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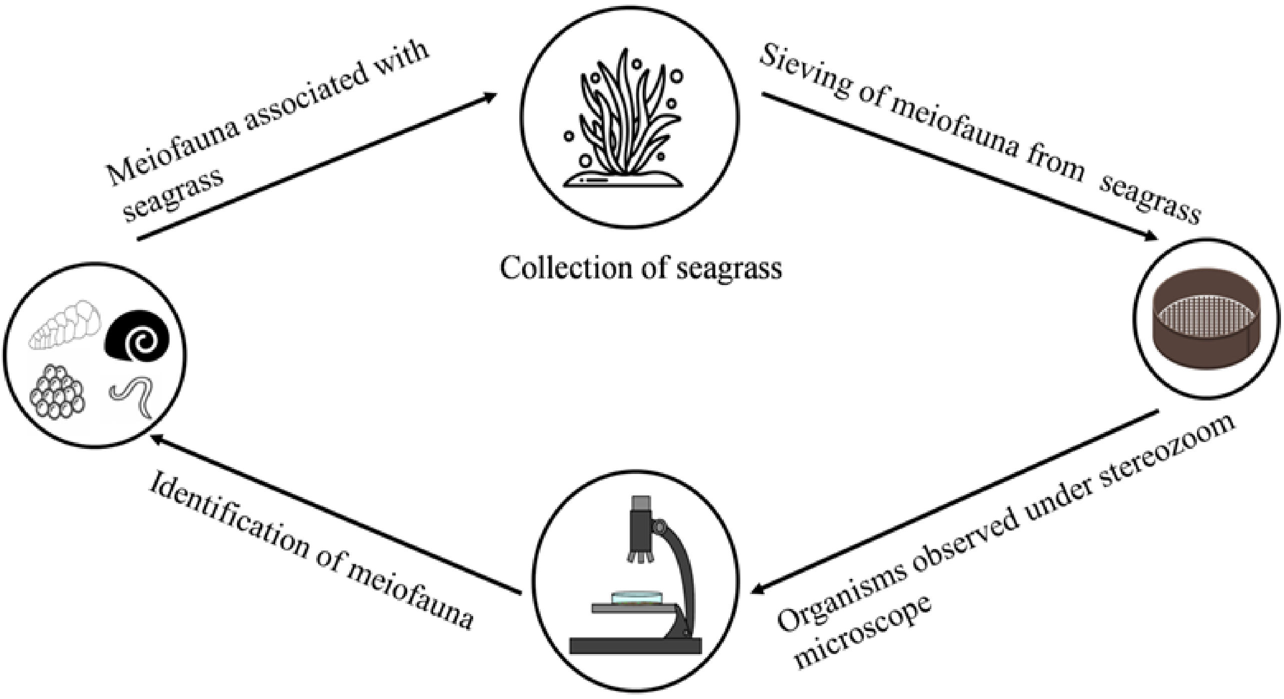
RESEARCH ARTICLE

Seagrass Morphometrics and Meiofauna Composition: A Comparative Study in South Andaman's Waters

R. Rasheed[1], G. Padmavati[1*] and A. Purkayastha[2]

Graphical Abstract



Highlights

- Assessed morphometry and meiofaunal communities of three seagrass species in South Andaman.
- *Halophila ovalis* had the highest meiofaunal abundance; nematodes and harpacticoid copepods dominated.
- Community composition was similar among species, with subtle structural differences.
- Air temperature and dissolved oxygen influenced key meiofaunal groups, indicating complex seagrass–meiofauna interactions.

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Seagrass Morphometrics and Meiofauna Composition: A Comparative Study in South Andaman's Waters

R. Rasheed[1], G. Padmavati[1*] and A. Purkayastha[2]

[1]*Department of Ocean Studies and Marine Biology, Pondicherry University, Brookshabad-744112, Andaman and Nicobar Islands*

[2]*Department of Biological Sciences, Graduate School of Science, Osaka University, Osaka-5600043, Japan*

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Abstract

A comprehensive assessment of seagrass morphometry and associated meiofaunal communities was conducted in South Andaman Island from January to March 2020. Three seagrass species, *Thalassia hemprichii*, *Halophila ovalis*, and *Halodule pinifolia*, were sampled fortnightly at two sites. Morphometric analysis indicated broad similarity among species, except for leaf length, which varied significantly. *Halophila ovalis* supported the highest meiofaunal abundance (191 individuals), followed by *T. hemprichii* (176) and *H. pinifolia* (104). Meiofauna were distributed across the root, stipe, and leaf regions of all species, with nematodes and harpacticoid copepods dominating the communities. Key taxa such as *Robertsonia robusta*, *Elphidium* sp., *Calcarina* sp., and *Sorites* sp. occurred consistently across all seagrasses. Statistical analyses revealed no significant differences in meiofaunal community composition among the three species, suggesting a relatively uniform distribution. However, strong correlations ($r = 0.98$) indicated subtle variations in community structure. Environmental variables exerted differential influences on meiofaunal groups: air temperature showed strong positive associations with Oligochaeta and Foraminifera, whereas dissolved oxygen exhibited strong negative correlations with several taxa, particularly Polychaeta and Tanaidacea. This study highlights the complex interactions between seagrass morphometry, environmental factors, and meiofaunal assemblages in South Andaman Island. Although overall community composition appeared uniform, the subtle species-specific associations observed here emphasize the need for broader spatial and temporal investigations to better understand the ecological processes shaping these critical marine habitats.

