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Structure of megabenthic invertebrate communities and ecological function of seagrass ecosystem in Walakiri Waters, Sumba Island, East Nusa Tenggara, Indonesia

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Abstract. *Hartati R, Widianingsih, Riniatsih I, Ginzel FI, Wirasatriya A, Mahendrajaya RT, Manullang C. 2025. Structure of megabenthic invertebrate communities and ecological function of seagrass ecosystem in Walakiri Waters, Sumba Island, East Nusa Tenggara, Indonesia. Biodiversitas 26: 5067-5080.* This study investigates the diversity and community structure of megabenthic fauna and their ecological relationship with the seagrass ecosystem at Walakiri Beach, Sumba Island, East Nusa Tenggara, Indonesia, a critical coastal habitat. Megabenthos sampling and seagrass assessments were conducted simultaneously along six transect stations, and five resilience indicators (water transparency, species richness, and seagrass and macroalgae/epiphyte coverage) were evaluated to determine the Seagrass Ecological Quality Index (SEQI). A total of 48 megabenthic species were recorded, belonging to five phyla: Mollusca (20 species), Echinodermata (14 species), Porifera (9 species), Arthropoda (4 species), and Chordata (1 species). Mollusca and Echinodermata were the most diverse and abundant groups, reflecting their important ecological roles as consumers, bioturbators, and environmental indicators. The megabenthic community showed high diversity and evenness, with no single species dominating. The seagrass beds consisted of five mixed species, dominated by *Thalassia hemprichii*, characterized by dense to very dense coverage, forming a suitable habitat that supports diverse megabenthic communities. SEQI results indicated good ecological status, with seagrass functioning effectively as a provider of shelter, food, and nursery grounds. Pearson correlation analysis demonstrated strong positive relationships between megabenthic diversity and evenness, as well as between seagrass cover and dominance, while negative correlations were observed with seagrass diversity and evenness. These results suggest that megabenthic communities flourish in areas dominated by a few seagrass species, particularly *T. hemprichii*. Although ecological conditions remain favorable, increasing tourism activities may threaten habitat integrity, highlighting the need for sustainable coastal management.

Keywords: Echinoderm, mollusca, SEQi, *Thalassia hemprichii*

INTRODUCTION

Seagrass ecosystems are vital coastal habitats that support significant biodiversity, ecological functions, and ecosystem services. Globally, seagrasses cover more than 300,000 km² of the coastal seafloor and play critical ecological and socio-economic roles (Waycott et al. 2009; Unsworth et al. 2019). The Indo-Pacific region, particularly Indonesia, represents a major global center of seagrass diversity, hosting a substantial number of the world's 72 recorded species (Coles et al. 2011; Unsworth et al. 2018). Seagrass meadows function as nursery grounds for ecologically and economically important marine biota, contribute to sediment stabilization and nutrient cycling, and serve as major reservoirs for blue carbon sequestration (Duarte et al. 2013; Nordlund et al. 2017). Furthermore, seagrass beds are crucial in mitigating coastal erosion and buffering hydrodynamic energy, thereby enhancing shoreline protection (Christianen et al. 2013). Their ecological importance extends to sustaining the early life stages of various invertebrates, fish, sea turtles (Stokes et al. 2019), and marine mammals (Said et al. 2025), thereby supporting coastal fisheries and community livelihoods (Riniatsih et al. 2018). Despite their value, seagrass ecosystems continue to decline globally due to anthropogenic disturbances, including eutrophication, tourism, coastal infrastructure, and climate change (Waycott et al. 2009; Unsworth et al. 2018; Hernawan et al. 2021).

Among the seagrass-associated fauna, megabenthic organisms (epibenthic fauna larger than 1 cm) constitute an important but understudied ecological group. This assemblage, which includes echinoderms, mollusks, crustaceans, and other taxa, plays essential roles in benthic–pelagic coupling, sediment turnover, nutrient regeneration, and trophic dynamics (Stratmann et al. 2020). Megabenthos also contribute to food webs as prey for higher trophic consumers and can serve as biological indicators of habitat quality and ecosystem change (Lundquist et al. 2018). Their spatial patterns and community structure are strongly influenced by habitat complexity, substrate type, vegetation cover, and the availability of organic matter (Macreadie et al. 2014). Despite their ecological relevance, megabenthic studies in Indonesia predominantly emphasize coral reef environments, as observed in Ternate-Maluku (Arbi et al. 2020), Banda Islands (Rosalina et al. 2023), Tuan Island-Aceh (Dewiyanti et al. 2020), Spermonde Archipelago (Tatipata and Mashoren 2019), Kera Island-Kupang (Kangkan et al. 2024), and eastern Sumba waters (Utama et al. 2023). In contrast, research on megabenthos within seagrass habitats remains limited. However, notable efforts include investigations in Bakau Bay-Bintan (Karlina and Idris 2019), Mantang Island-Riau (Nugraha et al. 2024), Jepara waters (Riniatsih et al. 2021; Saputri et al. 2023), Bontosua Island-Sulawesi (Kartika et al. 2023), and southern Lombok coasts (Basmalah et al. 2022). However, studies linking megabenthos community structure to seagrass ecological quality and habitat characteristics remain insufficient, creating a knowledge gap in our understanding of ecosystem function.

Walakiri Waters in East Sumba, East Nusa Tenggara, is a unique coastal ecosystem known for its ecotourism value, distinctive geomorphology, and biodiversity. The site is renowned for its endemic mangrove species *Aegialitis annulata*, known locally as the "dancing mangrove," characterized by twisted stilt roots exposed during low tide (Djiara et al. 2022). This area also exhibits distinct sediment zonation, transitioning from coarse white sand to fine, compacting sediment towards the lower littoral zone, followed by extensive seagrass meadows (Hartati et al. 2023). Walakiri lies within the Wallacea biogeographic transition zone, which supports diverse terrestrial and marine species (Myers et al. 2000). As one of Indonesia's driest and most vulnerable ecological regions, East Sumba demands adaptive management and habitat protection (MoEF Indonesia 2020). The seagrass ecosystem additionally supports subsistence fisheries and community-based tourism (Lestariningsih et al. 2025), placing the habitat under increasing pressure from climate change, land-use alteration, and recreational activities.

Given these conditions, understanding the ecological association between megabenthic invertebrates and seagrass habitat structure is essential. Seagrass meadows provide refuge from predation, supply organic matter, and function as critical nursery grounds (Dilipan et al. 2020; Valdez et al. 2020). Habitat complexity, including shoot density, canopy height, and biomass, may influence megabenthos abundance and diversity through enhanced niche availability (Daudi et al. 2023). Therefore, this study aims to analyze species composition, diversity, and spatial distribution of megabenthic invertebrates in relation to seagrass habitat quality in Walakiri waters. The outcomes are expected to support baseline ecological data, inform coastal conservation strategies, and guide sustainable management of tropical seagrass ecosystems.

