

Seagrass ecosystems as habitats for target fish (Siganidae and Lethrinidae) in the waters of the Aruri Islands, Papua Province, Indonesia

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Abstract. Tebayi S, Manan J, Manangkalangi E, Suruan SS, Mampiooper DC, Musyeri P, Manuputty A, Sawaki D. 2025. Seagrass ecosystems as habitats for target fish (Siganidae and Lethrinidae) in the waters of the Aruri Islands, Papua Province, Indonesia. *Biodiversitas* 26: 5726-5736. This study aimed to identify seagrass species, analyze their composition, percentage, and average cover, and determine the distribution and composition of fish species within seagrass ecosystems. Additionally, the relationships among various species and the presence of target fish, namely Siganidae and Lethrinidae, were examined. The research was conducted from November to December 2022 at three locations: Rayori Village, Nyambarai Village, and Munsaki Island in the Aruri Islands, Supiori District, Papua Province, Indonesia. Seagrass sampling employed the quadrat transect method modified from the Seagrass Watch protocol, while fish samples were collected using gill nets with the circle method. The results revealed the presence of six seagrass species in the study area, namely *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule pinifolia*, *Halophila ovalis*, *Oceana serrulata*, and *Thalassia hemprichii*. Target fish, *Siganus* sp. and *Lethrinus* sp. were found at all observation sites, with 139 and 9 individuals, respectively. Furthermore, *T. hemprichii* showed a clear relationship with the presence of *Siganus* sp. and *Lethrinus* sp. indicating its essential role in seagrass ecosystems as a habitat for these target fish species. This study's findings underscore the crucial role of *T. hemprichii* in seagrass ecosystems and its implications for the conservation of these vital habitats in the Supiori District.

Keywords: Canonical correspondence analysis, coastal area, oceanic diversity, shoreline ecosystem, species richness

INTRODUCTION

Papuan coastal ecosystems in Indonesia, rich in mangroves (Kasihiw et al. 2023; Asmuruf et al. 2024) and coral reefs (Mangubhai et al. 2012; Dirhamsyah 2013), are critical biodiversity reservoirs that sustain regional trophic dynamics and provide essential carbon sequestration services. These zones concurrently support Indigenous communities through traditional fishing and customary resource tenure, directly linking ecological integrity to local food security and socio-cultural resilience (Kasihiw et al. 2024). This condition is also evident in the Aruri Islands Sub-district, Supiori District, Papua, where natural resources are abundant and closely tied to traditional practices. Local communities rely heavily on coastal and marine ecosystems such as coral reefs, mangroves, and seagrasses for their livelihoods. A study by Purvis and Jiddawi (2021) utilized Geographic Information Systems (GIS) to evaluate changes in seagrass cover from 2006 to 2019, revealing that seagrass decline was negatively correlated with tourism activities. In contrast, other coastal activities, such as fisheries and seaweed farming, exhibited weaker correlations. These findings highlight the vulnerability of seagrass ecosystems to human pressure and the importance of their conservation.

In the Aruri Islands, mangroves, seagrasses, and coral reefs coexist and form interconnected coastal ecosystems, as oceanic conditions dominate this area. The mangroves serve to reduce sedimentation from the land, thereby maintaining water clarity in seagrass meadows and coral reefs. Seagrasses trap sediments and stabilize substrates, while coral reefs provide structural protection against waves. The ecological connectivity of these habitats supports biodiversity by providing nursery grounds and feeding areas for marine organisms (Nurul and English 2018). These ecosystem interactions demonstrate the environmental and economic importance of coastal ecosystems in Papua.

Seagrass meadows play crucial ecological roles, serving as nursery grounds, feeding habitats, and shelters for fish, turtles, and invertebrates. These services contribute to food security by supporting fisheries production for local communities (Kartika et al. 2023; Lima-Camara et al. 2023; Aiviji et al. 2024). Ecologically, seagrasses provide functions comparable to those of coral reefs and mangroves. They stabilize sediments, slow down wave energy, regulate nutrient cycles, and are highly productive in shallow marine environments (McClanahan 2002). Additionally, seagrasses are increasingly recognized as important carbon sinks, making significant contributions to blue carbon storage, regardless of whether the areas are

under formal protection (Muzani and Jalaluddin 2020; Analuddin et al. 2023).

As part of Papua's marine ecosystems, these areas, including seagrass meadows, are rich in biodiversity and have unique endemic characteristics (Kartikasari et al. 2012). Seagrass habitats in this region are not only ecologically essential but also socio-economically valuable. For example, they support sustainable fisheries and provide food resources for coastal communities (Tebaiy et al. 2013, 2014). Socioeconomic aspects, such as ethnic diversity, household size, education, and access to markets, influence how local communities interact with and manage seagrass ecosystems (Tebaiy et al. 2021). This emphasizes that conservation efforts must consider both ecological and human dimensions.