keywords: Association; Meiofauna; Morphometry; Seagrass; South-Andaman

INTRODUCTION

Seagrasses are exclusive marine angiosperms comprising <0.02% of the angiosperm flora that occur in all the coastal areas of the intertidal and subtidal marine environment except the polar region (Bell et al., 1989; McKenzie et al., 2002; Robertson & Lenanton, 1984). They inhabit a physically challenging environment, such as mud and sand, and protect the shorelines against erosion in the middle, lower intertidal, and subtidal zones. Currently, 72 species of seagrass belonging to six families are recognized (Duarte et al., 2008). Seagrass meadows are widely recognized in coastal systems for providing valuable ecosystem services (Costanza et al., 1997) as well as in contributing significantly to the net production of coastal ecosystems (Duarte & Cebrian, 1996). Morphometric measurements in seagrass are addressed at different levels of organization: the shoot, the whole plant, and the population level (Short & Duarte 2001). Various morphometric attributes included are leaf length, sheath length, leaf width, root length, rhizome diameter, internode length, and root diameter (Ramili et al., 2018).

The association of the meiofaunal community with seagrass species has been studied widely, showing a broad relationship (Hall & Bell, 1993). Factors such as pH, current, and amount of available oxygen, as well as seagrass density, affect the availability of meiofauna in seagrass meadows (Zulkifli et al., 2007). Ramamurthy et al. (1992) conducted a detailed survey on seagrass taxonomy in the Coromandel Coast, India. They gave the complete seagrass taxonomy note for 14 species of seagrass, along with their distribution and biomass. Walters & Bell (1994) studied the role of meio-benthic copepods' emergence in linkages among benthic, pelagic, and phytal habitats in a subtidal seagrass (*Thalassia testudinum*) meadow at the mouth of Tampa Bay, Florida. USA.

The health and condition of seagrass patches in the

**Corresponding Author's Email:*padma13021963@gmail.com
https://orcid.org/0009-0009-1299-3680

Andaman and Nicobar Islands are remarkably good, but studies concerning the distribution of species are limited (Thangaradjou et al., 2010). Studies on the Seagrass ecosystem are poorly known from the coastal waters of the South Andaman (Jayabarathi et al., 2015; Naufal & Padmavati, 2018; Savurirajan et al., 2015, 2018). To fill this lacuna, it was considered necessary to undertake a study on the seagrass ecosystem from the coastal waters of the South Andaman to assess the impact of seagrass morphology on the occurrence and abundance of associated fauna.

MATERIALS AND METHODOLOGY

Sampling site

Two different sites around South Andaman Island were selected based on seagrass distribution and abundance. The sites were Haddo (HD) {11°40´54´´N; 92°43´34´´E} and Burmanallah (BN) {11°35´58´´N; 92°44´07´´E}, which lie on the eastern coast of South Andaman Island (Figure 1). Both locations open up toward the Andaman Sea. HD has a vegetated intertidal region with a highly heterogeneous soft-bottom habitat, while BN has a homogenous, well-vegetated rocky intertidal habitat.

Physico-chemical parameters

Physico-chemical parameters such as the temperature (atmosphere and surface water), salinity, dissolved oxygen (DO), and pH were recorded. The temperature from the surrounding domain (atmosphere, water) was recorded in the field during each sampling occasion using a high-precision mercury-filled thermometer (accuracy ± 0.1°C). Salinity of near-shore seawater was estimated using a hand-held refractometer (ATAGO 2493 Master-S/MillM). pH was measured using an ESICO deep vision (model 1010) microprocessor-based pH meter. Dissolved oxygen of the water was estimated by Winkler's method (Strickland & Parsons, 1972).

Seagrass collection

A total of six random sampling surveys from each site were carried out. Seagrass samples (n=3) were collected by hand picking and kept in zip-lock pouches. The specimens were brought to the laboratory and identified using identification keys. For morphometric measurements, seagrass species were selected randomly and parameters such as leaf length, sheath length, shoot length, leaf width (top, middle, base), leaf thickness, petiole length, petiole thickness, internode length, node diameter, rhizome diameter, root length, and root diameter were measured using digital Vernier caliper (Sghaier et al., 2011).

Meiofaunal groups

For meiofauna identification, seagrass blades, stipe, and rhizome-root, which were cut in the field, were kept in different plastic pouches partially filled with filtered seawater. The pouches were added with 5% formaldehyde Rose Bengal solution (0.5g/L). The samples were then taken out in a Petri plate and filtered with seawater from the pouch. The seagrass leaf blade, stipe, and rhizome-root were scraped gently using a brush, and the contents were decanted into a 500 mL measuring cylinder and left for settlement for 24 hours. Later, the supernatant was slowly transferred over and sieved through 500 µm and 63 µm standard test sieves. The specimens retained on the 63 µm test sieve were placed into glass vials (10 ml). The preserved specimens were sorted and enumerated using a stereo-zoom microscope (Magnus MSZ-TR) and a compound microscope (Magnus MLX). Different groups of the meiofaunal community were identified. These were then further identified to species level or genus level, using standard identification keys (Conway et al., 2003; Higgins & Thiel, 1988; Lang, 1965; Wells & Rao, 1987; Wells, 1976)

Statistical analysis

Single-factor Analysis of Variance (ANOVA) test was conducted on seagrass species and meiofaunal communities using MS Excel, and PERMANOVA analysis was performed using PRIMER (Clarke & Gorley, 2006). These analyses assessed the variance within and between the groups to understand the influence of different factors on the community structure. Furthermore, the correlation between environmental parameters and meiofaunal species was analyzed using R Studio (R Core Team, 2024). This analysis helped identify significant relationships between abiotic factors and the distribution and abundance of meiofaunal species, providing insights into the ecological dynamics within the seagrass habitats.

