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The Ecological Role of Seagrass Ecosystems in Structuring Fish Communities: Species Composition, Feeding Ecology, and Activity Patterns in Tropical Coastal Waters

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ABSTRACT

Seagrass ecosystems play a vital role in supporting coastal biodiversity and ecological processes, particularly as habitats for fish communities. This study aims to analyze the ecological role of seagrass ecosystems in the coastal waters of Rutong by examining physicochemical parameters, fish species composition and abundance, stomach content composition, activity patterns, and seagrass density. A qualitative descriptive approach with a field-based ecological survey was employed. Data were collected through field observations, fish sampling, stomach content analysis, and environmental measurements, and analyzed using descriptive and thematic techniques. The results showed that water temperature (28 °C), pH (7.74), and salinity (33.3‰) were within optimal ranges for tropical marine ecosystems. A total of 23 fish species with 156 individuals were recorded, with the highest diversity and abundance found in Station 2, indicating the influence of habitat complexity and resource availability. Stomach content analysis revealed diverse feeding strategies, including herbivorous, omnivorous, and carnivorous behaviors, reflecting a well-structured trophic system. Feeding activity was dominant, confirming the role of seagrass as a primary feeding ground, while also functioning as shelter and nursery habitat. Variations in seagrass density across stations further influenced fish distribution and ecological interactions. This study highlights the importance of seagrass ecosystems in maintaining biodiversity and ecological balance in coastal waters and provides valuable insights for conservation and sustainable coastal resource management.

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1. INTRODUCTION

Seagrass ecosystems are among the most productive and ecologically significant coastal habitats in tropical and subtropical regions. These ecosystems provide essential ecological functions, including serving as feeding grounds, nursery habitats, and shelter for a wide range of marine organisms, particularly fish (Nordlund et al., 2017; Unsworth et al., 2019). Seagrass meadows also play a crucial role in maintaining coastal stability, enhancing water quality, and contributing to carbon sequestration (Duarte et al., 2018; Macreadie et al., 2019). Despite their importance, seagrass ecosystems are increasingly threatened by anthropogenic pressures such as coastal development, pollution, overfishing, and climate change, which lead to habitat degradation and loss of biodiversity (Jaxion-Harm et al., 2018). Indonesia possesses extensive seagrass ecosystems that support coastal fisheries and local communities. The coastal waters of Rutong Village, located in South Leitimur District, represent an area with diverse seagrass habitats characterized by variations in substrate type, water quality, and vegetation density. These environmental variations influence the ecological dynamics of fish communities associated with seagrass beds (Ambo-Rappe et al., 2018; Hernawan et al., 2020). However, studies that comprehensively examine the relationships between environmental parameters, seagrass characteristics, and fish ecological responses in this region remain limited. This condition highlights the importance of conducting integrated ecological research to better understand the functional role of seagrass ecosystems.

This study focuses on understanding the ecological interactions within seagrass ecosystems in Rutong coastal waters. The main issues addressed include the influence of physicochemical conditions on seagrass habitats, the variation in fish species composition and abundance across different stations, and the relationship between feeding behavior, activity patterns, and habitat characteristics. These aspects are essential for explaining how seagrass ecosystems support fish communities and maintain ecological balance.

Previous studies have demonstrated that seagrass ecosystems play a fundamental role in structuring marine biodiversity. Habitat complexity is widely recognized as a key factor influencing species richness and abundance. Seagrass beds with higher density and structural complexity provide greater protection from predators and increased availability of food resources, thereby supporting more diverse fish assemblages (Henderson et al., 2017; Hori et al., 2018). Empirical evidence from tropical coastal ecosystems consistently shows a positive relationship between seagrass density and fish diversity (Jaxion-Harm et al., 2018; Lefcheck et al., 2019). In addition, trophic interactions within seagrass ecosystems are highly diverse. Herbivorous fish species primarily consume seagrass and associated algae, while omnivorous and carnivorous species feed on plankton, benthic invertebrates, and crustacean larvae (Duffy et al., 2019; Hyndes et al., 2018). Stomach content analysis has been widely used to identify feeding strategies and understand energy flow within marine ecosystems. These studies emphasize the role of seagrass ecosystems as important feeding grounds that support multiple trophic levels (Whitfield, 2019).