Fish species in seagrass meadows can be permanent residents or temporary visitors. Permanent residents, such as *Siganus canaliculatus* and *Lethrinus atkinsoni*, use seagrass as their primary habitat. In comparison, species such as *Caranx papuensis*, *Gerris* sp., and *Siganus guttatus* utilise seagrass for feeding or temporary shelter (Latuconsina et al. 2019). Previous studies have demonstrated that the structure and complexity of seagrass beds influence the composition of fish communities. In Trang, Thailand, depth and habitat complexity were positively correlated with fish diversity (Tongnunui et al. 2024). In Urasoko Bay, Japan, small coral colonies within seagrass meadows were shown to provide additional nursery functions for fish (Nanami 2022). In West Papua, Pattipeilohi et al. (2021) recorded 56 fish species associated with seagrass beds, with distinct community patterns observed between day and night. These findings demonstrate the ecological importance of seagrass ecosystems in supporting diverse fish assemblages.

Among the fish species associated with seagrass habitats, *S. canaliculatus* is especially important both ecologically and economically. Its abundance is often

positively linked to seagrass density and diversity (Latuconsina et al. 2022). Likewise, research in Ambon Bay found that the distribution of rabbitfish correlated with seagrass beds that had different structural characteristics, with smaller individuals frequently associated with larger leaf morphologies (Munira et al. 2020). These examples emphasize the role of seagrass ecosystems in supporting fish populations at various life stages.

Therefore, the present study aimed to identify seagrass species in the waters of the Aruri Islands, analyze their composition, percentage, and cover, and determine the distribution and composition of fish species associated with seagrass ecosystems. This research has the potential to significantly impact fisheries, as it examined the relationship between seagrass species and the presence of target fish, namely *Siganidae* and *Lethrinidae*, to understand better the ecological role of seagrass habitats in supporting fisheries in the Supiori District, Papua Province, Indonesia.

MATERIALS AND METHODS

Time and location of study

This study was conducted from November to December 2022. Observations and data collection on seagrass and fish were conducted at three locations: the waters of Rayori Village, Nyambarai Village, and Munsaki Island in the Aruri Islands, Supiori District, Papua Province, Indonesia (Figure 1), where the islands lie in the Cenderawasih Bay off the northern coast of Tanah Papua (Indonesian New Guinea). Geologically, as part of the main islands of the Biak and Supiori groups, the smaller islands in the Aruri have rugged coralline limestone terrain. This geological foundation contributes to their unique coastal and marine ecosystems.

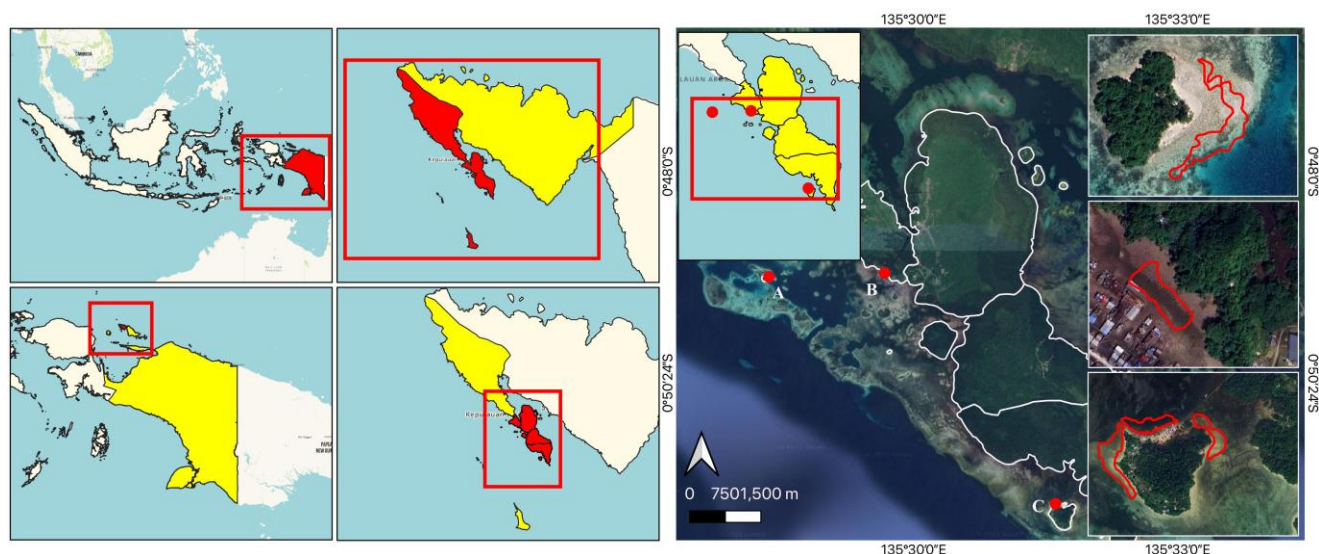


Figure 1. Red dots represent study locations in three coastal areas: the waters of Munsaki Island (A), Rayori Village (B), Nyambarai Village (C), and in the Aruri Islands, Papua Province, Indonesia

Study methods

This study employed a survey method suitable for both large and small populations to collect data from samples and to determine relative frequencies, distributions, and relationships among sociological and psychological variables (Kerlinger 1973). In quantitative studies, the survey method enables the collection and analysis of numerical data (Lawrence and Gladstone 2003). Particularly, data were collected on seagrass species and the composition of target fish species in seagrass habitats. Fish sampling was conducted within seagrass beds at three sampling points located in Rayori village, Munsaki Island, and Nyambarai Village, within the waters of the Aruri Islands. Each station was sampled with three replications.

