution pattern megabenthos GITA NADA MPA

Megabentos	Season	Depth	ID	Mu	Mc	I_p	Category
Crown of Thorn	Dry	3-5 m	23,05	247,76	513,26	0,022	Clumped
	Dry	8-10 m	23,4	271,81	603,49	0,019	Clumped
	Wet	3-5 m	6,29	218,65	446,22	0,006	Clumped
	Wet	8-10 m	23,40	271,81	603,49	0,019	Clumped
Blue sea stars	Dry	3-5 m	3,63	45,8	48,13	0,028	Clumped
	Dry	8-10 m	3,13	40,94	43,71	0,025	Clumped
	Wet	3-5 m	3,12	45,89	48,35	0,022	Clumped
	Wet	8-10 m	2,79	40,79	43,34	0,021	Clumped
Sea urchin	Dry	3-5 m	8,11	45,92	48,42	0,075	Clumped
	Dry	8-10 m	14,67	43,12	48,99	0,142	Clumped
	Wet	3-5 m	7,74	46,55	49,88	0,069	Clumped
	Wet	8-10 m	5,92	56,91	82,42	0,030	Clumped
Sea cucumber	Dry	3-5 m	2,64	63,41	88,69	0,009	Clumped
	Dry	8-10 m	36,58	36,75	37,18	0,492	Clumped
	Wet	3-5 m	2,85	61,98	85,41	0,011	Clumped
	Wet	8-10 m	36,42	39,31	39,75	0,457	Clumped
Clam	Dry	3-5 m	2,17	78,93	124,44	0,005	Clumped
	Dry	8-10 m	1,78	93,78	171,82	0,002	Clumped
	Wet	3-5 m	3,37	94,94	161,32	0,007	Clumped
	Wet	8-10 m	3,00	116,60	227,16	0,004	Clumped

Megabentos	Season	Depth	ID	Mu	Mc	Ip	Category
<i>Drupella sp</i>	Dry	3-5 m	6,78	56,1	71,88	0,041	Clumped
	Dry	8-10 m	29,25	172,03	361,56	0,039	Clumped
	Wet	3-5 m	4,70	83,44	134,82	0,014	Clumped
	Wet	8-10 m	-	-	-	-	-
<i>Trochus spp</i>	Dry	3-5 m	44	1266,54	2859,56	0,008	Clumped
	Dry	8-10 m	0,00	931,24	2257,94	-0,0002	Uniform
	Wet	3-5 m	14,67	655,27	1451,78	0,005	Clumped
	Wet	8-10 m	-	-	-	-	-
Lobster	Dry	3-5 m	0	349,63	747,89	-0,001	Uniform
	Dry	8-10 m	0,00	504,62	1167,97	-0,0004	Uniform
	Wet	3-5 m	0,00	451,51	982,52	-0,0005	Uniform
	Wet	8-10 m	2,60	225,25	490,59	0,0016	Clumped

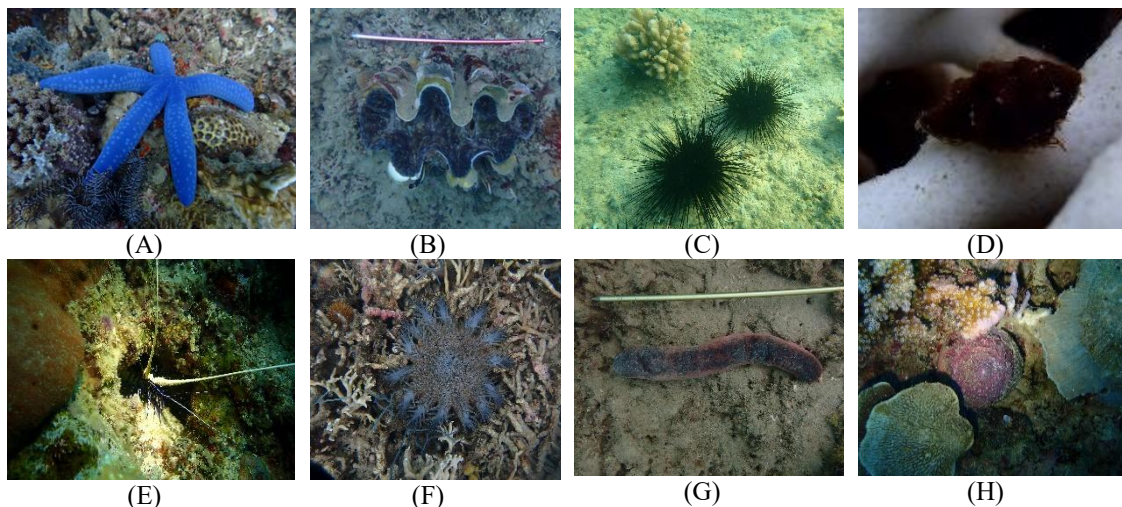


Figure 11. Megabenthos representative photos at GITA NADA MPA. A= Sea blue star, B= Clam, C= Sea urchin, D= *Drupella* spp, E= Lobster, F= Crown of thorn, G= Sea cucumber, H= *Trochus* spp

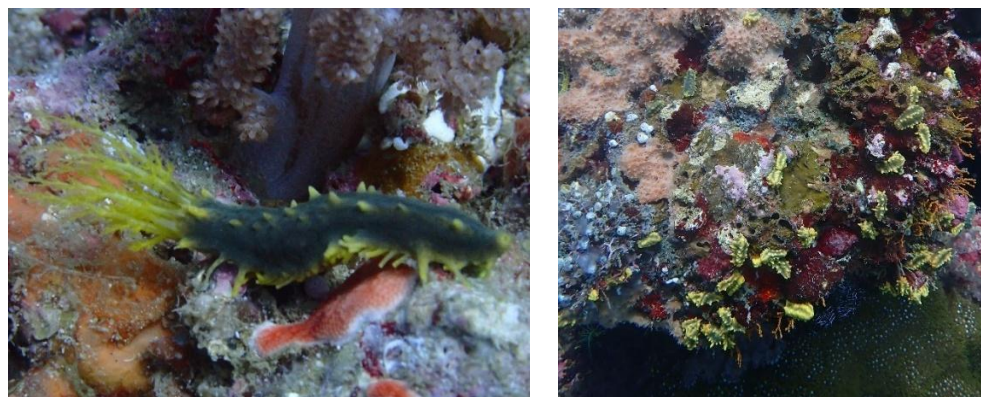


Figure 12. Yellow sea cucumber in station 17 at 8-10m.

Conclusion

Megabenthos abundance at depths of 3–5 m in the GITA NADA MPA was 16,59 ind/m² during the dry season and 13,83 ind/m² during the wet season, while at depths of 8–10 m abundance was 39,74 ind/m² in the dry season and 38,25

ind/m² in the wet season. Independent *t*-test analysis indicated no significant differences in megabenthos abundance between the dry and wet seasons at either depth (3–5 m and 8–10 m) ($P > 0,05$). Frequency of occurrence of megabenthos at depths of 3–5 m ranged from 2,27% to 70,45% (very rare to common occurrence) during the dry

season and from 4,55% to 65,91% (very rare to common occurrence) during the wet season. At depths of 8–10 m, frequency of occurrence ranged from 2,56% to 61,54% (very rare to common occurrence) in the dry season and from 0% to 79,49% (very rare to absolute occurrence) in the wet season. Distribution patterns of megabenthos were classified as either clumped or uniform, with Morisita degree (Ip) values ranging from –0,0005 to 0,492. These patterns suggest that megabenthos distribution in the GITA NADA MPA is primarily influenced by local habitat characteristics and resource availability rather than seasonal variation.

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