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Healthy seagrass habitats provide better support to the associated biodiversity in the Gulf of Mannar, India

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ABSTRACT

The biodiversity associated with the seagrass beds in the Gulf of Mannar, southeast India, offers livelihood options to thousands of fishermen. The present study was taken up at two seagrass sites in the Tuticorin region of the Gulf of Mannar: one is near Vaan Island, which is legally protected from human-induced threats, and the other is near Thirespuram, where serious disturbances occur. Standard underwater protocols were used to assess seagrass cover, shoot density, fish density and diversity, and macrofaunal density and diversity. The average seagrass percentage cover at Vaan Island is 44.52%, while 33.77% at Thirespuram. The overall shoot density is 184.5 m^{-2} at Vaan Island and 144m^{-2} at Thirespuram. A total of 34 fish species belonging to 25 families thrive at the Vaan Island site with an overall fish density of 188.5 250$m^{-2,}$ while only 23 species belonging to 19 families inhabit the Thirespuram site with a total density of 141.7 250m^{-2}. The density of macrofauna is also comparatively higher at Vaan Island, with 32.1 m^{-2} with 45 species, whereas it is 26 m^{-2} with 29 species at Thirespuram. Due to the legal protection from commercial fishing and pollution, the seagrass beds near Vaan Island are found to be comparatively more productive in biodiversity. Awareness creation, reduction of destructive fishing activities and seagrass restoration initiatives would reduce the disturbances and help sustain the seagrass biomass in the unprotected areas, providing sustainable fishery resources to the dependent fisher-folk.

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1. Introduction

Seagrass beds are ecologically and economically important marine habitats with a wide distribution globally, except for the polar ecosystems (Orth *et al.,* 2006). Seagrass beds play many key ecological roles, including bottom stabilization, primary production, nutrient cycling, provision of shelter to many marine organisms, and acting as carbon sinks (Orth *et al.,* 1984; Duffy, 2006). The economic value of seagrass beds in sheltering fish and other organisms has been estimated to range between US$ 21,105 and US$ 40,669 per hectare per year (Zulkifli *et al.,* 2021). In spite of their critical importance, seagrass beds have been severely damaged globally, with a probable loss of 110 km^2 yr^{-1} since 1980 (Waycott *et al.,* 2009) due to various climatic and non-climatic factors (Alsaffar *et al.,* 2020). Threats to seagrass beds include natural fragmentation by waves and currents, coastal development, eutrophication, employment of destructive fishing methods, pollution, and recreational activities (Alsaffar *et al.,* 2020). Of them, human-induced threats have been reported to cause more significant impacts on the survival of seagrass beds than natural factors (Short and Wyllie-Echeverria, 1996).

The biodiversity associated with seagrass beds is very rich, which includes commercially important fishes, molluscs, and other organisms (Orth *et al.,* 2006; Grech *et al.,* 2012; Nordlund *et al.,* 2018). Through many physical, chemical, and biological processes, seagrass beds are connected to coral reefs and mangroves (Alsaffar *et al.,* 2020). Many studies worldwide have proved that biodiversity around seagrass beds is much higher than in non-vegetated areas (Bell and Pollard, 1989; Bloomfield and Gillanders, 2005; Francis *et al.,* 2011; Morrison *et al.,* 2014). Seagrass beds have also been largely accepted as nursery habitats due to the greater densities of juvenile fish (Heck *et al.,* 2003; Morrison *et al.,* 2014). Thus, the loss of seagrass beds would directly affect the dependent biodiversity and, eventually, the associated livelihood and economy (Unsworth *et al.,* 2019; Jänes *et al.,* 2020).

Though seagrasses are found all along the Indian coastline, major seagrass beds have been reported from Tamil Nadu, Lakshadweep, Andaman and Nicobar Islands (Jagtap *et al.,* 2003). Gulf of Mannar and Palk Bay in the Indian mainland have extensive seagrass meadows supporting a significant amount of biodiversity (Jagtap, 1991; Parthasarathy *et al.,* 1991; Thangaradjou and Kannan, 2010; Mathews *et al.,* 2010; Bindu *et al.,* 2014; Edward *et al.,* 2019; Edward *et al.,* 2022). A total of 15 seagrass species have been reported from the Gulf of Mannar (Balaji *et al.,* 2012), and the seagrass-associated biodiversity in the Gulf of Mannar ranges from small fishes to the endangered sea cow *Dugong dugong*. The biodiversity associated with the seagrass beds of the Gulf of Mannar provides livelihood to thousands of fishermen who live along the coast of the Gulf of Mannar.