Seagrass data collection procedure

Seagrass data collection was carried out using supporting tools, including 50 cm x 50 cm square plots placed in transects, measuring tapes, stationery, cameras, and seagrass identification books. We made 30 plots at each location, consisting of three transects, with 10 plots per transect. The square transect (perpendicular) was used for sampling, modified from the Seagrass Watch method. Before collecting data, initial field observations were conducted to determine the distribution of seagrass species and identify suitable locations for transect placement. Data collection employed the quadratic line transect method, with a 50 cm x 50 cm frame used for sampling. The distance between transects was adjusted based on local conditions at each site (I, II, III), and was not kept uniform. The line transect was positioned at the starting point closest to the coast, where seagrass typically occurs.

Each quadratic transect was conducted three times at each location, perpendicular to the coastline. Data were then collected on seagrass species, dominance, and percentage cover. Identification of species was conducted directly by referring to the Seagrass Watch Northern Fisheries Centre, Australia (McKenzie et al. 2003; Hutomo and Nontji 2014) and the Decree of the Minister of State and Environment No. 200 of 2004. As the taxonomy including seagrass is dynamic, the scientific names of seagrass were standardized using Plants of the World Online (<https://powo.science.kew.org/>). Moreover, the conservation status and population trend of species were checked in the IUCN Red List of Threatened Species (<https://www.iucnredlist.org/>).

Fish data collection procedures

Data on fish associated with seagrass ecosystems were collected using circle gillnets. Gillnets are operated by encircling a school of fish. After target fish are trapped, the marine environment is shocked, causing various species to scatter and become caught in fishing gear (Idzhar et al. 2019). This fishing gear is one of the environmentally friendly, selective types that do not cause pollution or environmental damage. Meanwhile, in terms of selectivity, gillnets only catch fish of a particular species, depending on the mesh size, to minimize the catch of unsuitable species (Idzhar et al. 2019). The gill nets used had a mesh size of 2-3 inches, a length of 50-100 meters, a height of

150 cm, and a weight of 5-10 kg. They were equipped with floats for easy deployment and retrieval. Before deployment, the nets were arranged systematically to ensure proper separation of weights, floats, and netting for efficient spreading during fishing operations (Idzhar et al. 2019).

Data analysis

The composition of seagrass species was computed from the data on each species, followed by the calculation of the number and composition of individuals per species. We standardized the sampling area to 1 hectare per sample for sea greases. The results were then processed descriptively, qualitatively, and quantitatively, and the findings were presented in tables and images. Calculations of the percentage of seagrass cover (%) and the average seagrass cover at each location were also conducted. Then, fish composition was taken into account, and species and length were recorded for each fish. Subsequently, the number and composition of each species were calculated, and the results were presented both descriptively and quantitatively as images. Moreover, we analyzed the relationship between seagrass species and target fish using Canonical Correspondence Analysis (CCA). This analysis was conducted to investigate the specific relationship between a particular seagrass species and a target fish species, and CCA was computed using the R package 'vegan' (Oksanen et al. 2019).

RESULTS AND DISCUSSION

Taxonomic description of seagrass

Based on observation, seagrass is found to grow on every sloping seabed in the three sampling locations. The species of seagrass that grow on the bottom of the village waters have adapted to the existing conditions, both in terms of substrate and water quality. From these adaptations, the seagrass species dominate the sloping waters and each survey location. Vegetation data were collected at three locations: Rayori Village, Nyanbarai Village, and Munsaki Island. The distance between Rayori Village and Nyanbarai Village is ± 5.9 km, Rayori Village and Munsaki Island is ± 1.3 km, and Nyanbarai Village and Munsaki Island is approximately ± 6.5 km. Specifically, Rayori Village lies between Nyanbarai Village and Munsaki Island, with Nyanbarai to the east and Munsaki to the west. The distribution of seagrass species in each coastal area (Rayori and Nyanbarai Villages) is observed on both sides (east and west) as well as the front of Rayori village (south). The most dominant species found in the three observation locations are shown in Table 1.