MATERIALS AND METHODS

Sampling location

The study was conducted at Walakiri Beach, East Sumba, Sumba Island, East Nusa Tenggara, Indonesia (Figure 1). Six stations were laid between 09°37'31.9"S, 120°24'16.4"E and 09°35'23.3"S, 120°27'47.4"E, and the coordinates of the study site are presented in Table 1. East Sumba experienced a dual tide, so data were collected when conditions approached the lowest ebb, from 6:30 to 10:20 am and 4:00 to 6:40 pm, allowing easy sampling of megabenthic invertebrates and seagrass.

Seagrass sampling

The Seagrass-Watch and COREMAP-CTI guidelines were applied to collect seagrass data (McKenzie et al. 2003; McKenzie 2008). Three-line transects, as triplicates, were laid in each station, perpendicular to the coastline. A hundred-meter line transect was performed with 50 meters between lines. Seagrass data were recorded in a 100x100 cm^2 plot, placed along a line transect with a 10 m spacing between quadrats, towards the sea. Seagrass was identified based on den Hartog and Kuo (2006), Larkum et al. (2006), Kuo (2020), Dilipan and Arulbalachandran (2022), and Kwan et al. (2023) as species richness (St) and counted per transect as stand density per m^2.

Seagrass and macroalgal cover (Ct and Mt) were assessed using the percent cover standard in the Seagrass-Watch guideline (McKenzie 2008) and then categorized as rare (0-25%), moderate (26-50%), dense (51-75%), and very dense (76-100%) (Rahmawati et al. 2014, 2017). The epiphytes cover was estimated by a matrix consisting of % the leaves in quadrat covered by epiphytes and the average epiphyte cover on each leaf or blade (Hernawan et al. (2021), then were categorized as low (20%), moderate (20-40%) and high (>40%) which represent of good, mild and impaired water quality (Rahmawati et al. 2014, 2017).

Table 1. The coordinates of six stations and its characteristics in the study site of Walakiri Beach, Sumba Island, Indonesia

Station	Longitude (South)	Latitude (East)	Depth (m)	Water transparency (m)	Substrate type
1	09°37'31.9"S	120°24'16.4"E	2	2	Silty-sand
2	09°37'20.0"S	120°24'44.7"E	2	2	Silty-sand
3	09°36'42.0"S	120°26'13.0"E	2	2	Silty-sand
4	09°36'33.1"S	120°26'52.2"E	2	1.8	Silty-sand
5	09°36'14.9"S	120°27'17.4"E	2	1.3	Silty-sand
6	09°35'23.3"S	120°27'47.4"E	2	1.2	Silty-sand

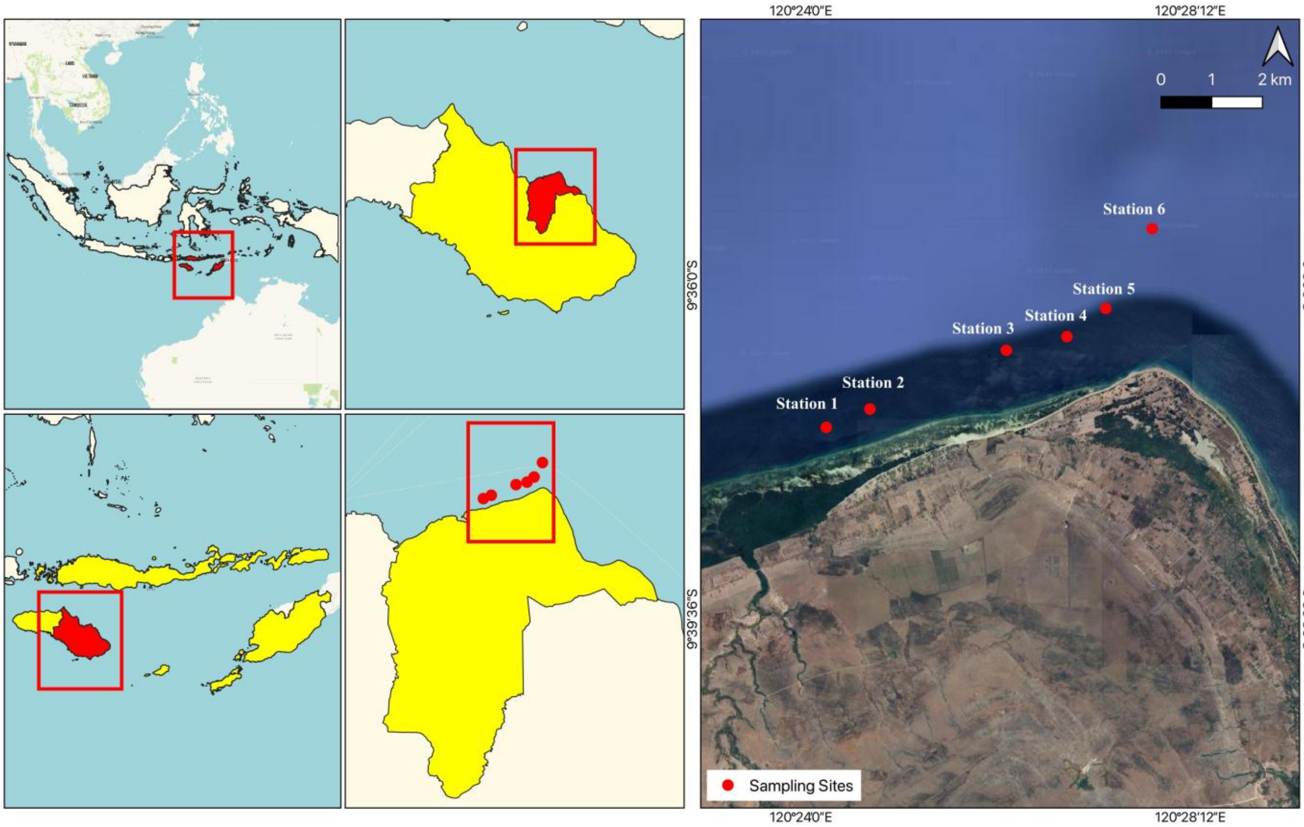

Figure 1. Map of the study site at Walakiri Beach, Sumba Island, East Nusa Tenggara, Indonesia

The ecological condition of the seagrass ecosystem as a megabenthos habitat was defined using the Seagrass Ecological Quality Index (SEQI) value, calculated from the seagrass resilience parameter. These values are compared to the reference or maximum values of each parameter (S_{ref}, C_{ref}, W_{ref}, M_{max}, E_{ref} for seagrass species richness, seagrass cover, macroalgae cover, the maximum value of water transparency, and epiphyte cover according to Hernawan et al. (2021) using the following equation.

$$SEQI = \left(\frac{St}{Sref}\right) * 0.2 + \left(\frac{Ct}{Cref}\right) * 0{,}2 \left(\frac{Wt}{Wref}\right) * 0.2 + \left(1 - \left(\frac{Mt}{Mmax}\right)\right) * 0.2 + \left(1 - \left(\frac{Et}{Emax}\right)\right) * 0.2$$

Where, St: Seagrass species richness observed, Sref: Max value of seagrass species richness (9), Ct: Seagrass percent cover observed, Cref: Max value of seagrass percent cover (100), Wt: Water transparency observed, Wref: Max value of water transparency (2), Mt: Macroalgae percent cover observed, Mmax: Max value of macroalgae cover (100), Et: Epiphyte percent cover observed, Emax: Max value of epiphyte cover (100) (Hernawan et al. 2021).