Being areas for intense fishing, the seagrass beds of the Gulf of Mannar are regularly disturbed by fishing activities. Bottom trawling, use of bottom settling gill nets, shell collection with surface-supplied fishing, and anchoring are some of the activities that directly damage the seagrass beds (Raj *et al.,* 2015, 2017) and consequently affect the associated biodiversity. Hundreds of studies have been conducted on the coral reef ecosystems of the Gulf of Mannar, but seagrasses have often been neglected, though they are equally or more important habitats. In particular, underwater studies on seagrass-associated biodiversity are almost absent, and knowledge of the difference between disturbed and undisturbed seagrass beds in terms of biodiversity is an important input for better managing seagrasses. Hence, the present study assessed the density and diversity of fishes and macrofauna in the disturbed and undisturbed seagrass beds in the Tuticorin region of the Gulf of Mannar.

2. Methodology

2.1 Study site

The Gulf of Mannar encompasses 21 uninhabited coral islands lying parallel to the mainland coast between Tuticorin and Rameswaram. They are biodiversity hotspots protected under the Gulf of Mannar Marine National Park (GOMMNP). A significant extent of seagrass beds occurs around these islands along with coral reefs (Mathews *et al.,* 2010). The GOMMNP is a 'no go' and 'no take' zone, where commercial fishing and other human activities are prohibited. The distances of these islands from the mainland range between 140 m and 9.3 km (Edward *et al.,* 2020). The areas between these islands and the mainland have also been reported to have extensive seagrass beds (Mathews *et al.,* 2010), but in the absence of legal protection, they are subject to commercial fishing and pollution. For the present study, two seagrass sites were selected in January 2022: one on the shoreward side of Vaan Island (Lat 8°50'13.90"N Long 78°12'26.06"E), the nearest of the 21 islands to Tuticorin, and the second site is near Thirespuram village of Tuticorin (Lat 8°49'15.39"N Long 78°10'32.69"E) as shown in Fig. 1.

2.2 Assessment of seagrass percentage cover and shoot density

Scuba diving was employed for all the underwater assessments in the present study. The percentage cover of seagrasses was assessed using 50-m line intercept transects (English *et al.,* 1997). At both sites, 10 transects were laid separated by a distance of 25 m. Along each transect, four 50cm X 50cm quadrats were laid at every 5 m interval on both sides of the transects to gauge the percentage cover of seagrasses following Saito and Atobe (1970). Underwater identification of seagrass species was carried out based on previous experience. Shoot density of seagrasses in the study sites was assessed by counting individual shoots within the quadrats, and the values are expressed as shoots per m^2.

2.3 Assessment of seagrass associated macrofauna and fishes

Seagrasses support a wide range of biodiversity, which includes fishes, molluscs, echinoderms, etc. Fishes and benthic macrofauna in the study site were assessed using standard protocols. The belt transect method (English *et al.,* 1997) was followed for a visual survey of fish to determine the density and diversity of the fish communities in the seagrass bed. Ten 50-m belt transects were laid separated at each site by a minimum interval of 50 m. Scuba divers swam along each transect within a 50 X 10 m corridor (5 m on each side) and recorded all the fishes encountered, identified and counted the fish species that were found near or at a visible distance of each transect. Permanent quadrats of 1 m X 1 m dimensions were used to assess the density of benthic macrofauna at each study site. Major macrofaunal categories such as molluscs, echinoderms, sponges, ascidians, and sea anemones were counted within the quadrats, and the values were expressed as numbers per m^2. Identification of fishes and macrofaunal communities was made using standard identification keys available for the Gulf of Mannar (Laju, 2018; Arathy, 2020; Edward *et al.*, 2022).

2.3. Data analysis

One-way ANOVA was performed to find the significance in the differences between the two sites in the seagrass covers and fish densities using the SPSS version 16.0. Multivariate analysis was performed for the seagrass and fish parameters of Vaan Island and Thirespuram. PCO, SIMPER and PERMANOVA tests were also conducted using PRIMER version 7.0. Fish diversity indices were calculated using Univariate Diversity indices, PRIMER 7.0.