Fish activity patterns further illustrate the multifunctional role of seagrass habitats. Seagrass beds provide shelter and nursery areas that enhance survival rates, particularly for juvenile fish. The structural complexity of seagrass vegetation reduces predation risk and creates microhabitats that support diverse ecological functions (Becker et al., 2020; Boström et al., 2017). However, many previous studies have examined these aspects separately, with limited integration of environmental parameters, species composition, feeding ecology, and behavioral patterns within a single framework.

This study aims to analyze the ecological role of seagrass ecosystems in supporting fish communities in Rutong coastal waters by examining physicochemical parameters, fish species composition and abundance, stomach content composition, activity patterns, and seagrass density. The novelty of this study lies in its integrative approach, which combines multiple ecological components to provide a comprehensive understanding of seagrass–fish interactions. Furthermore, this research contributes empirical data from a relatively understudied coastal area, offering new insights into tropical seagrass ecosystems. The results of this study contribute to both theoretical and practical aspects of marine ecology. Theoretically, this research enhances understanding of habitat complexity, trophic interactions, and ecological functions within seagrass ecosystems. Practically, the findings provide important information for coastal resource management, particularly in the conservation and sustainable utilization of seagrass habitats. The study also serves as a baseline for future research and supports the development of policies aimed at protecting marine biodiversity and improving the sustainability of coastal fisheries.

2. MATERIALS AND METHOD

2.1 Research Design

This study employed a qualitative descriptive approach with a field-based ecological survey design to explore the composition, feeding behavior, and activity patterns of fish associated with seagrass ecosystems. The descriptive approach was selected to provide an in-depth understanding of ecological interactions without manipulating environmental variables. This design is suitable for capturing natural conditions and interpreting complex relationships between seagrass habitats and fish communities (English et al., 2018; McKenzie et al., 2020).

2.2 Study Site

The study was conducted in the coastal waters of Rutong Village, South Leitimur District, Ambon Island, Indonesia, characterized by diverse seagrass habitats and varying substrate types. Three sampling stations were purposively selected based on ecological characteristics, including substrate composition (sand, mud, and coral fragments) and seagrass density. Station 1 represented sandy substrate conditions, Station 2 muddy substrate with high nutrient input, and Station 3 coral-fragment substrate with lower seagrass coverage. Sampling focused on capturing representative species across stations. A purposive sampling technique was applied to ensure that fish collected reflected the diversity of habitats and ecological conditions present in the study area.

2.3 Data Collection Techniques

Data collection involved direct field observations, fish sampling, and laboratory analysis. Fish samples were collected using appropriate fishing gear within transect plots established at each station. Each station consisted of three transects with multiple observation plots to ensure representative sampling. Collected fish specimens were preserved and transported to the laboratory for identification using standard taxonomic references. Stomach content analysis was conducted by dissecting fish specimens to identify dietary components, including seagrass, algae, plankton, and other materials. Environmental parameters, including temperature, pH, and salinity, were measured in situ using standard water quality instruments. Seagrass density was assessed by counting the number of shoots within quadrats ($1\ m^2$) along each transect. To ensure data validity, triangulation was applied by combining field observations, laboratory analysis, and literature references. Ethical considerations included minimizing ecological disturbance and ensuring proper handling of biological samples.

2.4 Research Procedures

The research procedure consisted of several systematic stages. First, preliminary observations were conducted to determine sampling locations and station characteristics. Second, field data collection was carried out, including fish sampling, environmental measurements, and seagrass assessment. Third, laboratory analysis was conducted to identify fish species and analyze stomach contents. Fourth, data organization and classification were performed to group fish species, feeding types, and ecological roles. Finally, data interpretation was conducted to understand patterns of fish distribution, feeding behavior, and habitat utilization in relation to seagrass density and environmental conditions.