The seagrass species observed are classified as mixed vegetation (2-6 species), with substrate growth at each location and slightly different characters. Furthermore, sandy substrate was found in Nyambarai and Rayori Village, mixed with mud, due to the presence of mangrove ecosystems and houses. Munsaki Island was situated far offshore and isolated from mangrove ecosystems, making it uninhabited. From Figure 2, field surveys across three

coastal sites (Nyambarai Village, Munsaki Island, and Rayori Village) identified a total of 6 seagrass species belonging to two families. The identified taxa included *Cymodocea rotundata*, *Oceana serrulata*, *Halodule pinifolia* of the family Cymodoceaceae, and *Halophila ovalis*, *Enhalus acoroides*, and *Thalassia hemprichii* of the family Hydrocharitaceae. Species richness varied spatially, with Nyambarai Village exhibiting the highest diversity by hosting all six species. *Cymodocea rotundata*, *O. serrulata*, and *T. hemprichii* were the most broadly distributed, occurring at all three locations, whereas *H. pinifolia* and *E. acoroides* were exclusively observed at Nyambarai Village. Regarding conservation status, five of the six species are categorized by the IUCN as 'Least Concern'. No conservation assessment data were available for *O. serrulata*. Despite the common 'Least Concern' designation, divergent population trends were noted. *Halodule pinifolia* and *E. acoroides* are reported as 'Decreasing', contrasting with the 'Stable' population trends documented for *C. rotundata*, *H. ovalis*, and *T. hemprichii*. This finding indicates that while the species are not presently threatened at a global scale, localized pressures may be impacting specific populations, particularly *H. pinifolia* and *E. acoroides* within the Nyambarai Village meadow. In Rayori Village, the *T. hemprichii* seagrass species dominates the muddy bottom substrate from the beginning of the quadrant to 16 meters. Subsequently, the species mixes with two seagrass species, *C. rotundata* and *O. serrulata*.

Oceana serrulata species was not observed frequently at the study site. At a distance of 20 meters, the *H. ovalis* is found growing on fine sand. By moving close to land near straight, the substrate becomes sandy mud, where the seagrass species *T. hemprichii* and *C. rotundata* are found. In Nyambarai Village, *E. acoroides* is the dominant species from land to sea at the meter limit determined for the last quadrant (50 meters). Between 20-30 meters from land to the sea (the middle part of the sampling area/line transect), a few *C. rotundata* are found, which are covered by a rich abundance of *E. acoroides*. With large numbers and sizes, this species inhabits and dominates the bottom of the water substrate near the sea, highlighting the ecosystem's richness. A total of six seagrass species grow on the bottom

substrate of the waters in Munsaki Island. From landward to seaward, five species were found, including *T. hemprichii* (only on landward), *O. serrulata*, *H. ovalis*, and *C. rotundata*. *Enhalus acoroides* were found at a distance of 35 meters, on a coarse-sand substrate. Based on data collected in Nyambarai Village, the distribution of seagrass species is more extensive, spreading openly across the sloping waters, with a cover of 85.50%. This result indicates that seagrass vegetation is in the very dense category, with *E. acoroides* as the dominant species.

Furthermore, the percentage cover in Munsaki Village (54.7%) is slightly higher than that in Nyambarai Village (lower) for *T. hemprichii*. This is good for supporting the lives of various biota, serving as a place to shelter, a source of food, and for other activities. Based on average cover, the results indicate that *C. rotundata* is the most dominant, accounting for 31.04%. The species with the smallest dominance value is *T. hemprichii*, with an average cover of 1.67%.

Figures 2 and 3 show the numbers and compositions of each seagrass species found at three locations. Based on the results of calculating the total number of seagrass species, *C. rotundata* is the most common in all places, with a total number of 2,181 ind/ha, and a composition value of 48%. *Thalassia hemprichii* follows this with composition value of 25%. Meanwhile, the species of seagrass found in the least at the observation location is *H. pinifolia*. The high and low compositions are significantly influenced by vegetation and the condition of the water substrate. Kaiway (2021) stated that the distribution of seagrass from the coast to the sea was classified as mixed vegetation because more than one species was found. Nainggolan (2011) also stated that mixed vegetation consisted of more than two seagrass species growing in shallow subtidal locations.

Seagrass with mixed vegetation typically has few species. This is because variations in location, habitat conditions, and environmental factors significantly influence the composition of seagrass species. Specifically, there is a noticeable spread due to differences in substrate, environmental conditions, and physiological needs, which are influenced by abiotic factors such as turbidity, depth, substrate, and nutrient content (Latuconsina et al. 2022).

Table 1. Species of seagrass found at sampling locations, with family, conservation status, and population trend