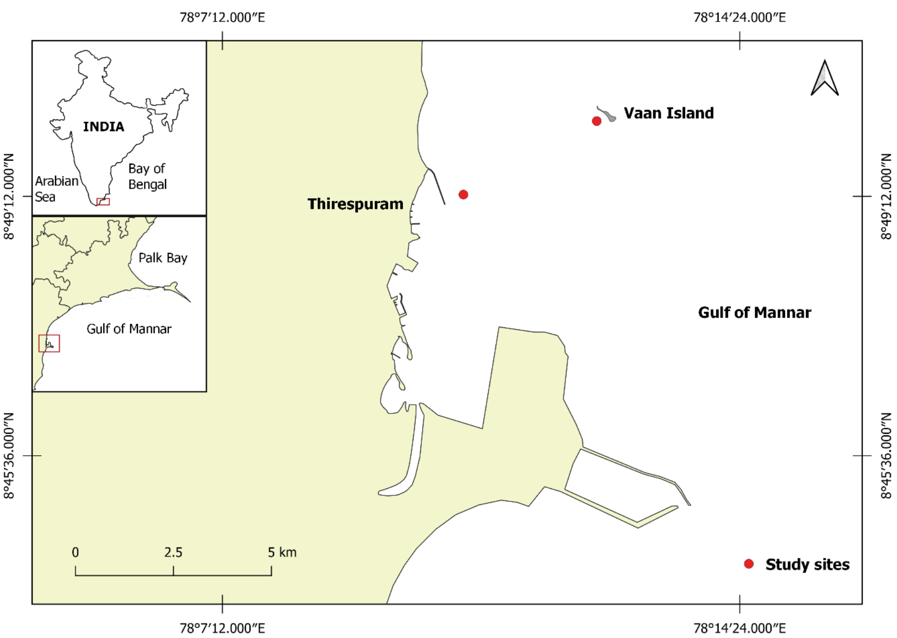

Fig. 1. Map showing the study sites in the Gulf of Mannar

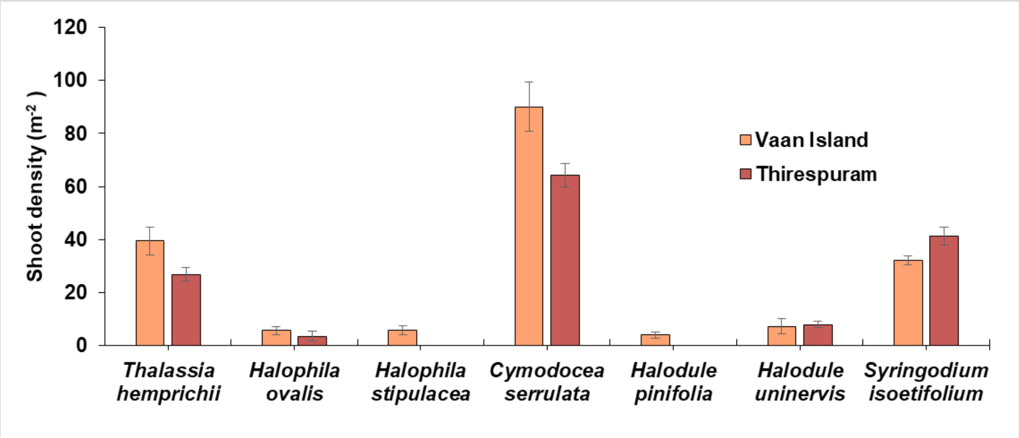

Fig. 2. Seagrass shoot density at study sites, Vaan island and Thirespuram

3. Results and Discussion

The study shows that the average seagrass percentage cover at Vaan Island is 44.52%, while 33.77% at Thirespuram. The overall shoot density is 184.5 m^{-2} near Vaan Island and 144 m^{-2} near Thirespuram. A total of seven seagrass species are found near Vaan Island, namely, *Thalassia hemprichii, Halophila ovalis, Halophila stipulacea, Cymodocea serrulata, Halodule pinifolia, Halodule uninervis,* and *Syringodium isoetifolium*. But only five species occur in Thirespuram, with *Halophila stipulacea* and *Halodule pinifolia* being absent here. *Cymodocea serrulata* is the dominant seagrass species near Vaan Island with a shoot density of 90.01 m^{-2} (SE±9.21) followed by *Thalassia hemprichii* with 39.5 m^{-2} (SE±5.34) (Fig. 2). *Cymodocea serrulata* is also the dominant species near Thirespuram with 64.3 m^{-2} (SE±4.44) followed by *Syringodium isoetifolium* with 41.2 m^{-2} (SE±3.34) (Fig. 2).

Cymodocea serrulata contributes 48.83% to the total shoot density, whereas *Thalassia hemprichii* and *Syringodium isoetifolium* make up 21.41 and 17.4%, respectively, at Vaan Island (Fig. 3). Near Thirespuram, *Cymodocea serrulata* contributes 44.65% followed by *Syringodium isoetifolium* and *Thalassia hemprichii* with 28.61 and 18.68% respectively. Seven of the 15 seagrass species reported from the Gulf of Mannar (Balaji *et al.,* 2012) were observed during this study at Vaan Island and five at Thirespuram, a good representation of smaller study sites. *Cymodocea serrulata, Thalassia hemprichii* and *Syringodium isoetifolium* have been reported to be the common seagrass species in the Gulf of Mannar (Mathews *et al.,* 2010). The average percentage cover has been reported to be 31% around Vaan Island (Mathews *et al.,* 2010), and the present observation of 44.52% at Vaan Island is significantly higher. Moreover, Mathews *et al.* (2010) reported only six species, and we observed seven species on Vaan Island in this study. Sam (2017) reported that the percentage cover of seagrasses was 30.22% in Thirespuram, which is slightly lower than our observation.