RESULTS

Three seagrass species were recorded at both study sites: *Thalassia hemprichii*, *Halophila ovalis* (family Hydrocharitaceae), and *Halodule pinifolia (*family Cymodoceaceae). These species were distributed in the intertidal region. *Thalassia hemprichii* was predominantly found in the Burmanallah site, whereas *Halophila ovalis* and *Halodule pinifolia* were mainly recorded at the Haddo site.

Throughout the study period, both sites exhibited slight variations in different physicochemical parameters (Table 1). The temperature and pH levels were relatively consistent between the two locations. However, salinity and dissolved oxygen (DO) showed noticeable differences, with higher values recorded in Burmanallah.

Leaf length ranged from 14.5 to 70.0 mm, and leaf width ranged from 1.3 to 6.5 mm. *Thalassia hemprichii* leaves were thicker compared to *Halodule pinifolia* and *Halophila ovalis*. *T. hemprichii* also had the longest roots and largest rhizome diameters, while *H. pinifolia had the* thinnest rhizomes. The node and internode diameters in *H. ovalis* were negligible. *T. hemprichii* and *H. pinifolia* showed slight similarities in most morphometric parameters, whereas *H. ovalis* had the least similar characteristics among the three species (Table 2).

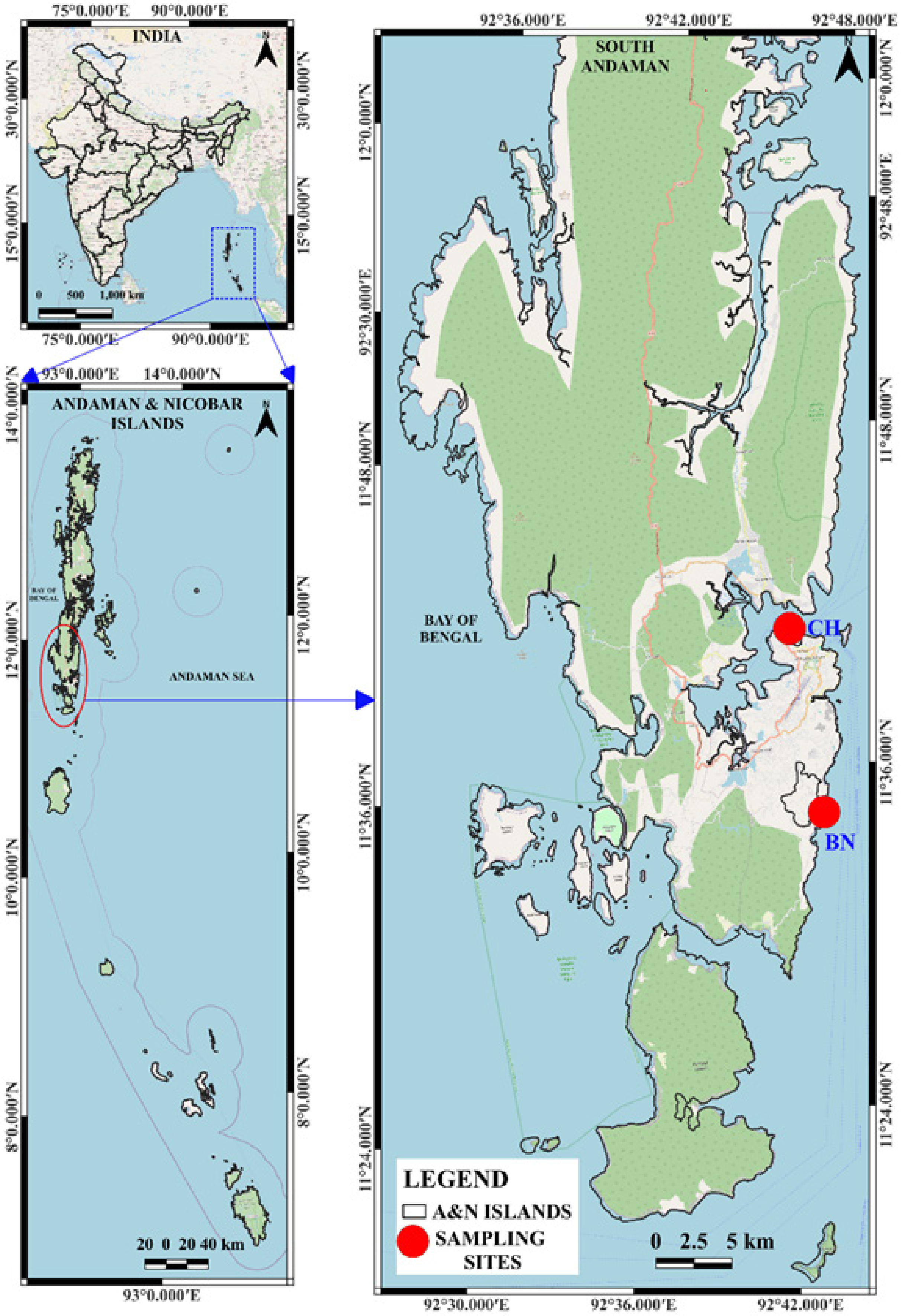

Figure 1: Geographic location of study area and sampling stations in South Andaman, India, showing the sites at Haddo (HD) & Burmanallah (BN).