The range of the SEQI value is 0 (the worst condition for resilience) to 1 (the optimal condition for resilience). Based on the SEQI value, five categories of seagrass ecological condition were determined: excellent (0.85-1.0), good (0.69-0.84), moderate (0.53-0.68), poor (0.37-0.52), and bad (0-0.36) (Hernawan et al. 2021; Rahmawati et al. 2021).

Megabenthos sampling and analyses

The megabenthos were sampled along the same seagrass transect in three lines at each station. All megabenthic organisms within the transects were collected by handpicking and identified to the lowest possible taxonomic level, preferably to the species level, based on morphological characteristics. The samples were identified in situ; otherwise, they were collected and preserved in 10% formaldehyde before being taken to the laboratory for identification (Arbi and Sihalohoa 2017). Identification was conducted using standard taxonomic references for each group: Ophiuroidea were identified following Pomory (2007), Benavides-Serrato and O'Hara (2008), Gondim et al. (2013), and O'Hara et al. (2017); Echinoidea following Fong et al. (2024); Asteroidea using keys by Wakano and Tetelepta (2015), Chan et al. (2018), and Fatemi and Fatemi (2018); and Holothuroide with references from Miller et al. (2017), Wirawati et al. (2019), and Abrogueña et al. (2023). For mollusks, gastropods were identified using Golikov and Starobogatov (1975), Poutiers (1998a), Dharma (2008), and Ravinesh et al. (2018); while bivalves were referred to in Poutiers (1998b) and Dharma (2008, 2023). Tunicates (Chordata) were identified based on Simpson et al. (2016) and Oliveira et al. (2017), and sponges (Demospongiae-Porifera) were classified following Van Soest (1980), Huang et al. (2008), Morrow and Cárdenas (2015), and Voogd et al. (2024). The number of species found within the transects is counted as species richness (Chao et al. 2014). Megabenthos density was calculated as the number of individuals per square meter for each transect. The community structure of megabenthos and seagrass was analyzed in terms of species richness, diversity, evenness, and dominance. Species richness and diversity (the Shannon-Wiener Diversity Index, H') were calculated using the approaches of Chao et al. (2014) and Roswell et al. (2021). Evenness and dominance were determined by the indices developed by Buzas and Havek (2005), Ulfah et al. (2019), and Ricotta et al. (2022), respectively, as follows.

$$H' = -\sum_{i=1}^{s} Pi\ log2Pi$$

Where, H': Shannon-Wiener Diversity Index (H'), Pi: Ratio ni/N, ni: Number of individuals of species I, N: Total number of individuals (Roswell et al. 2021).

$$E = \frac{H'}{\ln S}$$

Where, E: Uniformity Index, H': Diversity Index, S: Number of species (Buzas and Havek 2005; Ulfah et al. 2019; Ricotta et al. 2022).

$$C = \sum (pi)^2$$

Where, C: Dominance Index, pi: Number of individuals of the i^{th} species (Roswell et al. 2021).

The values of community structure were categorized as follows (Roswell et al. 2021): for diversity index, ($H'<1.0$) is low diversity and very low productivity, unstable ecosystem; $1.0<H'<3.322$ is moderate diversity, moderate productivity, balanced ecosystem, and $H>3.322$ is high diversity, high productivity, and stable ecosystem; while for evenness, $E<0.4$ is low evenness, $0.4<E<0.6$ is moderate evenness, and $E>0.6$ is high evenness. For dominance, $0<C<0.5$ means there are no dominant species, and $0.5<C<1$ means there is a dominant species.

To explore the ecological relationship between megabenthic communities and their seagrass habitat, Pearson's correlation coefficient was used to evaluate the strength and direction of the linear relationship between variables. Seagrass parameters included species richness, coverage, diversity, evenness, dominance, SEQI, water transparency, macroalgae presence, and epiphyte coverage, while megabenthos variables included richness, abundance, diversity, evenness, and dominance. This analysis aimed to assess how habitat characteristics may influence the structure and abundance of megabenthic assemblages in the study area.

RESULTS AND DISCUSSION

The seagrass community and seagrass ecological quality

Five species of seagrass were recorded from Walakiri Beach: *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *Halodule pinifolia*, and *H. ovalis* (Figure 2). All transects exhibited a mixed-species composition, with *T. hemprichii* and *C. rotundata* being the most frequently encountered and dominant across stations. *Thalassia hemprichii* was identified by its thick, segmented rhizomes and the presence of brown lines or spots on its leaf blades. *Cymodocea rotundata*, commonly known as smooth ribbon seagrass, features flat, linear leaves measuring 7-15 cm in length and 0.2-0.4 cm in width with 9-15 longitudinal veins and occasionally small marginal serrations. *Halodule pinifolia* was observed at five stations (i.e., Station 1, 2, 3, 4, 5) but in relatively low densities. It is characterized by its smooth, delicate leaves, which can grow up to 20 cm long, and a distinctive single black central vein that bifurcates near the rounded leaf tip (Dilipan and Arulbalachandran 2022). *Enhalus acoroides*, the largest species observed, was present in low densities at Stations 3 through 6. This species is recognizable by its thick, tough, dark green, ribbon-shaped leaves with many parallel veins (Kuo 2020). *Halodule ovalis,* distinguished by its ovate to elliptic leaf shape and 8-6 pairs of cross veins, was found only in Stations 1 and 5 (Figure 3).

In Walakiri, east of Sumba, although it grew in the same silty-sand substrate, seagrass relative density varied across stations and species. However, *T. hemprichii* generally showed a high relative density (33-90%), followed by *C. rotundata*, which ranged from 4% to 44% (Figure 3). *Halodule ovalis* is the lowest and rarest species, as it is only found at Station 5. *Thalassia hemprichii* dominates Walakiri's seagrass ecosystems due to its competitive advantages and its ability to thrive across a range of environments. It is a highly versatile species that can thrive in a variety of environments, including intertidal and subtidal zones. It can withstand a wide range of sediment types and salinity levels. Furthermore, in specific settings, *T. hemprichii* can outcompete other seagrass species due to its rapid growth and effective nutrient uptake (McKenzie et al. 2021). Several other factors influence seagrass relative density, including species-specific differences. Different seagrass species exhibit varying densities (Tebaiy et al. 2024), as observed in this study, where *C. rotundata* often shows higher densities than *H. ovalis.* Substrate type (Pineiro-Juncal et al. 2022), water depth (Ng 2023), nutrient availability, and nutrient levels (Fortes et al. 2018), as well as environmental factors such as wave action, light penetration, and temperature (Duarte et al. 2025), also influence the relative density of seagrass.