Both percentage cover and shoot density are significantly higher at Vaan Island than at Thirespuram. The results of one-way ANOVA indicate that the shoot density of seagrasses has a significant deviation between Vaan Island and Thirespuram (ANOVA, DF=19, F=15.965, P=0.001, $p<0.01$). Similarly, seagrass cover also shows a significant deviation between the two study sites (ANOVA, DF=19, F=16.529, P=0.001, $p<0.01$). PERMANOVA analysis shows a significant difference in seagrass community structure between the study sites (Pseudo-F = 10.489, p = 0.001). nMDS ordination suggests that there is a clear separate cluster between the study sites (Fig. 4). PCO test also discloses the variations between the study sites (81.5 %) (Fig. 5). Simper test indicates a higher similarity level within the sites as it is 83% for Vaan Island and 90% for Thirespuram. The overall dissimilarity is 14% between the two study sites, and this change is brought about by the species *Halophila stipulacea* and *Halodule uninervis*.

The intensity of disturbances can explain the difference in the seagrass biomass between Vaan Island and Thirespuram.

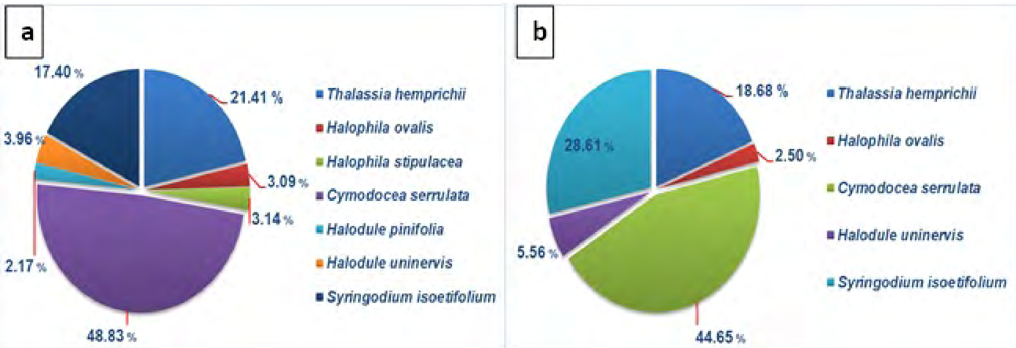

Fig. 3. Proportion of each seagrass species in the study sites: a, Vaan Island; b, Thirespuram

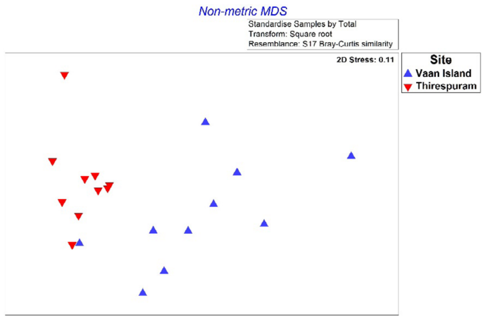

Fig. 4. Multi-dimensional scaling ordination (nMDS) showing the seagrass parameters between two sites, Vaan island and Thirespuram

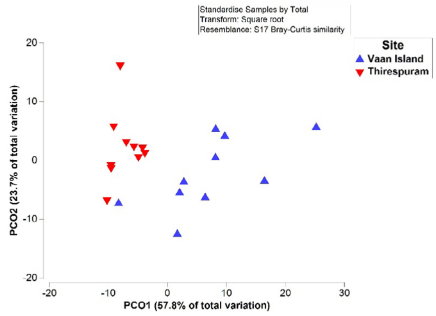

Fig. 5. Results of Principal Component Ordination (PCO) test for seagrass parameters

Being within the boundary of the GOMMNP keeps the seagrass beds near Vaan Island protected from human-induced threats such as fishing and pollution. On the other hand, hardcore fishing happens at the Thirespuram seagrass site, including bottom trawling activities such as shore seine and push net operations (Raj *et al*. 2017). It is also noted that untreated sewage from Tuticorin town is released into the Gulf of Mannar (Edward *et al.,* 2021) at Thirespuram, causing the area to be polluted. Local environmental factors are key in deciding the seagrass biomass and associated biodiversity (Alsaffar *et al*., 2020). Less than 30% of seagrass cover is generally considered poor in condition (Dewi *et al.* 2020), and the seagrass cover in Thirespuram is closer to being poor. Evaluation of environmental parameters such as the abundance of nutrients, heavy metals, and even microplastics is considered to assess the health of seagrass beds, and these parameters have been comparatively higher at Thirespuram due to the sewage outlet (Edward *et al*. 2021). However, despite the significant intensity of pollution and fishing, seagrass cover near Thirespuram is good enough to support the associated biodiversity, but chronic disturbances may cause irreversible damage to the Thirespuram seagrass beds in the future.