Table 1: Physico-chemical parameters (mean ± SE) recorded at the two study sites, Haddo and Burmanallah, in South Andaman, India from January, 2020 to March, 2020

Parameters	Haddo	Burmanallah
Air Temperature (°C)	32.50 ± 1.64	32.33 ± 1.63
Sea-Water Temperature (°C)	32.67 ± 0.82	32.67 ± 0.82
Salinity PSU	28.50 ± 2.74	31.50 ± 0.84
pH	7.42 ± 0.16	7.34 ± 0.11
Dissolved Oxygen (DO) mg/L	6.95 ± 0.79	8.30 ± 1.12

Table 2: Morphometric measurements (mean ± SE) of the three seagrass species from the study sites.

Morphometric measurements (in mm)	*Thalassia hemprichii*	*Halodule pinifolia*	*Halophila ovalis*
Leaf Length	70.00 ± 14.59	63.00 ± 6.13	14.52 ± 2.03
Leaf Width	6.53 ± 0.77	1.33 ± 0.30	5.62 ± 0.68
Leaf Thickness	0.18 ± 0.08	0.07 ± 0.08	0.10 ± 0.06
Sheath Length	25.58 ± 2.72	17.78 ± 2.22	20.82 ± 5.26
Rhizome Diameter	2.77 ± 0.74	0.88 ± 0.34	1.07 ± 0.40
Root Length	58.63 ± 6.06	40.94 ± 4.17	23.62 ± 11.68
Root Diameter	0.80 ± 0.46	0.33 ± 0.25	0.38 ± 0.29
Node Diameter	2.62 ± 0.35	0.65 ± 0.19	0.01
Internode Length	19.92 ± 5.37	12.28 ± 11.12	0.01

Meiofaunal association

Seagrass associations with meiofauna are very common, and it has been observed that most of the meiofauna are associated with seagrass for food and shelter. Meiofauna were observed to be associated with the leaves and roots. This study revealed a total of 471 different individuals of meiofauna belonging to eight different phyla. It includes adults, juveniles, and larval forms of most groups from various phyla. Some of these groups are polychaeta, copepoda, nematoda, foraminifera, amphipoda, oligochaete, and gastropod larvae.

The meiofauna associated with the collected seagrass species were primarily distributed across three distinct regions of the plants: the roots, stipes, and leaves. Among the studied species, *Halophila ovalis* harbored the most diverse and abundant meiofaunal community, hosting 191 individuals from various taxonomic groups. *Thalassia hemprichii* followed closely, supporting 176 individuals, while *Halodule pinifolia* exhibited the lowest meiofaunal abundance with 104 individuals. Figure 2 reveals the quantitative values of the meiofaunal groups, highlighting nematodes being the most abundant group, with a total count of 185 individuals and an average of about 62 individuals per seagrass species. *Halophila ovalis* supported the highest nematode population with 72 individuals, followed by *Thalassia hemprichii* with 64 individuals, while *Halodule pinifolia* hosted the least with 49 individuals. This hierarchical pattern of abundance was consistently observed in other key meiofaunal taxa, including harpacticoid copepods, polychaetes, and foraminiferans.

Harpacticoida and Polychaeta are the next most abundant groups, with nearly identical total counts (74 and 73, respectively) and averages (around 24-25 individuals per species). Copepoda and Foraminifera show moderate abundance, with a total of 32 and 30, respectively, and averages of about 10-11 individuals per species. Amphipoda and Tanaedacea have a lower but notable presence, with totals of 28 and 20, respectively. Other groups, such as Oligochaeta, Gastropod larvae, were present in smaller numbers.

The results of the ANOVA conducted to assess the statistical significance of differences in meiofaunal abundance among the three seagrass species, there is no statistically significant difference in the numbers of meiofauna associated with *Halophila ovalis, Thalassia hemprichii*, and *Halodule pinifolia* (p =0.51). The ANOVA results also report an F-value of 0.69, which is lower than the critical F-value (Fcrit) of 3.40. This comparison further supports the conclusion of non-significance, as the calculated F-value does not exceed the critical value required to reject the null hypothesis of equal means. The correlation analysis of meiofaunal communities across three seagrass species reveals high similarities in distribution patterns. Correlation coefficients between *Halophila ovalis* and *Thalassia hemprichii* (0.97), *Thalassia hemprichii* and *Halodule pinifolia* (0.95), and *Halodule pinifolia* and *Halophila ovalis* (0.98) indicate that, despite differences in total meiofaunal abundance (*H. ovalis*: 191, *T. hemprichii*: 176, *H. pinifolia*: 104), the relative proportions of meiofaunal groups remain consistent.

The PERMANOVA and Principal Coordinate Analysis (PCoA) were employed to investigate the differences in meiofaunal community composition among three seagrass species. PERMANOVA analysis revealed no statistically significant differences in overall meiofaunal community composition among the three seagrass species ($p > 0.05$). Pairwise tests revealed that three seagrass species were not significantly different from each other in terms of meiofaunal composition. This suggests that, at a broad level, the meiofaunal assemblages associated with these seagrass species are relatively similar. However, it's important to note that the lack of statistical significance could be due to the limited sample size (one sample per seagrass species), which reduces the power of the test to detect differences. The PCoA plot (Figure 3) provides a visual representation of the similarities and differences in meiofaunal communities among the seagrass species. The first two PCoA axes explained 92.63% and 7.37% of the total variation, respectively. The relative positions of the three seagrass species on the PCoA plot indicate subtle differences in their associated meiofaunal communities e.g., *Halophila ovalis* and *Thalassia hemprichii* appear closer to each other compared *to Halodule pinifolia*, suggesting more similar meiofaunal compositions. The arrows on the PCoA plot represent the influence of different meiofaunal groups e.g., Nematodes show a strong association with *Halophila ovalis*, while harpacticoid copepods are more closely associated with *Thalassia hemprichii*. The length and direction of the arrows suggest that Foraminifera and Tanaidacea are the primary drivers of community differences among the seagrass species.