| Location | Species | Family | Conservation status | Population trend |
|-------------------|---|------------------|---------------------|------------------|
| Nyambarai Village | <i>Cymodocea rotundata</i> Asch. & Schweinf. | Cymodoceaceae | Least Concern | Stable |
| | <i>Oceana serrulata</i> (R.Br.) Byng & Christenh. | Cymodoceaceae | - | - |
| | <i>Halodule pinifolia</i> (Miki) Hartog | Cymodoceaceae | Least Concern | Decreasing |
| | <i>Halophila ovalis</i> (R.Br.) Hook.f. | Hydrocharitaceae | Least Concern | Stable |
| | <i>Enhalus acoroides</i> (L.f.) Royle | Hydrocharitaceae | Least Concern | Decreasing |
| | <i>Thalassia hemprichii</i> (Ehrenb.) Asch. | Hydrocharitaceae | Least Concern | Stable |
| Munsaki Island | <i>Cymodocea rotundata</i> Asch. & Schweinf. | Cymodoceaceae | Least Concern | Stable |
| | <i>Oceana serrulata</i> (R.Br.) Byng & Christenh. | Cymodoceaceae | - | - |
| | <i>Thalassia hemprichii</i> (Ehrenb.) Asch. | Hydrocharitaceae | Least Concern | Stable |
| Rayori Village | <i>Thalassia hemprichii</i> (Ehrenb.) Asch. | Hydrocharitaceae | Least Concern | Stable |
| | <i>Cymodocea rotundata</i> Asch. & Schweinf. | Cymodoceaceae | Least Concern | Stable |
| | <i>Oceana serrulata</i> (R.Br.) Byng & Christenh. | Cymodoceaceae | - | - |
| | <i>Halophila ovalis</i> (R.Br.) Hook.f. | Hydrocharitaceae | Least Concern | Stable |

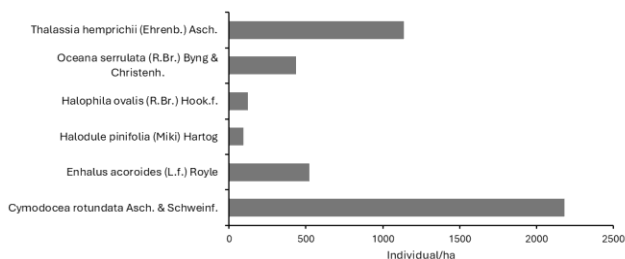


Figure 2. Number of seagrass species at the observation location

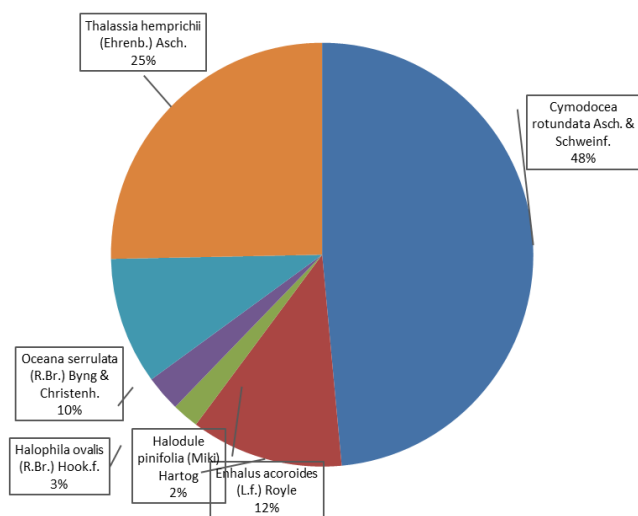


Figure 3. Composition (%) of seagrass species at study locations

Composition of fish species in seagrass ecosystems at observation locations

Seagrass ecosystems play a crucial role in supporting the lives of various organisms, including fish (Kartika et al. 2023). The presence of fish species often has a significant positive impact on aquatic environments, particularly seagrass. According to Assa et al. (2015), seagrass beds play various roles in the lives of fish, serving as nursery grounds, feeding areas, and places of refuge.

Based on the observation, several species of fish that are often associated with seagrass ecosystems include Mullidae sp., *S. canaliculatus*, *Siganus argenteus*, *Lutjanus* sp., *Parapeneus multifasciatus*, *Scarus* sp., *Neonipon* sp., *Meripristis* sp., *Upeneus*, and *Sphyraena barracuda*. According to Assa et al. (2015), seagrass species can serve as a direct food source for fish. In addition, several experts emphasize the importance of ecosystems for fish, including their habitats. More than 20% of the world's 25 largest fisheries depend on seagrass meadows as spawning and larval rearing habitats, emphasizing the importance of these ecosystems in supporting global fisheries production (Phinrub et al. 2015), juvenile fish rearing (Jones 2014; McDevitt-Irwin et al. 2016; Jianguo et al. 2018), juvenile fish food sources (Nakamura et al. 2012; Kwak et al. 2015), direct food sources for herbivores (Scott et al.

2018), and connecting the spatial distribution of fish between habitats (ontogenetic habitats) in coastal waters (Whitfield 2017; Lee et al. 2019; Ruel et al. 2024). Habitat connectivity of Siganidae and Lutjanidae fishes in mangrove, seagrass, and coral reef ecosystems in the coastal waters of Misamis Occidental, Philippines, has yielded significant findings. It was discovered that several species of these fish were present in all ecosystems, with the highest abundance in coral reefs. Species such as *Siganus spinus* and *S. guttatus* exhibit ontogenetic shifts, in which young individuals prefer mangrove and seagrass habitats before migrating to coral reefs as adults. Stomach content analysis revealed that Siganidae were herbivorous, while Lutjanidae were carnivorous. These findings highlight the crucial role of connectivity between habitats in ensuring the survival of these species. The composition of fish species found in the waters surrounding the Aruri Islands' ecosystems is illustrated in Figure 4, providing a visual representation of this study.