Studies on the underwater census of fishes are scarce in the Gulf of Mannar. A few studies have dealt with reef-associated fishes (Mathews *et al.,* 2015; Laju, 2018; Emmett *et al*. 2021), while seagrass-associated fishes have not been given importance, although commercial fishing happens primarily in the seagrass beds. A total of 34 fish species belonging to 25 families were observed during the present study in the seagrass area at Vaan Island, with an overall fish density of 188.5 $250m^{-2}$. *Lutjanus* sp. is the most common fish species with an average density of 12.6 $250m^{-2}$ followed by *Parupeneus indicus* with 10.6 $250m^{-2}$ (Table 1). In the seagrass site at Thirespuram, a total of 23 species belonging to 19 families were observed with a total density of 141.7 $250m^{-2}$, of which *Lutjanus* sp. is the most abundant species with 10.7 $250m^{-2}$ followed by *Lethrinus* sp. with 8.9 $250m^{-2}$. Most of the fish species observed in both sites are commercially important, contributing significantly to the livelihood of the fishermen in the Tuticorin region. Seagrass beds have been proven to be significant contributors to global fisheries production (Unsworth *et al.,* 2019). PERMANOVA analysis shows a significant difference in fish community structure between the study sites (Pseudo-F = 4.416, p = 0.001, p<0.01). The nMDS plot shows distinct clusters of fish assemblages across the two sites (Fig. 6). PCO test also shows variations between the densities of the study sites (51 %) (Fig. 7). SIMPER test reveals that the variations in the fish abundance between the two sites are mainly driven by the species *Plotosus lineatus, Stolephorus commersonnii* and *Apogon* sp. As far as the fish community indices are concerned, Vaan Island has a higher mean Shannon diversity index (H') at 2.95 and Thirespuram a relatively lower value at 2.70. Likewise, species richness (D) is 4.37 for Vaan Island and 3.36 for Thirespuram.

The number of fish species reported to be associated with seagrass beds at various locations of the world is: 746 species in the Indo-Pacific, 486 in Australia, 222 in the North East Pacific, 313 in the Caribbean, and 297 in the North Atlantic (Unsworth *et al.,* 2019). The great diversity of fishes in the seagrass beds can be correlated with their capacity to act as nurseries and foraging grounds (Nordlund *et al.,* 2016;

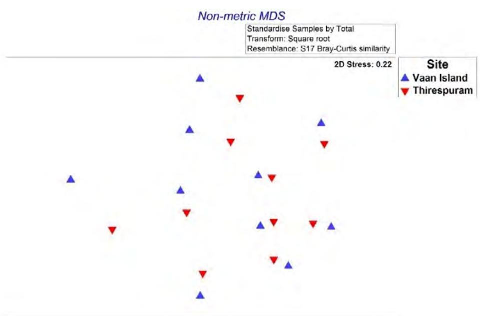

Fig. 6. Multi-dimensional scaling ordination (nMDS) showing the fish parameters between two sites

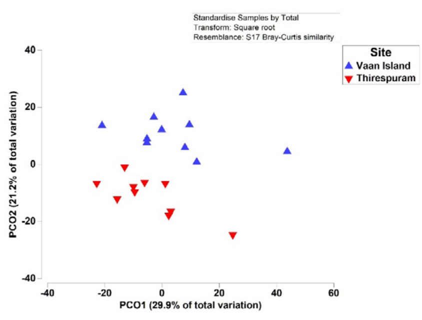

Fig. 7. Results of Principal component ordination (PCO) test for fish parameters

Unsworth *et al.,* 2019). Considering the smaller size of the study sites, the observed numbers of fish species, 34 (in Vaan Island) and 23 (in Thirespuram), are comparatively high. Certainly, detailed surveys on seagrass-associated fishes along the entire coast of the Gulf of Mannar would yield a significantly greater number of seagrass-associated fishes. The results of PERMANOVA analysis show a significant difference in fish community structure between the two study sites (Pseudo-F = 4.416, p = 0.001, p<0.01). Higher seagrass cover and structural complexity strongly relate to associated biodiversity (Jones *et al.,* 2021). The higher density and richer diversity of fishes in the seagrass site at Vaan Island than in Thirespuram can thus be related to the comparatively higher seagrass percentage cover and shoot density. Moreover, protected seagrass beds have been reported to support more fish assemblages (Kiggins *et al.,* 2020). However, it is impracticable to bring all the seagrass beds within the boundary of the GOMMNP as these beds are the primary fishing grounds for the fishermen.