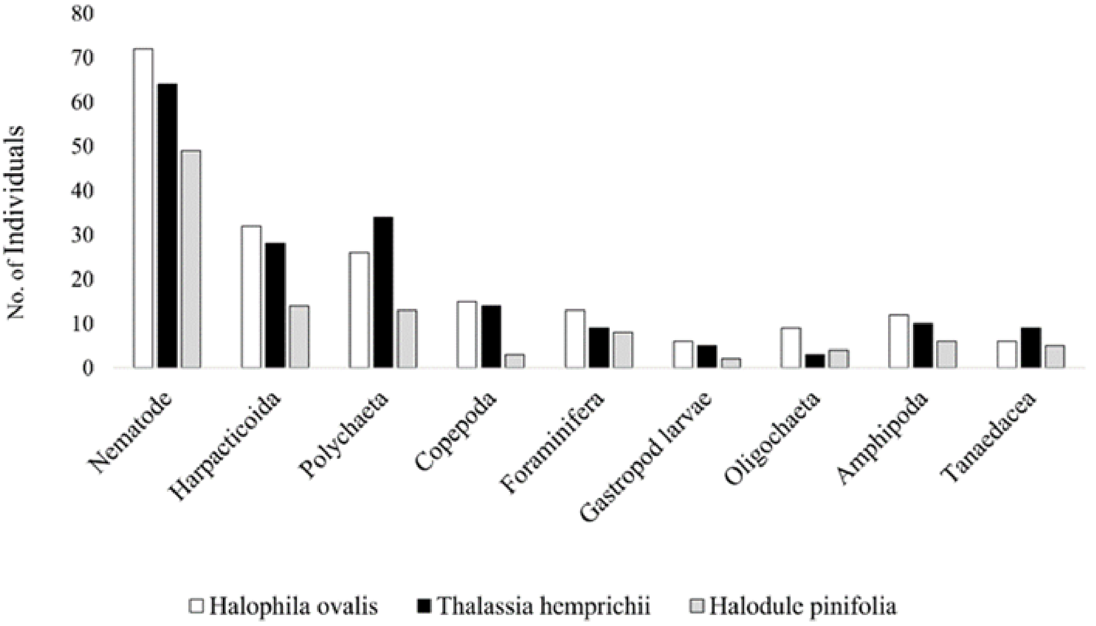

Figure 2: Meiofaunal groups associated with three seagrass species across the study locations in South Andaman, India.

Statistical correlation using Principal Component Analysis (PCA) biplot (Figure 4) illustrates the relationships between abiotic parameters and meiofauna composition in the respective seagrass. The plot shows the first two principal components (PC1 and PC2) and how various meiofauna groups and environmental factors correlated with these components. The biplot showed significant positive and negative relationships between the meiofaunal group and the abiotic factors. Air Temperature showed a strong positive correlation with Oligochaeta and Foraminifera, while pH appears to be positively correlated with Amphipoda and Gastropod larvae. Nematoda showed a slight positive correlation with Salinity. On the other hand, Dissolved Oxygen shows a strong negative correlation with most meiofauna groups, particularly Polychaeta and Tanaidacea. Copepoda appeared to be negatively correlated with Air Temperature, while Polychaeta and Tanaidacea showed negative correlations with Air Temperature and pH. Some meiofaunal groups appear to have weak correlations with most abiotic factors, as they are positioned near the center of the plot. The plot also shows three numbered points (sit1, sit2, sit3) which represent the different seagrass species, viz., *Halophila ovalis*, *Thalassia hemprichii*, and *Halodule pinifolia*, respectively. It is important to note that the length of the arrows indicates the strength of the correlation, with longer arrows suggesting stronger correlations. The angles between arrows represent the degree of correlation between variables, with acute angles indicating positive correlations and obtuse angles indicating negative correlations.