Figures 4 and 5 show that the ichthyofaunal community structure, quantified through sampling, exhibited a clear pattern of species dominance driven primarily by a single taxon. A total of 183 individuals were collected, representing 12 distinct fish species. The family Siganidae, collectively comprising four species, accounted for the overwhelming majority of the individuals sampled. Specifically, *S. canaliculatus* emerged as the dominant species, accounting for 71% (130 individuals) of the total assemblage. This substantial proportion indicates that *S. canaliculatus* is the prevailing ecological driver in the sampled habitat, likely due to a combination of effective local recruitment, high resource utilization efficiency, or resistance to regional pressures. Conversely, a significant portion of the remaining species demonstrated extremely low representation. Seven species (*Upeneus* sp., *S. barracuda*, *S. spinus*, *S. argenteus*, *Neonipon* sp., *Meripristis* sp., *Mulloidichthys* sp.) were observed at a composition of 2% or less, with five of these contributing only 1% each.

Beyond the dominant *Siganus*, the assemblage was characterized by several commercially and ecologically essential genera, though at much lower abundances. *Lutjanus* sp. (snapper) and *Lethrinus* sp. (emperor fish) were the most notable secondary constituents, accounting for 11% (21 individuals) and 4% (8 individuals) of the total catch, respectively. The remaining individuals were distributed sparsely across genera, including *Mulloidichthys* sp. (2%), *Hipposcarus* sp. (2%), and *Siganus doliatus* (5%). The observed distribution, highly skewed towards *S. canaliculatus* and a few other species, indicates a low evenness and suggests a community that is structurally simplified or highly influenced by selective environmental conditions. Future research should focus on the trophic dynamics and habitat preferences that confer such a significant ecological advantage to *S. canaliculatus* within this system. Meanwhile, *C. papuensis*, *Gerres* sp. and *S. guttatus* only use seagrass beds as a source of food or temporary shelter (Latuconsina et al. 2019). The same results were found by Rappe (2010), who experimented on Barrang Lompo Island, where the most common species

was *S. canaliculatus*. These results also aligned with a study conducted in the waters of Tanjung Tiram-Teluk Ambon Dalam, where the fish species with the highest abundance in seagrass beds was *S. canaliculatus* (Latuconsina et al. 2015). The high abundance of *S. canaliculatus* is due to the habit of living in groups in seagrass beds (Irawan et al. 2024). *Siganus canaliculatus* is a species of rabbitfish that is associated with seagrass ecosystems, but it is necessary to pay attention to the aspect of sustainable use (Rauf et al. 2024).

The number of fish species in seagrass communities depends on the ecosystem's role. According to Latuconsina et al. (2020), *S. canaliculatus* is a demersal fish associated with seagrass beds, where it serves as a habitat for nurturing, growth, foraging, and protection. Several factors, including the density of the seagrass ecosystem, the ebb and flow of water, and the availability of food, influence the high composition of this species. Latuconsina et al. (2015) and Suardi et al. (2019) confirmed that, in addition to the relatively wide distribution, *S. canaliculatus* was found dominantly in mangrove and coral reef habitats adjacent to seagrass beds. The tidal rhythm of coastal waters interconnects both of these habitats.

Factors contributing to the low abundance of fish include competition with dominant species, limited resource availability, or poor adaptation to seagrass habitats (Tebaiy et al. 2021). The high diversity of fish species indicates that seagrass areas provide suitable habitats. However, the presence of dominant species shows an imbalance in ecosystems caused by environmental factors or specific conditions (Andrimida and Hardiyani 2022). Additionally, ecological interactions are decreasing the proportion of particular species. This highlights the pressing need to address environmental pressures, particularly the impact of human activities, on fish habitats.

Composition and size distribution of target fish (Siganidae and Lethrinidae)

Rabbit fish (*Siganus*) is one of the critical economic biotas, which is included in the Siganidae family and lives on the bottom of the waters (demersal). This species is often found in seagrass beds and coral reefs (Syafudin 2008). Seagrass ecosystems are utilized by rabbitfish as feeding, spawning, and nursery sites (Kordi 2011). Based on the results, the target fish species residing in seagrass ecosystems at the three locations include 139 *Siganus* spp. and 9 *Lethrinus* spp. According to Latuconsina et al. (2019), fish in seagrass ecosystems can be permanent or temporary. Fish that are permanent residents of the seagrass ecosystem, such as rabbitfish (*Siganus* sp.) and *Lethrinus* sp., rely on this habitat as their primary habitat. Indrawati et al. (2020) stated that one commercially essential species from the Siganidae family was *S. canaliculatus*.