2.5 Data Analysis Techniques

Data were analyzed using qualitative descriptive analysis supported by basic quantitative summaries. Fish species composition and abundance were analyzed by calculating total individuals and species richness across stations. Stomach content data were categorized into major food groups to identify feeding patterns and trophic levels. Seagrass density was calculated using standard ecological formulas based on shoot counts per unit area (ind./m^2). Environmental parameters were interpreted descriptively to assess habitat suitability. The analysis followed thematic interpretation, focusing on key ecological themes such as habitat complexity, trophic interactions, and species distribution. Data validity was ensured through credibility (consistent field observations), transferability (clear site description), dependability (systematic procedures), and confirmability (data-supported interpretation).

3. RESULTS AND DISCUSSION

3.1 Physicochemical Characteristics of Seagrass Waters

The physicochemical parameters of seagrass waters in the Rutong coastal area (Table 1) indicate environmental conditions that are suitable for supporting seagrass ecosystems and associated fish communities. The recorded temperature (28 °C), pH (7.74), and salinity (33.3‰) fall within optimal ranges for tropical marine environments. These conditions are known to enhance primary productivity and provide a stable habitat for marine organisms, particularly seagrass-associated fish. The composition and abundance of fish species reveal spatial variation across the three stations. A total of 22 species and 155 individuals were recorded, with Station 2 showing the highest diversity and abundance. This pattern is likely influenced by denser seagrass cover and nutrient availability, which provide better shelter and feeding opportunities. In contrast, Station 3 exhibited the lowest species richness, indicating less favorable habitat conditions.

Table 1. Physicochemical Parameters of Seagrass Waters in Rutong Coastal Area.

Parameter	Unit	Value
Temperature	°C	28
pH	–	7.74
Salinity	‰ (ppt)	33.3

Stomach content analysis further demonstrates that fish species in seagrass ecosystems exhibit diverse feeding strategies. The dominant food items include seagrass, algae, zooplankton, and phytoplankton, indicating a combination of herbivorous and omnivorous feeding habits. The presence of gastropod larvae and crustacean larvae suggests that some species occupy higher trophic levels. Variations in diet composition among stations reflect differences in resource availability and habitat structure (Duffy et al., 2019). Fish activity patterns highlight that feeding behavior is the most dominant ecological activity in seagrass beds, followed by sheltering and nursery functions. Species such as *Atherinimorus endrachtensis* and *Siganus spinus* show high activity levels related to feeding, emphasizing the role of seagrass as a primary feeding ground. Additionally, several species utilize seagrass beds as nursery and refuge areas, supporting their ecological importance in maintaining fish populations (Heck et al., 2017). Overall, the integration of environmental parameters, species composition, feeding habits, and activity patterns confirms that seagrass ecosystems in Rutong coastal waters play a crucial role in sustaining fish biodiversity and ecological functions.

3.2 Fish Species Composition and Abundance Across Seagrass Stations

The composition and abundance of fish species across the three seagrass stations in Rutong coastal waters (Table 2) reveal significant spatial variation in species distribution and population structure. A total of 23 species belonging to multiple families were recorded, with an overall abundance of 155 individuals. The results indicate that seagrass ecosystems in the study area support a relatively high diversity of fish species, reflecting their ecological importance as productive coastal habitats. Station 2 exhibited the highest species richness and abundance, with 13 species and 109 individuals, compared to Station 1 (10 species; 34 individuals) and Station 3

(7 species; 13 individuals). This pattern suggests that environmental conditions and habitat complexity differ among stations, influencing fish assemblage structure. The higher abundance in Station 2 may be associated with denser seagrass coverage, finer substrate (muddy sediment), and higher nutrient input from nearby freshwater sources, which together enhance food availability and shelter. In contrast, Station 3, characterized by coarser substrate and less dense seagrass, showed the lowest diversity and abundance, indicating less favorable ecological conditions for fish habitation.

Table 2. Composition and abundance of fish species across three seagrass stations in Rutong Coastal Waters.