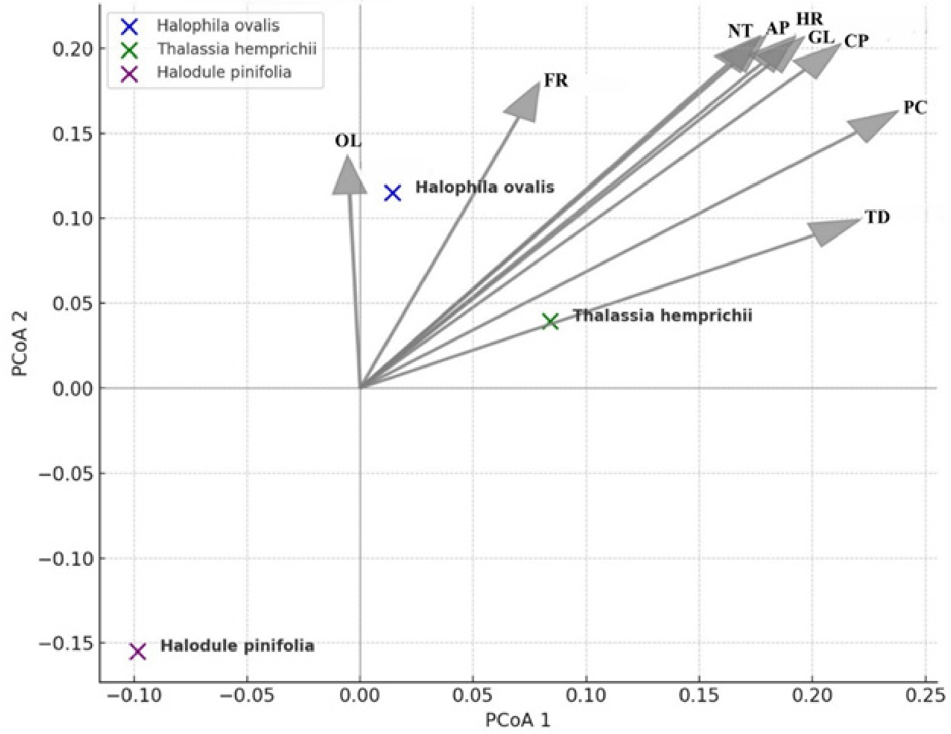

Figure 3: Principal Coordinate Analysis (PCoA) of meiofaunal groups associated with seagrass species. Meiofauna: AP- Amphipoda, TD- Tanaidacea, PC- Polychaeta, Copepoda, NT- Nematoda, FR- foraminifera, OL-Oligochaete, and GL- gastropod larvae, HR- Harpacticoida.

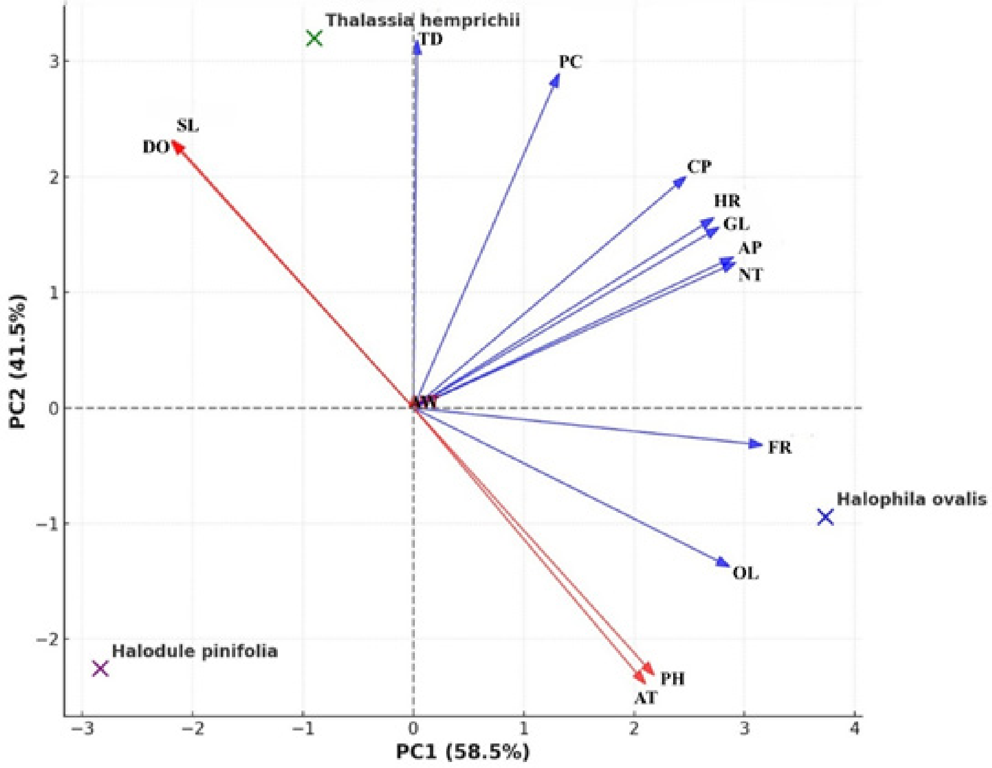

Figure 4: Principal Component Analysis (PCA) biplot illustrating correlations between measured abiotic factors and meiofaunal groups. Meiofauna: AP- Amphipoda, TD- Tanaidacea, PC- Polychaeta, CP- Copepoda, NT- Nematoda, FR- Foraminifera, HR- Harpacticoida, OL- Oligochaete, and GL- Gastropod larvae. Environmental parameters: AW- Water temperature, AT- Air temperature, PH- pH, SL- Salinity, DO- Dissolved oxygen.

Meiofauna distribution

Table 4 gives a list of the different meiofaunal groups that were identified from the three seagrass species. Foraminifera species such as *Sorites* sp., *Calcarina* sp., *Elphidium* sp., Harpacticoida species *such as Brianola hamondi, Scottolana longipes, Scutellidium* sp., *Robertsonia robusta,* Polychaete species *such as* Polychaeta larvae, *Microphthalmus listensis,* Nematode species *such as Cobbia* sp., Amphipod and Gastropod larvae were seen to be common in all the seagrass species studied. While some species, such as *Globigerina* sp. *Quinequeloculine* sp., *Spirolina* sp., *Atthyella* sp., *Ectinasoma reductum, Halophytophilus simplex, Euplete aurulenta, Canuellina nicobaris,* and *Ectinosoma melaniceps* were only restricted to *Thalassia hemprichii.*

Table 4: List of meiofaunal taxa identified associated with the different parts (leaf, stipe and root) of three seagrass species, *Thalassia hemprichii, Halodule pinifolia* and *Halophila ovalis*.