At the study locations, the minimum total length of *Siganus* sp. was 116.15 mm, with a body weight of 129 grams, while the maximum total length was 211.95 mm, corresponding to a body weight of 156 grams. The minimum and maximum total lengths of *Lethrinus* sp. fish were 194.12 mm and 280.65 mm, with corresponding body

weights of 91 grams and 177 grams, respectively. According to Jemi et al. (2022), size variations in fish are influenced by gonad maturity level, gender, and spawning season (Phạm et al. 2022). Other influencing factors include food availability, habitats, and environmental conditions, which contribute to variation in fish size (Asriyana 2015). The condition of seagrass ecosystems, which is not significantly different between locations, is assumed to affect the absence of size variation in the rabbitfish found. All observation locations feature a seagrass ecosystem structure characterized by mixed vegetation. Seagrass ecosystems with mixed vegetation structure are habitats for juvenile and growing rabbitfish (Latuconsina et al. 2020). Based on the length and weight, rabbit fish can be grouped into juveniles ranging from 32.50-62.50 mm, pre-adults 77.60-122.50 mm, and adults >137.50 mm (Kwak et al. 2015). According to Latuconsina et al. (2022), the length and weight criteria for *S. canaliculatus* are as follows: juveniles at 2.50-6.50 cm; pre-adults at 6.60-12.50 cm; and adults at ≥ 12.60 cm.

Morphologically, *S. canaliculatus* can be described as the mean lengths and standard deviations of *S. canaliculatus* across stations: Station Munsaki Island: 191.063 mm (± 3.411), Station Rayori Village: 171.715 mm (± 7.755), and Station Nyambarai Village: 192.796 mm (± 3.701). The comparison reveals that Stations Munsaki Island and Nyambarai Village exhibit relatively similar mean lengths (approximately 191-193 mm). In contrast, Station Rayori village shows a significantly smaller mean length of approximately 171.7 mm, indicating the presence of generally smaller individuals in this location. In terms of variability, Rayori Village recorded the highest standard deviation (± 7.755 mm), suggesting greater size heterogeneity. In contrast, Munsaki Island and Nyambarai Village displayed much lower variability (± 3.411 mm and ± 3.701 mm, respectively), indicating more uniform fish sizes. These findings suggest that Station Rayori village supports a population of *S. canaliculatus* that is smaller and more size-diverse, whereas Munsaki Island and Nyambarai Village host populations with larger, more uniform individuals. Such differences may reflect local ecological conditions, food availability, environmental pressures, or connectivity among sampling stations (Coghlan et al. 2024; Musyeri et al. 2025).

Relationship between seagrass species and target fish (Siganidae and Lethrinidae)

Seagrass ecosystems play a crucial role as nurseries and feeding grounds for various marine species, and they are the largest carbon absorbers (Koch et al. 2012). One of the aquatic biotas associated with seagrass ecosystems is rabbitfish (Kawaroe et al. 2016). In this study, we performed CCA to examine relationships among locations, target fish, and seagrass species, and the CCA explained Axis 1 (63.1%) and Axis 2 (9.8%) (Figure 6). The results showed that *T. hemprichii* and *C. rotundata* had a positive relationship with target fish. This suggested that the relationship between the two seagrass species affected Siganidae and Lethrinidae in Rayori Village, where both *Siganus* sp. and *Lethrinus* sp. were found, along with four

seagrass species. However, in locations of Nyambarai Village and Munsaki Island, only *Siganus* sp. was recorded during the study.

The Canonical Correspondence Analysis (CCA) biplot (Figure 6) illustrates the interrelationships among seagrass species, fish communities (represented by *Siganus* sp. and *Lethrinus* sp.), and three sampling locations: Nyambarai Village (N_V), Munsaki Island (M_I), and Rayori Village (R_V). The first two canonical axes explain a substantial portion of the constrained variance, with Axis 1 accounting for 63.1% and Axis 2 for 9.8%, indicating strong environmental gradients influencing species distribution. Vectors representing species and environmental variables are positioned relative to the origin, with their directions and lengths indicating the strength and nature of their correlations with the ordination axes. The biplot reveals distinct associations. Rayori Village (R_V) and Nyambarai Village (N_V) are strongly associated with the presence of *Lethrinus* sp., and *Siganus* sp., respectively, suggesting that these locations exhibit environmental conditions favorable to these specific fish genera. Furthermore, certain seagrass species cluster with particular locations or fish groups. For instance, *C. rotundata* (Cy_rot) shows a strong positive correlation with Axis 1, suggesting its prevalence in environments characterized by conditions represented by the positive direction of this axis, and potentially distinct from areas where *E. acoroides* (En_acoro) and *H. pinifolia* (Ha_pini) are abundant. The spatial arrangement of seagrass species points to varying habitat preferences or sensitivities to environmental drivers. *Oceana serrulata* (Oc_ser) and *H. ovalis* (Ha_ova) are closely associated with Rayori Village, and somewhat with *Lethrinus* sp., indicating that the environmental conditions at this site may support both these seagrass species and the associated fish. Conversely, *E. acoroides* (En_acoro), *H. pinifolia* (Ha_pini), and *T. hemprichii* (Th_hemp) tend to cluster towards the negative end of Axis 2 and Axis 1, suggesting a preference for environmental conditions distinct from those favoring *C. rotundata* and the fish species at Rayori Village. These patterns underscore the complex interplay between habitat, flora, and associated fauna in these coastal ecosystems.