No	Family	Species	Station 1 (n)	Station 2 (n)	Station 3 (n)	Total (n)
1	Lutjanidae	*Lutjanus fulvus*	1	–	1	2
2	Lutjanidae	*Lutjanus ehembergii*	–	3	–	3
3	Siganidae	*Siganus canaliculatus*	5	–	–	5
4	Siganidae	*Siganus spinus*	6	19	1	26
5	Siganidae	*Siganus vermiculatus*	–	1	1	2
6	Pomacentridae	*Pomacentrus* sp.	2	–	–	2
7	Pomacentridae	*Dischistodus chrysopecilus*	1	–	–	1
8	Plotosidae	*Plotosus anguilaris*	1	–	–	1
9	Atherinidae	*Atherinimorus endrachtensis*	9	50	–	59
10	Carangidae	*Caranx melampygus*	2	–	–	2
11	Nemipteridae	*Scolopsis lineata*	4	9	–	13
12	Apogonidae	*Apogon melas*	3	–	–	3
13	Apogonidae	*Apogon nigrofasciatus*	–	–	3	3
14	Apogonidae	*Sphaeramia orbicularis*	–	–	1	1
15	Diodontidae	*Diodon holocanthus*	–	3	–	3
16	Geriidae	*Gerres oyena*	–	7	–	7
17	Lethrinidae	*Lethrinus harak*	–	2	–	2
18	Tetraodontidae	*Arothron reticularis*	–	1	–	1
19	Synodontidae	*Synodus dermatogenys*	–	1	–	1
20	Mugilidae	*Crenimugil crenilabis*	–	7	3	10
21	Mugilidae	*Chelon macrolepis*	–	5	–	5
22	Terapontidae	*Terapon jarbua*	–	–	3	3
23	Gobiidae	*Amblygobius phalaena*		1		1
		Total Individuals	34	109	13	156
		Total Species	10	13	7	23

In terms of species dominance, *Atherinimorus endrachtensis* was the most abundant species, with a total of 59 individuals, predominantly found in Station 2. This species is known to associate closely with vegetated coastal habitats, particularly seagrass beds, where it utilizes the environment for feeding and protection. Similarly, *Siganus spinus* showed relatively high abundance (26 individuals) across all stations, highlighting its adaptability and strong association with seagrass ecosystems. The presence of herbivorous species such as *Siganus canaliculatus* and *Siganus spinus* further emphasizes the role of seagrass as a primary food source.

Several species exhibited restricted spatial distribution, occurring only in specific stations. For example, *Gerres oyena*, *Lethrinus harak*, and *Arothron reticularis* were only found in Station 2, while *Apogon nigrofasciatus* and *Terapon jarbua* were exclusive to Station 3. This distribution pattern suggests niche differentiation and habitat preference among species, likely influenced by variations in substrate type, seagrass density, and food availability (Gullström et al., 2018) The presence of Mugilidae species (*Crenimugil crenilabis* and *Chelon macrolepis*) further indicates connectivity between seagrass ecosystems and adjacent habitats such as estuaries and mangroves.

The observed variation in fish assemblages across stations can be explained by ecological theories related to habitat complexity and resource availability. Seagrass beds with higher structural complexity tend to support greater biodiversity due to increased shelter from predators and enhanced feeding opportunities (Hemmingsen et al., 2019). The dominance of certain species in Station 2 aligns with this concept, as denser seagrass vegetation provides more niches and supports a more complex food web. Conversely, reduced habitat complexity in Station 3 limits the availability of ecological niches, resulting in lower species diversity. Furthermore, the presence of both herbivorous and carnivorous species indicates a well-structured trophic system within the seagrass ecosystem. Herbivorous species primarily rely on seagrass and algae, while carnivorous species feed on zooplankton, crustacean larvae, and other small organisms. This trophic diversity reflects the ecological function of seagrass beds as both feeding grounds and nursery habitats. Juvenile fish, in particular, benefit from the protective structure of seagrass, which reduces predation risk and increases survival rates (Whitney et al., 2021).