There were five seagrass species in this study, fewer than in previous studies of the entire coast of Sumba Island conducted by Welly et al. (2016). In their research, they found *C. serrulata, C. rotundata, H. ovalis*, and *Syringodium isoetifolium* on the Southwest Coast, *C. serrulata, C. rotundata, and S. isoetifolium* on the West Coast, and *C. serrulata*, *C. rotundata, H. ovalis, H. uninervis*, and *S. isoetifolium* in the Central Coast, and *C. serrulata, C. rotundata, H. ovalis,* and *S. isoetifolium* on the East Coast of Sumba. *Halodule uninervis* was not observed in this research.

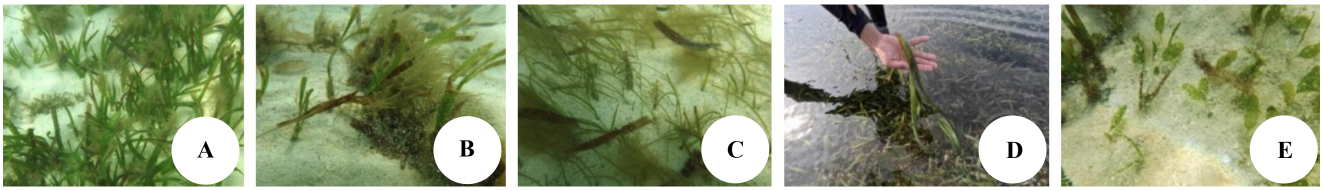

Figure 2. The species of seagrass found in Walakiri Beach, Sumba Island, East Nusa Tenggara, Indonesia. A. *Thalassia hemprichii*, B. *Cymodocea rotundata*, C. *Halodule pinifolia*, D. *Enhalus acoroides*, E. *Halodule ovalis*

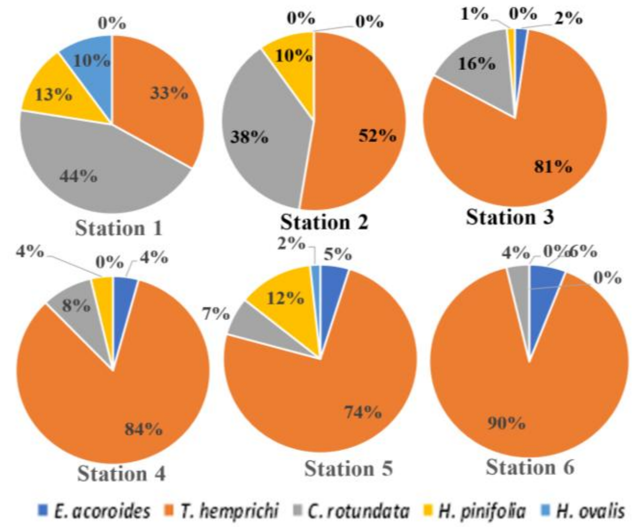

Figure 3. Relative density (%) of seagrass species at six stations in Walakiri Waters, Sumba Island, East Nusa Tenggara, Indonesia

The structure of the seagrass community was evaluated using ecological and biological indicators, including species diversity, evenness, and dominance (Figure 4). The Shannon-Wiener diversity ranges from 0.61 to 1.22, indicating low diversity across the study area, with only five seagrass species recorded. Evenness values ranged from 0.24 to 0.76, representing a variation from low to high uniformity in species distribution. Stations 3 to 6 exhibited a relatively stable community structure, as indicated by their higher evenness values. The dominance index value (Simpson's dominance index, C) ranged from 0.33 to 0.82, with *T. hemprichi* as the dominant species across most stations (Figure 4), since it is a highly adaptable species, found in diverse habitats like intertidal and subtidal zones, and tolerates a range of salinity and sediment types (Shi et al. 2025).

To assess the ecological condition of the seagrass habitat, five resilience criteria were considered: seagrass species richness and coverage, water transparency, macroalgal and epiphyte coverage (Hernawan et al. 2021). These indicators were used to calculate the Seagrass Ecological Quality Index (SEQI), as shown in Figure 5. A critical measure of the resilience of seagrass ecosystems is seagrass cover. Seagrass coverage at Walakiri Beach was generally dense (Stations 2-5) with an average cover of 58.15±18.47%, and categorized as very dense at Station 6. In contrast, Station 1 exhibited sparse seagrass cover (26.1%), classified as rare; The higher cover indicated the greater capacity to tolerate and bounce back from perturbati ons (Unsworth et al. 2015). The macroalgae coverage was low across all stations, ranging from 3.69% to 10.80% with a mean of 7.53±2.97%, indicating a minimal presence (categorized as rare, i.e., <26%) (Figure 5). When the macroalgae abundance is high, it could reduce light penetration and impede seagrass photosynthesis. Macroalgae can harm seagrasses by shading them and decomposing, creating hypoxic (low-oxygen) conditions that can be detrimental to seagrass health. Furthermore, seagrasses may experience additional stress due to competition for resources, such as nutrients, during macroalgal blooms (Richard and Quijon 2023).

Epiphyte coverage was low across all stations, ranging from 7.95% to 38.64% (mean 21.97±10.82%), indicating low to moderate levels. When epiphyte growth on seagrass leaves is low to moderate, the seagrass can experience both positive and negative effects. Low to moderate epiphyte cover can be beneficial as it may stimulate seagrass growth in some cases (Ruesink 2016). However, excessive epiphyte growth can negatively impact seagrass by reducing light availability, hindering photosynthesis, and potentially affecting gas exchange (Jian et al. 2023). At the 6 stations, water transparency ranged from 1.2 to 2.0 meters, allowing sufficient light penetration to support seagrass photosynthesis and growth (Wong and Dowd 2023). Based on the five resilience indicators shown in Figure 5, the SEQI value ranged from 0.66 to 0.77. Overall, the ecological condition of the seagrass ecosystem at Walakiri Beach was rated as good (SEQI 0.69-0.84), except at Station 6, which was rated moderate (SEQI 0.66). This state indicates a healthy and functional environment with some room for improvement. This suggests the seagrass meadow is well-established, provides essential habitat and ecosystem services (Kusnadi et al. 2024), but may be facing some minor pressures or stressors (Hernawan et al. 2021; Rina et al. 2021).