Seagrass beds also support the other nearby habitats, such as coral reefs, in various ways, enhancing fishery production (Ogden and Gladfelter, 1983; Saunders *et al.,* 2014). The islands of the Gulf of Mannar are surrounded by coral reefs and constitute one of the major coral reef ecosystem regions in the country. Reef fishes of the families Lutjanidae, Lethrinidae, Scaridae, Siganidae, etc., often use seagrass beds as nursery grounds (Honda *et al.,* 2013). Due to the close proximity of the seagrass beds to the coral reef ecosystem, reef fishes of the above-mentioned families are commonly observed in the seagrass site of Vaan Island. Thus, the link between coral reefs and seagrasses in the Gulf of Mannar through animal migration can be understood. As the seagrass site at Thirespuram is about 4.5 km away from the nearby reef area of Vaan Island, the abundance of reef fish is very little.

The density of macrofauna is also comparatively higher at Vaan Island, with 32.1 m^{-2}, whereas it is 26 m^{-2} at Thirespuram. Molluscs dominate the benthic macrofauna at both sites, with 11.3 and 11.6 m^{-2}, respectively, at Vaan Island and Thirespuram. Sponges are the next dominant category, with 10.6 m^{-2} at Vaan Island and 5.9 m^{-2} at Thirespuram (Fig. 4). A total of 48 macrobenthic species are found at both sites, and the diversity is comparatively higher at Vaan Island with 45 species while it is 29 species for Thirespuram (Table 2). The structural complexity of seagrasses provides shelter to various macrobenthic organisms (Tilman *et al.,* 1997) and the higher density of macrofauna at Vaan Island is thus understood. As reported in many studies (Rueda *et al.,* 2009; Hyman *et al.,* 2019; Barnes, 2022), molluscs are the dominant benthic category in the seagrass areas of the present study sites. Molluscs, possessing durable shells, are abundant, ecologically important, and sensitive to substrate type and sediment characteristics (Veiga *et al.,* 2017; Hyman *et al.,* 2019). The diversity of molluscs is higher in Vaan Island by virtue of being proximate to the reef area as reef-associated molluscs such as *Cypraea tigris* are observed in Vaan Island. Underwater photos of seagrass-associated biodiversity are given in Fig. 5.

Table 1. Fish species observed in the study sites and their densities

Species	Family	Vaan Island Density -250m^{-2}	Thirespuram Density -250m^{-2}
Strongylura strongylura	Belonidae	6.5	5.8
Alepes djedaba	Carangidae	5.2	5.1
Caranx para	Carangidae	6.8	6.4
Parupeneus indicus	Mullidae	10.6	8.8
Upeneus sulphurens	Mullidae	7.5	6.3
Sphyraena baracuda	Sphyraenidae	5	4
Sphyraena obtusata	Sphyraenidae	6	4.7
Lactoria cornuta	Ostraciidae	7.6	6.1
Liza vaigiensis	Mugilidae	5.9	5.8
Mugil cephalus	Mugilidae	6.2	6.6
Lutjanus sp.	Lutjanidae	12.6	10.7
Plotosus lineatus	Plotosidae	6.6	7.7
Leiognathussplendens	Leiognathidae	8.7	7.6
Terapon puta	Terapontidae	8.8	7.9
Tetraodon fluviatilis	Tetraodontinae	7.3	6.5
Plata xorbicularia	Ephippidae	5.8	4.8
Amphiprion sp.	Pomacentridae	3.1	2.7
Stolephorous commersonnii	Engraulidae	7.8	7.3
Acanthurus sp.	Acanthuridae	5.6	0
Acanthurus mata	Acanthuridae	4	0
Apogon sp.	Apogonidae	7.6	0
Chaetodon collare	Chaetodontidae	1.5	0
Chaetodon sp.	Chaetodontidae	2.6	0
Scolopsisvosmeri	Nemipteridae	1.8	0
Pempheris sp.	Pempheridae	1.8	0
Siganus javus	Siganidae	8.5	7
Siganus canaliculatus	Siganidae	3.9	2.4
Epinephelus tauvina	Serranidae	1.6	0
Cephapholis formosa	Serranidae	1.9	0
Scarus ghobban	Scaridae	6.9	0.9
Sardinella sp.	Clupeidae	3.4	7.5
Lethrinus sp.	Lethrinidae	9.4	8.9
Gymnothorax sp.	Muraenidae	0.8	0
	Total	188	141.5