Overall, the findings demonstrate that seagrass ecosystems in Rutong coastal waters play a critical role in supporting fish biodiversity and maintaining ecological balance. The variation in species composition and abundance across stations highlights the importance of habitat quality and environmental conditions in shaping fish communities. These results underscore the need for conservation and sustainable management of seagrass habitats to ensure the ecological functions and fisheries productivity in coastal ecosystems.

3.3 Stomach Content Composition of Fish Across Seagrass Stations

The stomach content composition of fish species across the three seagrass stations in Rutong coastal waters is presented in Table 3. The stomach content composition of fish species across the three seagrass stations in Rutong coastal waters reveals diverse feeding patterns and trophic interactions within the seagrass ecosystem. The identified food items include seagrass, algae, phytoplankton, zooplankton, gastropod larvae, crustacean larvae (megalopa), and inorganic materials such as sand particles. This diversity indicates that seagrass ecosystems function as productive feeding grounds that support multiple trophic levels. At Station 1, the diet composition is dominated by seagrass, algae, and planktonic organisms. Herbivorous species such as *Siganus canaliculatus* and *Atherinimorus endrachtensis* primarily consumed seagrass and algae, while species like *Pomacentrus* sp. and *Apogon melas* relied on zooplankton and phytoplankton. The presence of gastropod larvae in several species suggests opportunistic feeding behavior and the availability of epifaunal organisms associated with seagrass leaves. These findings highlight the role of Station 1 as a mixed feeding habitat supporting both herbivorous and omnivorous fish.

Station 2 exhibited the highest diversity of food items, including seagrass, plankton, gastropod larvae, crustacean larvae, and even sand particles. This indicates a more complex trophic structure compared to other stations. Species such as *Diodon holocanthus*, *Lethrinus harak*, and *Arothron reticularis* consumed animal-based food such as larvae, reflecting carnivorous feeding strategies. Meanwhile, *Crenimugil crenilabis* and *Chelon macrolepis* consumed seagrass and sediment, indicating detritivorous behavior. The presence of multiple trophic groups suggests that Station 2 provides abundant and varied food resources, likely due to higher nutrient availability and denser seagrass vegetation (Nagelkerken et al., 2017). In contrast, Station 3 showed a simpler diet composition, with fewer food types and several instances of empty stomachs. Species such as *Lutjanus fulvus*, *Siganus spinus*, and *Siganus vermiculatus* exhibited empty stomachs, which may be attributed to feeding periodicity, digestion processes, or limited food availability. The dominance of basic food items such as seagrass and algae, along with sediment ingestion, indicates lower trophic complexity. This pattern is consistent with the lower seagrass density and reduced habitat quality observed in Station 3 (Klumpp et al., 2018).

The variation in stomach content composition across stations reflects differences in habitat characteristics and resource availability. Seagrass beds with higher density and structural complexity tend to support more diverse food webs, allowing coexistence of herbivorous, omnivorous, and carnivorous species (O'Farrell et al., 2017). The findings also indicate that seagrass ecosystems serve not only as feeding grounds but also as habitats that facilitate trophic interactions and energy transfer within coastal marine systems. Overall, the results demonstrate that fish species in Rutong coastal waters exhibit flexible feeding strategies in response to environmental conditions. This adaptability enhances their survival and contributes to the stability of the seagrass ecosystem. The study underscores the ecological importance of seagrass habitats in sustaining fish communities through the provision of diverse and abundant food resources (Viana et al., 2020).

Table 3. Stomach content composition of fish species across seagrass stations in Rutong Coastal Waters.