The megabenthos' diversity and community structure

The distribution of megabenthic organisms in the study area is summarized in Table 2. A total of 48 species were recorded, belonging to five phyla: Echinodermata, Arthropoda, Mollusca, Chordata, and Porifera. The Mollusca exhibited species richness of 20, particularly in Station 3. The mollusks, including bivalves and gastropods, are often abundant in seagrass ecosystems due to the favorable conditions and resources they provide. Seagrass beds offer a diverse range of food sources, shelter from predators, and suitable substrates for attachment and reproduction (Aji et al. 2025). In contrast, only one species from the Phylum Chordata, the tunicate *Didemnum perlucidum*, was found, limited to Stations 1, 2, and 5 (Figure 6.A), and was present only in very low densities (0.3-0.5 individuals m^{-2}). At high densities, this invasive colonial ascidian can negatively impact seagrass by overgrowing and smothering it, reducing photosynthesis and potentially affecting the seagrass ecosystem as a whole (Simpson et al. 2016). According to Novak and Shenkar (2020), this fouling can reduce seagrass leaf biomass and potentially reduce their photosynthetic capacity.

The second most diverse group was Echinodermata, comprising 14 species, which were mainly recorded at Station 1, with the majority belonging to the Class Ophiuroidea. Echinoderms and seagrass have a complex relationship, with some echinoderms relying on seagrass beds for habitat and food (Muzaki et al. 2019), while others may be negatively impacted by seagrass presence. Seagrass beds provide shelter, nursery grounds, and feeding areas for various echinoderms (Hartati et al. 2020b; 2023). Echinoderms, such as Holothuroidea, can contribute to nutrient cycling in seagrass ecosystems by consuming detritus and releasing nutrients back into the water column (Mariasingarayan et al. 2024), thereby benefiting seagrass growth. However, some echinoderms, particularly sea urchin species such as *Echinometra mathaei* and *Diadema setosum* at Walakiri Beach, can graze on seagrass, potentially impacting its health (Czaja and Pomory 2022).

Porifera accounted for 9 species, all classified under the Class Demospongiae, the most diverse class of sponges. This class can be found in seagrass ecosystems and has various relationships with the seagrass (Setiawan et al. 2021). They can benefit from seagrass by using it as a substrate for attachment and shelter, while also impacting seagrass through competition for space or resources, or by influencing nutrient cycling (Tangaradjou and Bhatt 2018; Briceño-Vera et al. 2021). Members of Arthropoda found in the seagrass bed of Walakiri were primarily from the Class Malacostraca, including various crabs and hermit crabs. Seagrass meadows provide crucial habitats and resources for many Malacostracan species (Titioatchasai et al. 2023). Some of these species play an essential role in maintaining the health of seagrass beds (Waheeda et al. 2023), including through nutrient cycling and sediment stabilization (Briones-Fourzán et al. 2020).

In terms of density, the Phylum Echinodermata dominated, with densities ranging from 8.8 to 19.9 individuals.m^{-2}, followed by Mollusca with 1.4-10.3 individuals.m^{-2} (Figure 6.B). A variety of abiotic factors, such as water quality, light availability, and sediment characteristics (Zabarte-Maeztu et al. 2021; Capistrant-Fossa and Dunton 2024), as well as biotic factors, such as predation, competition, and seagrass health (Song et al. 2025), determine the abundance of megabenthos in seagrass habitats. The abundance of Porifera ranged from 0.8 to 9.9 individuals m^{-2}, with the commonly observed species being *Petrosia nigricans* and *Chalinula molitba*, at 3.7 and 1.3 individuals.m^{-2}, respectively. The sponge *P. nigricans* is recognized as a successful species due to its diverse morphology and adaptability to various environmental conditions, even in areas near human settlements (Prabowo et al. 2023), while *C. molitba,* according to Ugalde et al. (2015), is often found in shallow water and is frequently encountered in *Thalassia* meadows.

Table 2. Diversity of megabenthos in the seagrass habitat of Walakiri Beach, Sumba Island, East Nusa Tenggara, Indonesia

Echinodermata	Malacostraca	Mollusk	Ascidiacea	Demospongiae
Ophiuroidea	*Clibanarius longitarsus*	**Gastropods**	*Didemnum perlucidum*	*Petrosia nigricans*
Ophiolepis impressa	*Pagurus annulipes*	*Conus glans*		*Hymeniacidon parleve*
Ophiocoma scolopendriona	*Portunus pelagicus*	*Conus chaldaeus*		*Ircina felix*
Ophioderma cinerea	*Pilumnus vespertilio*	*Conus capitaneus*		*Amphimedon viridis*
Ophiactis quinqueradia		*Cyprea annulus*		*Spheciospongia vagabunda*
Ophiocoma erinaceus		*Cypraea moneta*		*Neopetrosia carbonaria*
Asteroidea		*Cypraea chinensis chinensis*		*Hyrtius proteus*
Archaster typicus		*Cypraea arabica arabica*		*Clathria reinwardti*
Luidia maculate		*Fissilabia decollata*		*Chalinula molitba*
Protoreaster nodosus		*Oliva hirasei*		
Echinoidea		*Oliva irisans*		
Echinometra mathaei		*Oliva manticora*		
Diadema setosum		*Pyrene punctata*		
Holothuroidea		*Rhinoclavis fasciata*		
Synapta maculata		*Strombus microaureus*		
Holothuria albiventer		**Bivalves**		
Holothuria atra		*Donax faba*		
Holothuria scabra		*Gafrarium pectinatum*		
		Pholas orientalis		
		Spondylus pictorum		
		Tellina timorensis		
		Vasticardium flavum		

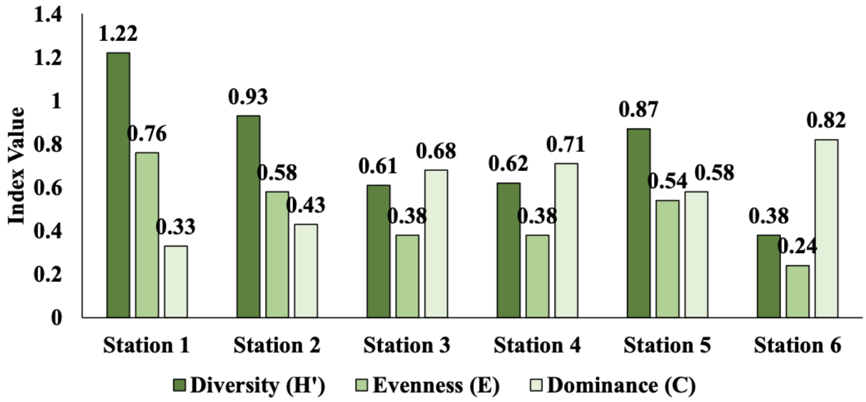

Figure 4. Seagrass community structure (H': Diversity, E: Evenness, C: Dominance) in the Sumba Island, East Nusa Tenggara, Indonesia