Taxa	*Thalassia hemprichii*			*Halodule pinifolia*			*Halophila ovalis*		
	Leaf	Stipe	Root	Leaf	Stipe	Root	Leaf	Stipe	Root
Foraminifera									
Sorites sp.	*	-	-	*	-	*	*	-	*
Penaroplis sp.	-	*	*	*	-	-	-	-	-
Calcarina sp.	-	*	*	-	-	*	*	-	*
Rotalia sp.	*	*	*	*	-	-	-	-	-
Amphistegina sp.	-	*	-	*	-	-	-	-	-
Elphidium sp.	-	*	*	-	-	*	*	-	*
Globigerina sp.	*	-	*	-	-	-	-	-	-
Quinequeloculine sp.	*	-	-	-	-	-	-	-	-
Spirolina sp.	-	*	-	-	-	-	-	-	-
Harpacticoida									
Atthyella sp.	*	*	-	-	-	-	-	-	-
Brianola hamondi	*	-	*	-	*	*	*	*	*
Scottolana longipes	*	*	*	-	-	*	-	-	-
Scutellidium sp.	-	*	*	-	-	-	*	*	*
Robertsonia robusta	-	*	*	*	-	-	*	-	-
Ectinasoma reductum	-	*	-	-	-	-	-	-	-
Halophytophilus simplex	*	*	-	-	-	-	-	-	-
Euplete aurulenta	-	*	*	-	-	-	-	-	-
Porcellidium ravanae	*	-	-	*	-	*	-	-	-
Idyella sp.	-	-	*	-	-	*	-	-	-
Diathrodes sp.	-	*	-	-	-	-	-	-	*
Canuellina nicobaris	-	-	*	-	-	-	-	-	-
Ectinosoma melaniceps	*	-	-	-	-	-	-	-	-
Polychaeta									
Polychaeta larvae	*	*	*	-	*	-	*	*	*
Microphthalmus listensis	*	*	-	*	-	-	*	*	-
Tendorillus serratus	-	*	*	-	-	-	-	-	-
Dorvilea sp.	*	*	-	-	-	-	-	-	-
Oligochaeta	-	*	-	-	-	*	-	-	-
Nematode									
Cobbia sp.	*	*	*	-	*	-	*	*	*
Epsilonema sp.	-	-	-	-	*	*	-	-	-
Amphipoda	*	*	*	*	*	*	-	-	-
Gastropod larvae	*	*	-	*	*	*	*	*	*
Tanaedacea	*	*	*	*	-	-	*	*	-

The symbols '*' and '–' indicate the presence and absence of a tax on, respectively

DISCUSSION

All seagrass species grow well in the intertidal region under favorable environmental conditions (Savurirajan et al., 2018). Morphometric parameters reveal that root length, sheath length, and leaf length were higher compared to other attributes, particularly in *T. hemprichii*. This could be due to the influence of nutrients that are required for the growth of this seagrass in this area (Lee & Dunton, 2000).

Naufal & Padmavati (2018) reported that *Halodule uninervis* and *Thalassia hemprichii*, with their longer leaf blades (6.0±0.2 cm) and flat surface areas, supported a greater abundance of associated fauna compared to *Halophila ovalis* (2.1±0.3 cm). However, the present study yielded contrasting results. *Halophila ovalis* harbored the highest number of meiofauna individuals (201), followed by *Thalassia hemprichii* (183), while *Halodule pinifolia* supported the lowest meiofaunal abundance (104 individuals). This could be attributed to the oval and wide leaf structure of *H. ovalis*, which provides a more suitable substratum for meiofaunal attachment compared to the flat surface of *T. hemprichii*. This anomaly highlights the complexity of seagrass-meiofauna interactions and suggests that factors beyond leaf length and surface area play crucial roles in determining meiofaunal abundance and distribution. The oval shape of *H. ovalis* leaves might offer increased surface area per unit length, potentially creating more diverse microhabitats or offering better protection from predators. Additionally, the wider leaves could trap more detritus or epiphytic growth, providing enhanced food resources for meiofauna.

Nematodes dominated in abundance in all three seagrass species, followed by harpacticoids. This is a general remark reviewed in many earlier studies (Bell et al., 1984; Dennis, 1981; Hall & Bell, 1993; Hopper & Meyers, 1967; and Sogard, 1982). In this study, nematodes were more abundant in seagrass samples, whereas an earlier study from the same area (Jayabarathi et al., 2015) reported higher abundance in benthic sediments. This could be due to habitat preference and the load of organic matter that these organisms depend on. Single-factor ANOVA and PERMANOVA showed no significant difference between the numbers of meiofauna associated with the three species of seagrass, suggesting that despite the observed numerical differences in meiofaunal abundance among the three seagrass species, these variations are not statistically meaningful. This implies that factors other than seagrass species identity may be more influential in determining meiofaunal distribution and abundance in these habitats. The non-significant result prompts further consideration of other variables that might influence meiofaunal communities, such as environmental parameters, spatial heterogeneity, or temporal fluctuations. It also highlights the importance of considering ecological significance alongside statistical significance when interpreting biodiversity patterns in complex marine ecosystems. Further, based on the PCA biplot analysis of abiotic parameters and meiofauna distribution, several key ecological relationships emerge. Air temperature appears to strongly influence the abundance of Oligochaeta and Foraminifera, suggesting these groups may thrive in warmer conditions. Conversely, dissolved oxygen shows a negative correlation with most meiofauna groups, particularly Polychaeta and Tanaidacea, indicating these organisms might be more tolerant of or adapted to low-oxygen environments. The varied responses of different meiofauna groups to abiotic factors highlight the complex interplay between environmental conditions and community composition in marine ecosystems. This analysis underscores the importance of considering multiple environmental parameters when studying meiofaunal ecology and distribution patterns in coastal habitats.