No	Species	Station 1	Station 2	Station 3
1	*Lutjanus fulvus*	Seagrass, phytoplankton	Seagrass	No food
2	*Lutjanus ehembergii*	–	–	–
3	*Siganus canaliculatus*	Seagrass, zooplankton, gastropod larvae	–	–
4	*Siganus spinus*	Algae, seagrass, zooplankton	Algae, seagrass, phytoplankton	No food
5	*Siganus vermiculatus*	–	Gastropod larvae, seagrass	No food
6	*Pomacentrus* sp.	Zooplankton, phytoplankton	–	–
7	*Dischistodus chrysopecilus*	Gastropod larvae, zooplankton	–	–
8	*Plotosus anguilaris*	Algae, zooplankton, phytoplankton	–	–
9	*Atherinimorus endrachtensis*	Seagrass, algae	Seagrass, algae	–
10	*Caranx melampygus*	Zooplankton	–	–
11	*Scolopsis lineata*	Phytoplankton	Zooplankton	–
12	*Apogon melas*	Zooplankton	–	–
13	*Apogon nigrofasciatus*	–	–	Algae / seagrass (general)
14	*Sphaeramia orbicularis*	–	–	No food
15	*Diodon holocanthus*	–	Gastropod larvae, zooplankton, phytoplankton, seagrass	–
16	*Amblygobius phalaena*	–	Phytoplankton	–
17	*Gerres oyena*	–	Zooplankton	–
18	*Lethrinus harak*	–	Megalopa larvae (crustacean)	–
19	*Arothron reticularis*	–	Megalopa larvae (crustacean)	–
20	*Synodus dermatogenys*	–	No food	–
21	*Crenimugil crenilabis*	–	Seagrass	Seagrass
22	*Chelon macrolepis*	–	Sand particles	–
23	*Terapon jarbua*	–	–	Sand particles/algae

3.4 Fish Activity Patterns in Seagrass Ecosystems

The activity patterns and ecological roles of fish species associated with seagrass ecosystems in Rutong coastal waters (Table 4) demonstrate the functional importance of seagrass beds as feeding, shelter, and nursery habitats. The data show that feeding-related activities dominate fish behavior, indicating that seagrass ecosystems primarily function as productive feeding grounds. The highest relative activity was recorded for *Atherinimorus endrachtensis* (37.82%), followed by *Siganus spinus* (16.00%) and *Scolopsis lineata* (8.33%). These species are strongly associated with feeding and foraging activities, suggesting that they actively utilize seagrass habitats to obtain food resources. Herbivorous species such as *Siganus spinus* and *Siganus canaliculatus* rely on seagrass and algae as primary food sources, highlighting the role of seagrass beds in supporting primary consumers. Meanwhile, species such as *Caranx melampygus*, *Lethrinus harak*, and *Synodus dermatogenys* exhibit predatory feeding behavior, indicating the presence of higher trophic levels within the ecosystem. This combination of herbivorous and carnivorous feeding strategies reflects a well-structured trophic system supported by seagrass productivity (Olds et al., 2018).

In addition to feeding, several species demonstrate ecological roles related to shelter and nursery functions. For instance, *Crenimugil crenilabis* (6.04%) and *Apogon nigrofasciatus* (1.92%) are associated with shelter and protection, particularly for juvenile stages. Seagrass vegetation provides structural complexity that reduces predation risk and offers a safe habitat for growth and development. This structural function is critical for early life stages of fish, which are highly vulnerable to predation (Kimirei et al., 2017). Species such as *Pomacentrus* sp. and *Apogon melas* exhibit dual roles, utilizing seagrass beds for both feeding and shelter, reflecting behavioral flexibility and adaptive habitat use in response to environmental conditions.

Table 4. Activity patterns of fish species in seagrass beds.

No	Species	Relative Activity (%)	Ecological Role in Seagrass Beds
1	*Atherinimorus endrachtensis*	37.82	Feeding and foraging (herbivore)
2	*Siganus spinus*	16.00	Feeding and grazing
3	*Scolopsis lineata*	8.33	Feeding
4	*Crenimugil crenilabis*	6.04	Nursery ground & shelter
5	*Gerres oyena*	4.04	Feeding
6	*Chelon macrolepis*	3.02	Feeding (detritus/sediment)
7	*Siganus canaliculatus*	3.20	Feeding
8	*Apogon melas*	1.92	Shelter & feeding
9	*Apogon nigrofasciatus*	1.92	Shelter
10	*Plotosus anguilaris*	1.92	Feeding
11	*Diodon holocanthus*	1.92	Feeding
12	*Terapon jarbua*	1.92	Feeding
13	*Pomacentrus* sp.	1.28	Shelter & feeding
14	*Caranx melampygus*	1.28	Predatory feeding
15	*Lutjanus fulvus*	1.28	Feeding
16	*Siganus vermiculatus*	1.28	Feeding
17	*Lethrinus harak*	1.28	Predatory feeding
18	*Arothron reticularis*	1.00	Feeding
19	*Synodus dermatogenys*	1.00	Predatory feeding
20	*Sphaeramia orbicularis*	1.00	Shelter