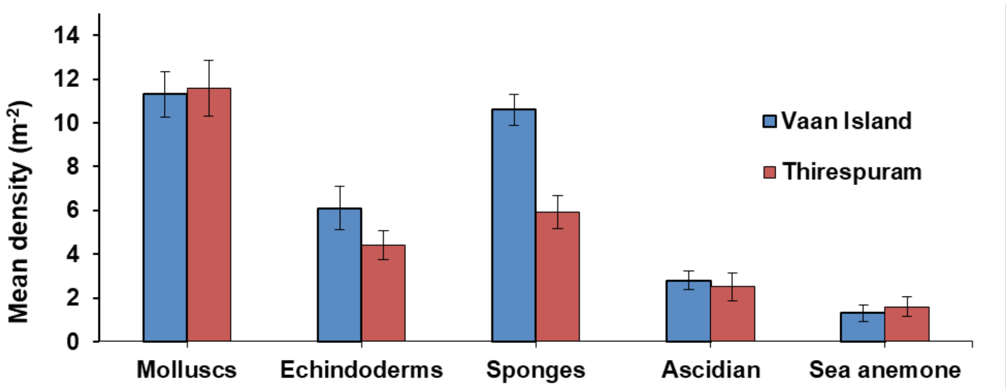

Fig. 8. Densities of macrofaunal categories in Vaan island and Thirespuram

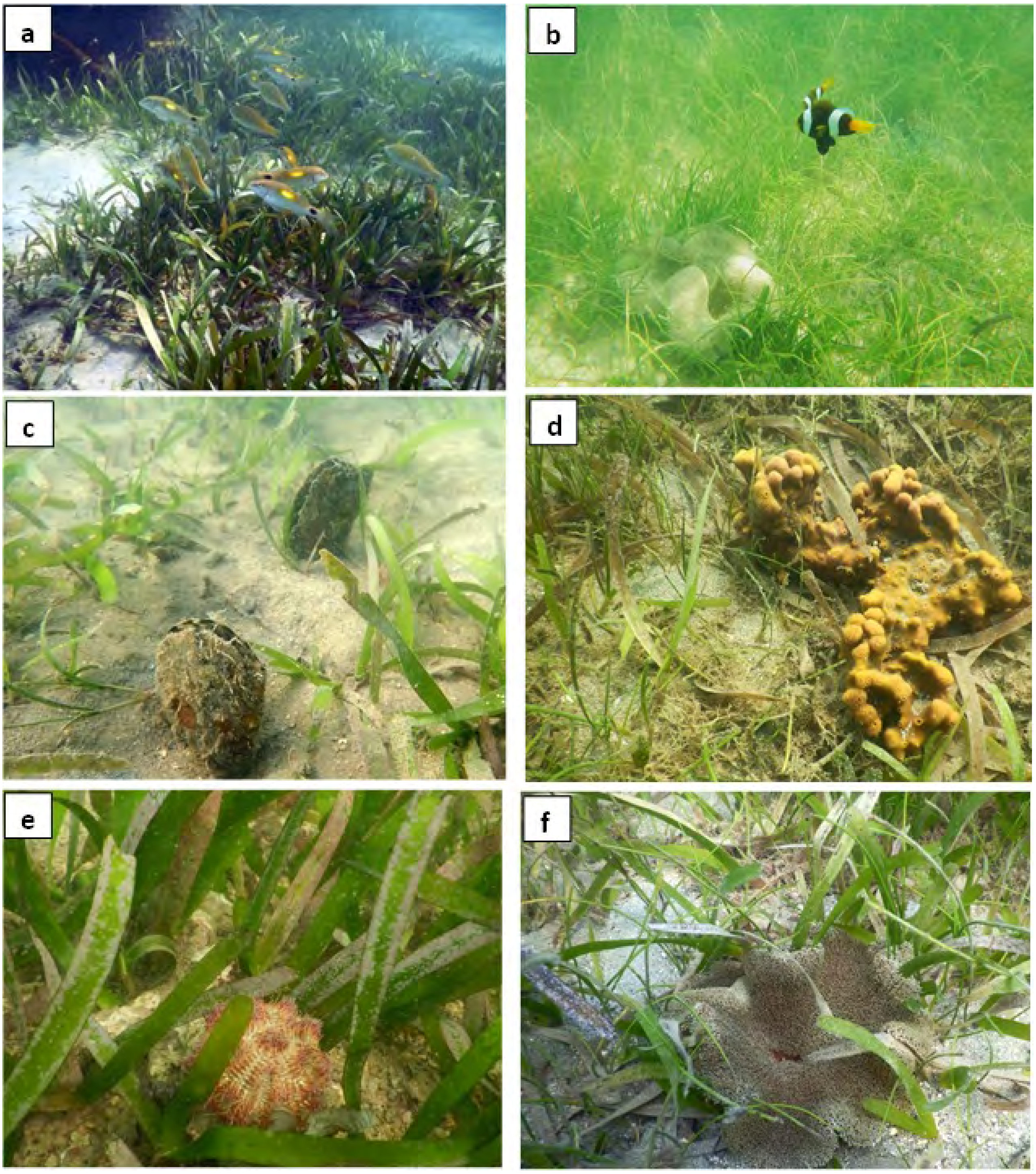

Fig. 9. Seagrass associated biodiversity in the Tuticorin region of the Gulf of Mannar
a. *Parupeneus indicus* (fish), **b.** *Amphiprion* sp. (fish), **c.** *Pinna bicolor* (mollusc), **d.** *Rhabdastrella* sp. (sponge), **e.** *Salmacis bicolor* (echinoderm), **f.** *Stichodactyla* sp. (sea anemone)