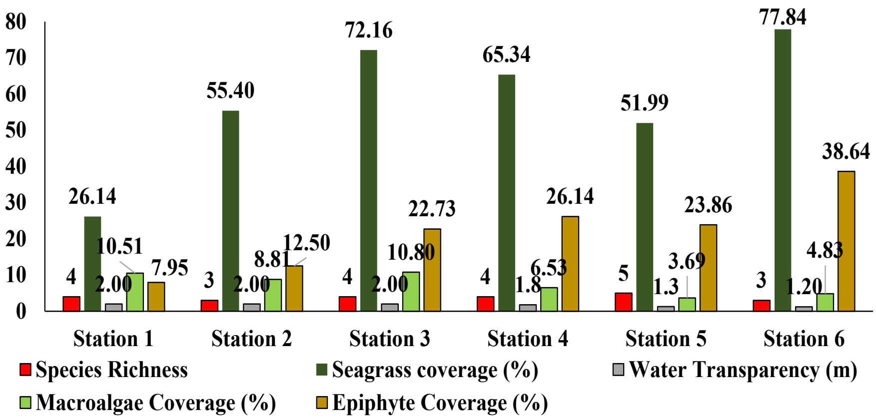

Figure 5. Seagrass resilience value for SEQI evaluation

The diversity of megabenthos organisms across stations ranged from 36 to 45 species, with abundance varying from 8 to 34 individuals.m^{-2} (Figure 8.A). Station 3 exhibited the highest diversity and abundance, with 45 species and 34.9 individuals m^{-2}, whereas Station 5 had the lowest values, recording only 28 species and 8 individuals m^{-2}. To evaluate megabenthos community structure, diversity indices, including Shannon-Weiner diversity, evenness, and dominance, were calculated (Figure 8.B). The results indicated a high diversity (ranging from 0.98 to 4.93), high evenness (0.77-0.93), and no single species dominating (0.04-0.13).

Pearson's correlation analysis (Figure 9) was conducted to explore the relationship between megabenthic richness and seagrass ecological quality in their shared habitat. During the present study, fourteen ecological parameters were examined, including megabenthic species richness, abundance, diversity, evenness, and dominance; seagrass species richness, coverage, diversity, evenness, and dominance; macroalgae and epiphyte cover; and visibility (Hernawan et al. 2021). The results showed a strong positive correlation between megabenthic diversity and evenness, as well as between seagrass coverage and dominance; however, there were also strong negative correlations with seagrass evenness and diversity. Findings on megabenthic diversity and evenness relative to seagrass dominance show regional variation across Indonesian seagrass habitats, with some studies reporting a positive correlation between high seagrass coverage/ dominance and increased benthic diversity (Tasabaramo and Nugraha 2023). For instance, the Kepulauan Banyak region indicates that seagrass bed characteristics drive this relationship. At the same time, other areas, such as the Riau Archipelago, show poor benthic health despite high seagrass cover, suggesting that other factors influence benthic health (Nasution et al. 2024).

In contrast, megabenthic dominance showed the opposite pattern, reinforcing the conclusion that megabenthic communities are more diverse and evenly distributed in the areas dominated by a few seagrass species, particularly *T. hemprichii* (Figure 3), and with broad seagrass coverage. This supports the study by Rodil et al. (2021) in the Hanko Peninsula (Finland), which found that seagrass-associated macrofauna showed an apparent increase in abundance and α-diversity metrics with increasing habitat complexity attributes (i.e., shoot density, plant biomass, and canopy height). Additionally, megabenthic diversity positively correlated with epiphyte coverage, likely reflecting the structural complexity and resource availability in well-developed seagrass habitats (Jian et al. 2023). Conversely, macroalgae coverage negatively correlated with megabenthic diversity, likely due to its competitive interaction with seagrass. Trends in species richness and abundance of megabenthos followed a similar, albeit weaker, pattern to those observed in diversity and evenness, further supporting the idea that extensive and uniform seagrass beds foster more diverse and abundant megabenthic communities (Zabarte-Maeztu et al. 2021; Capistrant-Fossa and Dunton 2024; Song et al. 2025). Notably, the Seagrass Ecological Quality Index (SEQI) indicated that most stations were in a good ecological condition. The dominance of *T. hemprichii* and its associated epiphyte likely provides a favorable habitat for various megabenthic taxa, including Echinodermata, Mollusca, Arthropoda, Chordata, and Porifera. Overall, these findings highlight the crucial role of healthy seagrass ecosystems in supporting thriving and stable megabenthic communities at Walakiri Beach.

The seagrass ecosystem inhabits gently sloping coastal waters, often on muddy or sandy substrates at the lowest tidal zones adjacent to mangrove forests or coral reef flats. They thrive to a depth of 30 meters in protected, calm waters, with growth highly dependent on sunlight penetration. Optimal metabolic activity, including reproduction, occurs when the entire plant is submerged in seawater, supported by a well-developed root system (Rahmawati et al. 2018). Despite biological functions, seagrass offers important ecosystem services by stabilizing sediment, reducing wave energy, preventing erosion (Duarte et al. 2013), and enhancing the health of nearby coral reefs (Lamb et al. 2017).

However, seagrass ecosystems are increasingly threatened by multiple stressors, including anthropogenic pressures from coastal development, tourism, and land-based inputs. Activities such as land conversion and tourism (Karlina et al. 2018; Arriesgado et al. 2024), particularly those documented at Walakiri Beach, contribute to habitat degradation (Rifai et al. 2024). Elevated nutrient input and sedimentation increase turbidity (Bulmer et al. 2018), leading to eutrophication and epiphytic algal overgrowth, which blocks sunlight and impairs photosynthesis (Hernawan et al. 2021). These factors significantly compromise the health of seagrass and the broader marine ecosystem it supports (Benham et al. 2016). Nonetheless, the seagrass ecosystem at Walakiri Beach appears relatively unaffected by this threat, as evidenced by the low macroalga and epiphyte cover (Figure 5) and favorable SEQI values, indicating overall good ecological health (Figure 7).