While PERMANOVA did not detect statistically significant differences, the PCoA reveals subtle variations in meiofaunal community structure among the three seagrass species. These differences may be attributed to several factors, such as the varying leaf structures and root systems of the seagrass species, which could provide different microhabitats for meiofauna, influencing community composition. Differences in the structural complexity offered by each seagrass species may affect the abundance and diversity of meiofaunal groups; variations in epiphyte growth, detritus accumulation, or sediment characteristics associated with each seagrass species could influence food availability for different meiofaunal groups. Unaccounted local environmental variations, such as hydrodynamics and sediment grain size, may also contribute to the observed patterns. The strong association of certain meiofaunal groups with specific seagrass species suggests potential species-specific interactions or habitat preferences. For instance, Alsaffar et al. (2020) investigated the influence of seagrass canopies on benthic biodiversity in a Red Sea lagoon and showed that seagrass presence and local sedimentary features significantly affected macroinvertebrate and bacterial communities, with notable differences in benthic habitats compared to overlying waters. The highest diversity of macroinvertebrates was found in high-density seagrass areas. However, in this study, PCoA revealed no clear patterns among vegetated treatments but showed separate grouping for unvegetated treatments, with PERMANOVA indicating significant differences in macrofauna structure by treatment and location. The correlation coefficients (0.98, 0.95, and 0.98) representing correlations between different aspects of the meiofaunal communities across the three seagrass species were all very high. The correlation coefficients (0.98, 0.95, and 0.98) all demonstrate strong positive correlations between the meiofaunal communities across the three seagrass species. These high correlations suggest that despite the differences in total abundance, the relative proportions of different meiofaunal groups remain consistent across the three seagrass species. This is particularly interesting given that the ANOVA results showed no significant difference in overall meiofaunal abundance among the seagrass species. The high correlations provide a more nuanced understanding, showing that not only are the total abundances statistically similar, but the community structures are also remarkably consistent across species. Thus, this information could be valuable for understanding the ecology of seagrass beds and the roles of different meiofaunal groups within these ecosystems. It also raises interesting questions about the factors driving meiofaunal distribution and the potential interchangeability of these seagrass species as habitats for meiofauna.

From a total of 43 different species of meiofauna obtained in this study, 13 species belonged to harpacticoida, followed by 9 species of foraminifera, 4 species of polychaeta, 2 species of nematoda, and 1 species of oligochaeta. Most of these species were found in the middle stipe region (30 species), followed by the leaf (24 species) and root (23 species) of *T. hemprichii*. Some of the groups that are observed to be common in all three species of seagrass are polychaete larvae, gastropod larvae, *Robertsonia robust*a, *Brianola hamondi*, *Elphidium* sp., *Calcarine* sp., and *Sartis* sp. Thus, from the entire study, it can be inferred that the three seagrass species found from both Haddo and Burmanallah showed a high degree of association with the different meiofaunal communities. Among the three species, *Halophila ovalis* showed the maximum association, followed by *Thalassia hemprichii*, while *Halodule pinifolia* showed the least association, which could be due to the thin leaves of *Halodule pinifolia.*

Generally, nematodes dominate the marine sediments (Hicks, 1986a, 1986b); thus, in this study, it was seen that even in the association with seagrass, they were in the majority, which could be due to the abundance of epiphytes on the seagrass (Jayabarathi et al., 2012). Harpacticoids were the second most abundant group associated with the seagrass species, particularly in *Thalassia hemprichii*, as found in this study. Earlier studies from this area and elsewhere (Hall & Bell, 1993; Jayabarathi et al., 2012) have shown that harpacticoids were the most abundant group associated with *Thalassia* sp. the type of association is not clear yet, although it gives the impression of how important the seagrass beds are to benthic and intertidal organisms in providing habitats. They offer a wide range of assistance to these organisms, from food to shelter and protection as well. Thus, seagrass patches play a very important role in the marine environment, which needs continuous monitoring.

CONCLUSION

This study provides valuable insights into the habitat preferences of meiofauna in seagrass beds. A more extensive, holistic investigation is needed to fully understand the relationships between seagrass species and their associated meiofaunal communities in this area. The morphometric differences among seagrass species in this study were found to influence the composition of associated meiofauna, suggesting that these seagrass species provide functionally similar habitats. This implies that local environmental factors may play a more significant role in shaping meiofaunal communities than seagrass-specific characteristics. These findings have important implications for seagrass bed ecology and biodiversity conservation. Future studies should focus on the combined effects of seagrass morphology and epiphytic components to elucidate the mechanisms linking seagrass canopy structure with associated meiofaunal assemblages.

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STATEMENT OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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DATA AVAILABILITY

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AUTHOR CONTRIBUTION

Conceptualization: R.R.; Methodology: R.R.; Data Curation: R.R., A.P., G.P.; Meiofauna Identification: R.R., G.P.; Writing **- Original Draft Preparation: R.R.; Writing - Review and Editing: R.R., A.P., G.P.;** Statistical Analysis: **A.P., R.R.; Supervision: G.P**.

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