The presence of detritivorous behavior, as observed in *Chelon macrolepis*, which feeds on sediment and organic matter, further indicates the role of seagrass ecosystems in nutrient cycling and energy transfer. Detritus derived from decomposed seagrass contributes significantly to the food web, supporting species at different trophic levels and enhancing ecosystem productivity (Jankowska et al., 2018). In addition, microbial decomposition processes within seagrass sediments play an important role in transforming organic matter into bioavailable nutrients, which are then utilized by various organisms within the ecosystem.

Overall, the variation in activity patterns among fish species reflects the multifunctional role of seagrass ecosystems. These habitats support diverse ecological functions, including feeding, protection, and reproduction, which are essential for maintaining fish population dynamics. The dominance of feeding activities, combined with the presence of shelter and nursery functions, confirms that seagrass beds in Rutong coastal waters play a critical role in sustaining biodiversity and ecosystem stability. Furthermore, ecosystem connectivity between seagrass beds and adjacent habitats such as coral reefs and mangroves enhances ecological resilience and supports fish life cycles across different habitats (Berkström et al., 2020; Nagelkerken & van der Velde, 2017; van der Linden & van der Vleuten, 2023).

3.5 Seagrass Density

The average density of seagrass across the three sampling stations is illustrated in Figure 1, showing significant spatial variation in both species' composition and density values. These variations reflect differences in environmental conditions, substrate characteristics, and nutrient availability, all of which influence seagrass growth and distribution. At Station 1, the seagrass community is characterized by relatively high density and moderate species diversity. The dominant species, *Enhalus acoroides*, exhibits a density of 698.42 ind./m^2, followed by *Halodule uninervis* at 185.08 ind./m^2 and *Halophila ovalis* at 18.16 ind./m^2. The presence of these species indicates that Station 1 provides favorable ecological conditions, particularly for larger and more established seagrass species such as *E. acoroides*. The sandy substrate observed in this station likely facilitates root penetration and anchoring, while also allowing adequate water circulation and nutrient exchange. The relatively high density contributes to increased habitat complexity, which is essential for supporting fish assemblages by providing shelter, feeding grounds, and nursery habitats. The coexistence of multiple species further enhances ecological stability by promoting functional diversity within the seagrass ecosystem.

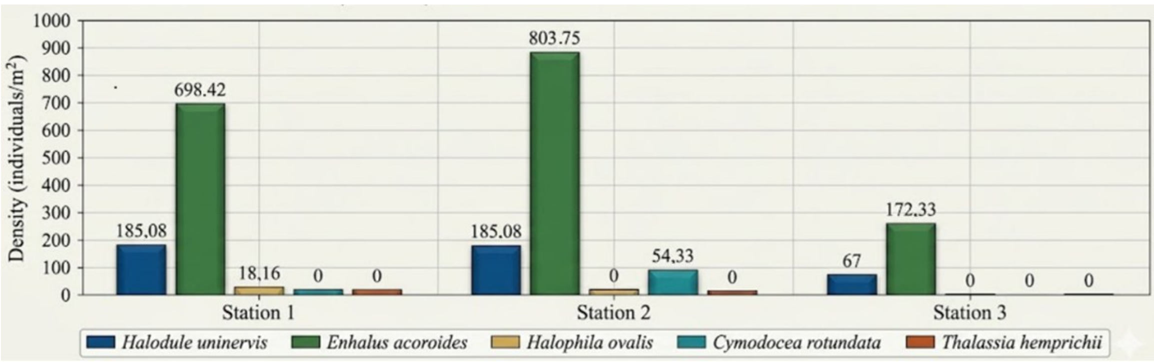

Figure 1. Average seagrass density histogram at Station 1, Station 2, and Station 3.