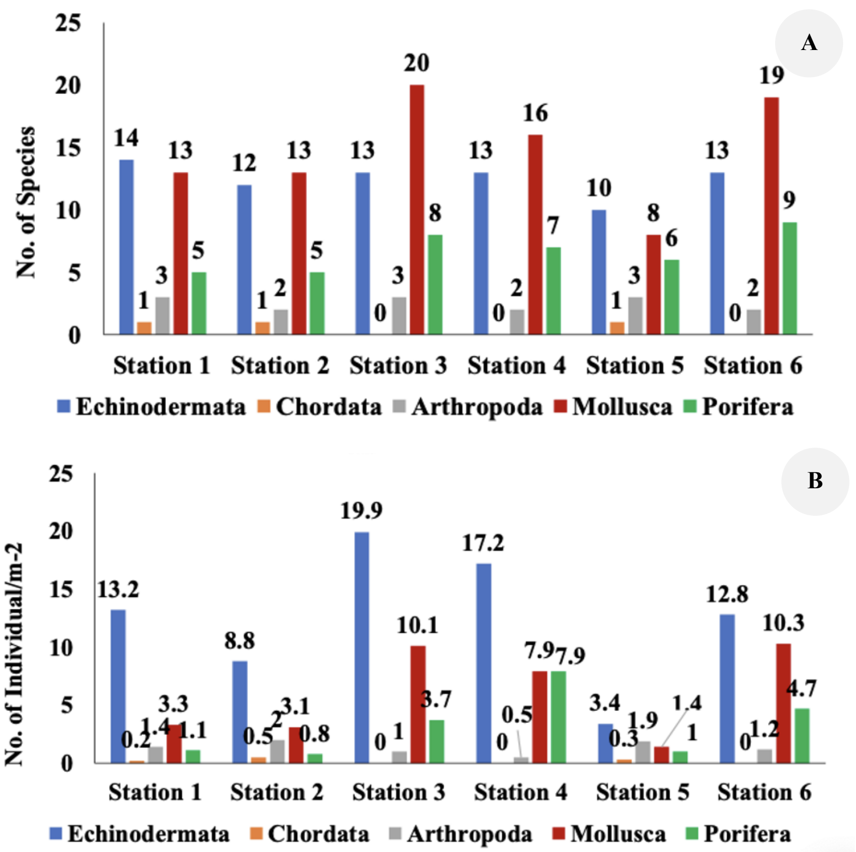

Figure 6. A. Species Diversity of Megabenthos in the Seagrass bed, B. Abundance of Megabenthos in the Seagrass bed

Seagrass meadows are home to many ecologically and economically significant marine organisms, including megabenthic-benthic invertebrates larger than one centimeter (Schratzberger and Ingels 2018). These organisms play a crucial role in bioturbation, organic matter cycling, and the dynamics of food webs (Stratmann et al. 2020), and are essential resources for coastal communities. Our findings show that mollusks, specifically gastropods and bivalves, exhibited the highest diversity among megabenthos (Figure 6.A). This aligns with observations from other seagrass regions across Indonesia, such as Tanakeke Island, South Sulawesi (Litaay et al. 2017), Bontosua Island, Pangkep (Kartika et al. 2023), Panjang Island, Jepara (Saputri et al. 2023), Banda Island, Maluku (Rosalina et al. 2023), and Biak Island, Papua (Aji and Widyastuti 2020).

The distribution and richness of mollusk species are influenced by seagrass species and coverage, substrate type, organic content, seasonality, tides, and anthropogenic activities (Aji and Widyastuti 2017; Aji et al. 2018). The seagrass structure, comprising rhizomes, leaves, and roots, protects from predators and supports a diverse array of benthic organisms, including echinoderms, crustaceans, tunicates, and sponges (Porifera) (Attrill et al. 2000). Seagrasses accumulate detritus and organic matter, serving as food sources and microhabitats that enhance faunal diversity (Rodil et al. 2021).

Among the megabenthos observed, Echinoderms were the most abundant group in Walakiri Beach (Figure 7.B), as also occurred in Luwuk Bay, Central Sulawesi (Vimono et al. 2025), and Mantang Island, Riau Islands (Nugraha et al. 2024). This phylum includes seastar (Asteroidea), brittle stars (Ophiuroidea), sea urchins (Echinoidea), and sea cucumbers (Holothuroidea) (Espinoza-Rodríguez et al. 2021) and is a major component of benthic biomass in various marine habitats (Rosellon-Druker and Stokesbury 2019; Pabis et al. 2020). Echinoderms exhibit diverse feeding strategies and play multiple ecological roles, from sediment bioturbation to omnivory and scavenging (Stöhr et al. 2012; Belaústegui et al. 2017). Their habitat preferences often reflect their morphology and ecological adaptations (Espinoza-Rodríguez et al. 2021). Species of Holothuroidea, such as *Holothuria atra* and *H. scabra* (sea cucumber), as well as Asteroids and Ophiuroids, are closely associated with the seagrass environment due to food availability and foraging activities (Muzaki et al. 2019; Hartati et al. 2020a, b; Thuy et al. 2020). Moreover, the study by Floren et al. (2021) highlights the importance of seagrasses in the early life stage development of sea cucumbers, as their juveniles often settle on seagrass leaves.

Several megabenthic species recorded at Walakiri beach are economically important. These include sea cucumber (*H. scabra*, *H. atra*), blue swimming crab (*P. pelagicus*), and bivalves (*D. faba, and G. pectinatum*). Others, such as Conus, Cypraea, Oliva, and Strombus species (gastropods), are harvested for souvenirs or handicrafts (Aji and Widyastuti 2020). Their relatively low abundance in this study may be attributed to overharvesting and anthropogenic disturbances. The correlation analysis revealed a positive relationship between seagrass coverage and megabenthic abundance (Figure 9), suggesting that denser seagrass beds support higher faunal richness, as seen in Stations 3 and 6, where there are 72.16 and 77.84% seagrass coverage (Figure 5) supporting 45 and 46 species of megabenthos, respectively (Figure 8.A).

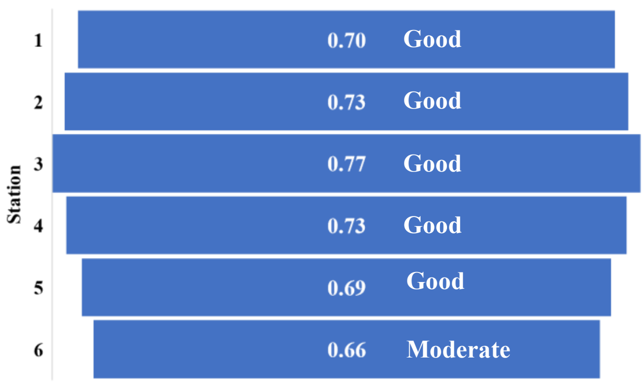

Figure 7. The Seagrass Ecological Quality Index (SEQI) value and the health status in Walakiri Beach, Sumba Island, East Nusa Tenggara, Indonesia