Marine sponges have been reported to rise in the Gulf of Mannar due to climate change implications, especially in the coral reef areas (Raj *et al.,* 2018; Ashok *et al.,* 2018). This is due to their capacity to withstand extreme temperatures and poor water quality (Carballo, 2006; Schönberg *et al.,* 2017; Raj *et al.,* 2019, 2022). It is evident from the present study that sponges occur in great abundance in the seagrass beds. The comparatively higher density and diversity of sponges at Vaan Island can be due to their occurrence near the reef area. An increase in the sponge cover in the reef areas of the Gulf of Mannar has been reported recently (Raj *et al.,* 2018, 2022, 2023). Other taxa, such as ascidians, echinoderms, and sea anemones, are also found inhabiting the study areas, pointing to the productivity of the seagrass beds. All the observed major taxa are found to be higher at Vaan Island due to its proximity to the reef area.

The present study in the Tuticorin region of the Gulf of Mannar reveals that seagrass beds provide shelter to a wide

Table 2. Macrofaunal species observed in the study sites

Species	Vaan Island Density -m^{-2}	Thirespuram Density -m^{-2}
Molluscs		
Lambis lambis	√	√
Lambis sp.	√	-
Jujubinus striatus	√	√
Colina sp.	-	√
Trochus radiatus	√	-
Euchelus asper	√	√
Bulla ampulla	√	-
Conus sp.	√	√
Cerithium punctatum	√	√
Cerithium sp.	√	√
Cypraea tigris	√	-
Pinctada imbricata	√	-
Bursa crumena	√	√
Cardium flavum	√	√
Donax cuneatus	√	√
Pinna bicolor	√	√
Drupella sp.	√	-
Modiolus modulaides	-	√
Modiolus sp.	√	-
Aplysia argus	√	-
Echinoderms		
Holothuria atra	√	√
Holothuria scabra	√	-
Actinopyga miliaris	√	-
Salmacis bicolor	√	√
Tripneustes gratilla	√	√
Stomopneustes variolaris	√	-
Protoreasterlincki	√	√
Pentaceraster sp.	-	√
Pentaceraster affinis	√	√
Cuclita schmideliana	√	-
Linckia laevigata	√	√
Sponges		
Halichondria sp.	√	-
Haliclona sp.	√	-
Cliona sp.	√	-
Spheciospongia sp.	√	√
Callyspongia sp.	√	-
Rhabdastrella sp.	√	√
Amphimedon sp.	√	√
Clathria vulpina	√	√
Clathria sp.	√	√
Ascidians		
Didemnum sp.	√	√
Trididemnum sp.	√	√
Polyclinum sp.	√	√
Diplosoma sp.	√	√
Aplidium sp.	√	-
Eudistoma sp.	√	-
Sea anemones		
Stichodactyla haddoni	√	√
Stichodactyla sp.	√	-

range of biodiversity (Fig. 9). Most of these organisms, including the fishes and molluscs are commercially important and provide a livelihood to the dependent fishermen. This preliminary study paves the way for more focused studies on seagrass-associated biodiversity in the Gulf of Mannar. It is also imperative that detailed and continuous studies on seagrass-associated biodiversity should be undertaken in the Gulf of Mannar, as threats to seagrass beds are increasing every day. Studies on animal migration between ecosystems are also critical to understanding the impact of damage to one ecosystem on the other. It is clear from the study that undisturbed seagrass beds support comparatively higher biodiversity. The study thus demonstrates that the removal of or reduction in human-induced threats would help seagrasses to flourish, which in turn would enhance the associated biodiversity.

There are several threats to the survival of seagrasses in the Gulf of Mannar, predominantly destructive fishing practices and pollution (Mathews *et al.,* 2010; Raj *et al.,* 2017; Edward *et al.,* 2019), as is evident in Thirespuram. It is difficult to ban fishing activities in the seagrass areas as these are the main fishing grounds for dependent fishermen. Hence, to reduce the disturbances, the fishermen must be made aware of the importance of seagrass habitats and be educated to abstain from destructive fishing activities such as bottom trawling. Treatment of sewage water near Thirespuram is important for seagrass beds and all living marine organisms in the area. Low-cost and low-tech protocols for the restoration of seagrasses through manual transplantation of sprigs have been standardized for the Gulf of Mannar (Edward *et al.,* 2019). Using this standardized protocol, wide-scale restoration initiatives should be taken up to keep the seagrass biomass intact. This is particularly important as seagrass habitat restoration would mean the restoration of associated biodiversity.

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