Station 2 demonstrates the highest seagrass density and species richness among all stations, indicating optimal habitat conditions. The density of Enhalus acoroides reaches 803.75 ind./m^2, the highest recorded value, accompanied by *Halodule uninervis* (185.08 ind./m^2), *Cymodocea rotundata* (54.33 ind./m^2), and *Thalassia hemprichii* (18.33 ind./m^2). The presence of four seagrass species suggests a well-developed and structurally complex ecosystem. This condition is likely influenced by the muddy substrate and proximity to freshwater inputs, which contribute to higher nutrient availability. Fine sediment particles enhance nutrient retention, promoting seagrass growth and productivity. The dense vegetation increases surface area for epiphytic organisms, which serve as food sources for various fish species. Consequently, Station 2 supports higher biological productivity and trophic complexity, consistent with the higher fish abundance observed in this area. The strong correlation between seagrass density and fish diversity highlights the ecological importance of dense seagrass beds in sustaining coastal biodiversity.

In contrast, Station 3 exhibits significantly lower seagrass density and reduced species diversity. Only two species were recorded, namely *Enhalus acoroides* (172.33 ind./m^2) and *Halodule uninervis* (67 ind./m^2). The absence of other seagrass species and lower density values indicate suboptimal environmental conditions. This station is characterized by a substrate composed of coral fragments, which limits the ability of seagrass roots to anchor effectively and reduces nutrient retention capacity. Coarse substrates generally provide less stability and lower organic matter content, which can hinder seagrass growth (Booth et al., 2017). As a result, the seagrass cover is less dense and less diverse, leading to reduced habitat complexity. This condition likely contributes to the lower abundance and diversity of fish species observed in Station 3, as fewer ecological niches and food resources are available.

The variation in seagrass density across stations can be interpreted within the framework of habitat complexity theory, which states that structurally complex habitats support higher biodiversity due to increased availability of shelter and resources. In this study, Station 2 represents a highly complex habitat with dense vegetation and multiple species, resulting in greater ecological functionality. Station 1 represents an intermediate condition, while Station 3 reflects a simplified habitat with limited ecological capacity. Furthermore, seagrass density plays a critical role in ecosystem functioning, particularly in terms of primary production, nutrient cycling, and trophic interactions. Dense seagrass beds enhance organic matter production, which supports detritivores and higher trophic levels. They also act as sediment stabilizers, reducing erosion and improving water clarity, which in turn benefits photosynthetic organisms. The reduced density in Station 3 may therefore have cascading effects on ecosystem processes, including lower productivity and diminished ecological resilience.

4. CONCLUSION

This study demonstrates that seagrass ecosystems in the coastal waters of Rutong play a crucial role in supporting fish biodiversity and ecological functions. The physicochemical parameters indicate that environmental conditions are within optimal ranges for tropical marine ecosystems, contributing to the stability and productivity of seagrass habitats. A total of 23 fish species were recorded, with spatial variation in composition and abundance across stations, where Station 2 exhibited the highest diversity and abundance due to greater habitat complexity and resource availability.

Stomach content analysis reveals diverse feeding strategies, including herbivorous, omnivorous, and carnivorous behaviors, reflecting a well-structured trophic system. Feeding activity dominates fish behavior, confirming the role of seagrass as a primary feeding ground, while also serving as a shelter and nursery habitat. Variations in seagrass density further influence habitat quality, with higher density supporting greater biodiversity and ecological interactions.

Overall, seagrass ecosystems function as essential habitats that sustain marine life and ecological balance. These findings highlight the importance of conserving seagrass habitats to maintain biodiversity and support sustainable coastal fisheries. Future studies are recommended to incorporate long-term monitoring and broader spatial analysis to better understand ecosystem dynamics.

AUTHORS CONTRIBUTION

YR, and ES designed and conducted the research, SS analyzed and interpreted the data, and all authors contributed to writing the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest and take full responsibility for the content of the article, including any implications of AI-generated art.

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