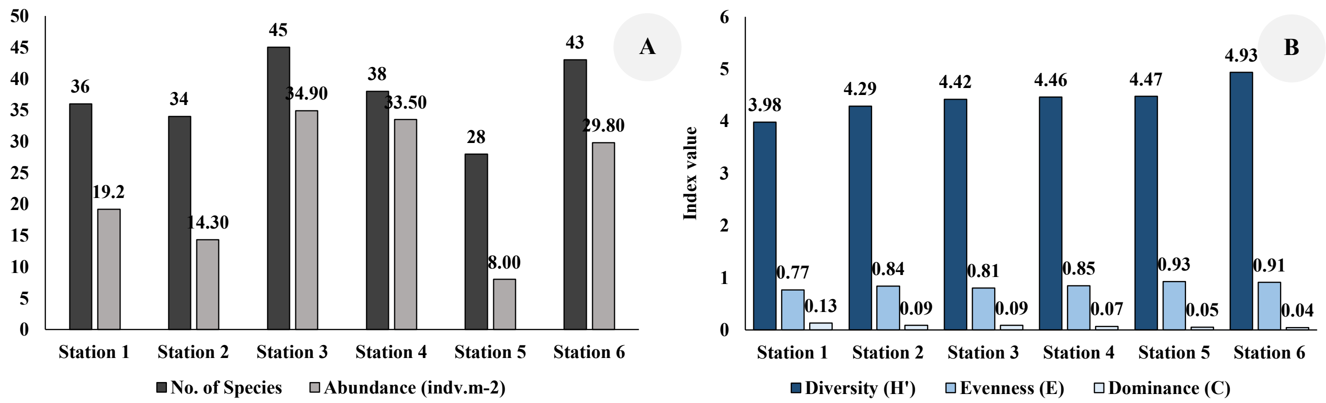

Figure 8. A. Diversity and abundance of megabenthos in the Seagrass bed, B. Community structure of megabenthos in the Seagrass bed

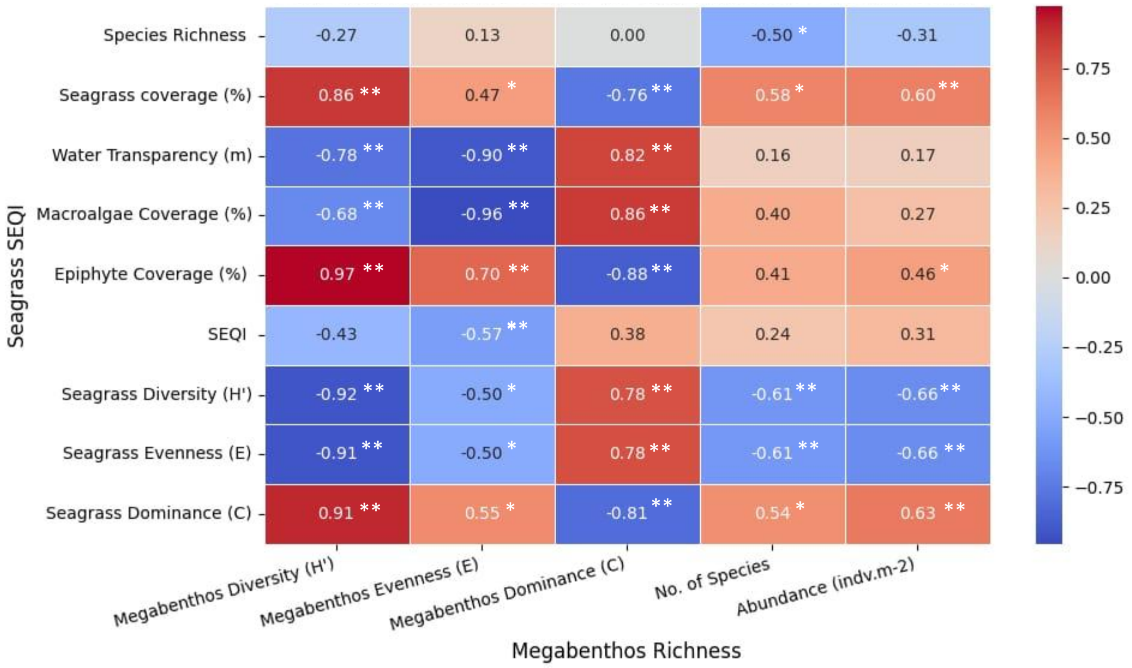

Figure 9. Pearson correlation analysis of megabenthic and seagrass as their habitat. *: Indicating significant correlation at 0.05 level, p< 0.05; **: Indicating significant correlation at 0.01 level, p<0.01

On the contrary, in Stations 1 and 5, seagrass coverage was 26.14% and 51.99%, respectively, with only 36 and 28 megabenthos species, respectively. Nagahama et al. (2025) stated that intertidal seagrass meadows support benthic communities by supplying organic matter and enhancing bacterial production. However, some weak relationships suggest that other environmental or anthropogenic factors may also influence this association. Tourism, gleaning, fishing, aquaculture, and domestic activities are key anthropogenic stressors affecting the seagrass ecosystem and the megabenthic life within it, ultimately impacting the lives of those living in the area. Arriesgado et al. (2024) demonstrated that increased tourism and gleaning are associated with reduced seagrass cover. As Walakiri Beach is a prominent tourist destination, it is vital to integrate seagrass conservation into broader coastal management strategies to ensure the long-term sustainability of its valuable ecosystem and the biodiversity it supports. Another significant threat to Walakiri Beach's seagrass ecosystems is coastal development, including infrastructure such as hotels and harbors, which can degrade habitat and cause sedimentation. Pollution from household waste disposal at sea and runoff from urban, industrial, and agricultural activities also directly harms seagrass beds. Human activities, including unregulated fishing, the use of boat anchors and propellers, and destructive practices such as gleaning for resources, also contribute to seagrass loss. Effective management strategies for balancing tourism and seagrass conservation can be implemented, including establishing Marine Protected Areas (MPAs), implementing eco-friendly tourism practices, and developing sustainable community-based management plans. Strategies also involve enhancing community engagement and local conservation capacity, promoting research and monitoring to understand ecosystem health, and restoring degraded habitats through methods such as seagrass transplantation (Syukri et al. 2024; Prawira et al. 2025).

While some of seagrass's functions, such as sediment stabilization, can be performed by other coastal ecosystems like marshes or mangroves, the suite of services it provides, particularly its unique role in carbon sequestration and in delivering diverse habitats for fisheries, is complex and challenging to replicate entirely. A comprehensive approach is necessary, recognizing that different ecosystems offer synergistic benefits. Focusing on specific seagrass contributions, like nutrient cycling and nursery grounds for commercial species, reinforces their irreplaceable value for coastal resilience and community well-being. This study highlights the ecological and socio-economic significance of the seagrass ecosystem in structuring the megabenthic community at Walakiri Waters. Seagrasses serve as bioindicators of environmental change, providing crucial ecosystem services, including habitat provision, shoreline protection, and nutrient cycling. This study reveals a positive correlation between seagrass coverage (30-90% *T. hemprichii*) and megabenthos diversity (34-48 species) and abundance (8-34 individuals.m^{-2}), underscoring the importance of well-preserved seagrass meadows in maintaining a healthy benthic community. Despite moderate anthropogenic pressures, the seagrass bed at Walakiri Waters remains ecologically healthy, supporting diverse and economically important megabenthic communities. Coastal management should prioritize protecting its integrity against the growing impact of human activities.

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