This suggests that the presence of *T. hemprichii* plays a crucial role in the settlement of target fish, which are primarily found in two families (Latuconsina et al. 2019). Moreover, *T. hemprichii*, commonly known as the turtle grass, is a cornerstone species and a dominant ecosystem engineer in tropical and subtropical Indo-Pacific seagrass meadows. Its primary role is as a highly productive foundation species, contributing a substantial portion of primary production within its ecosystem, which supports detrital food webs and higher-order consumers (Waycott et al. 2009). Morphologically, *T. hemprichii* possesses an extensive and robust below-ground network of thick rhizomes and fleshy roots. This subterranean structure is critical for sediment stabilization and coastal defense; it effectively reduces water velocity, traps suspended

particles (enhancing water clarity), and anchors the seabed against wave- and current-driven erosion.

Furthermore, its dense canopy offers vital three-dimensional habitat complexity, providing shelter, foraging areas, and crucial nursery grounds for a diverse array of fish, invertebrates, and epiphytic organisms (Li et al. 2024). This real relationship assumes that all target fish species and their associates have a particular affinity for certain seagrass species as nurseries, feeding grounds, or refuges. Therefore, *Siganus* spp. and *Lethrinus* spp. only have an interest in *T. hemprichii*, compared to others. This is because *T. hemprichii* is often found in all locations, impacting the number of target fish in the waters of the Aruri Islands, Supiori District (Figure 7).

In larval and juvenile stages, seagrass beds dominated by *T. hemprichii* provide essential habitats for fish of the Lethrinidae family. These habitats protect fish from predators and provide abundant food sources, supporting their survival and growth before they migrate to coral reef habitats as adults (Nakamura and Sano 2004). The results suggest that seagrass beds serve as important habitats for the early life stages of various fish species.

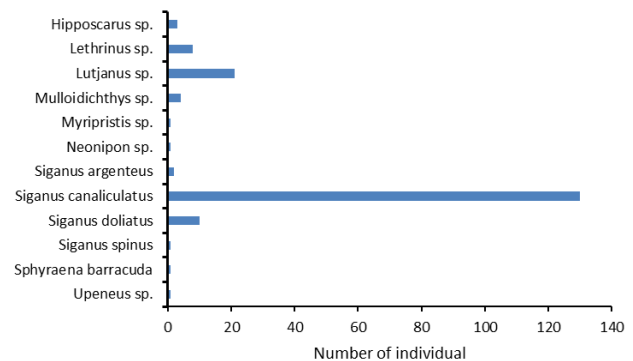


Figure 4. Number of fish species in seagrass ecosystems at the observation location

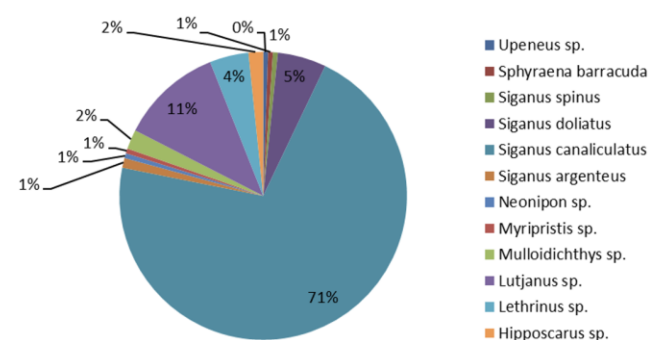


Figure 5. Percentage composition of fish species in seagrass ecosystems at the observation location

The accompanying image (Figure 7) presents a visual documentation of eight distinct fish species, providing a comparative visual representation of these species, categorized into two families: Siganidae and Lethrinidae, thereby illustrating aspects of fish taxonomy. The upper panel displays six species from the family Siganidae, commonly known as rabbitfishes. These include *S. argenteus*, *Siganus vermiculatus*, *S. doliatus*, *S. canaliculatus*, *Siganus lineatus*, and *Siganus puellus*. Morphological distinctions, such as variations in body shape, fin coloration, and intricate patterning, are evident among these species, highlighting the interspecific diversity within the *Siganus* genus. The lower panel features two species belonging to the family Lethrinidae, or emperor fishes: *Gymnocranius euanus* and *Gymnocranius grandoculis*. These two *Gymnocranius* species exhibit characteristic differences in their epidermal pigmentation and general physiognomy, which are critical features for their taxonomic differentiation. This compilation of images serves as a valuable visual aid for the identification and comparative morphological study of these ecologically significant reef fish families. These species collectively illustrate the intra-familial variation in body coloration, fin morphology, and overall body shape, ranging from the more elongated profile of *S. argenteus* to the deeper-bodied forms characteristic of *S. canaliculatus*. Notably, *S. puellus* exhibits a distinct speckled pattern and a yellowish caudal

fin, distinguishing it from the more uniformly silvery or mottled patterns seen in other *Siganus* species. This diversity in external features often correlates with ecological niches, dietary preferences, and the camouflage strategies these herbivorous or omnivorous fish employ in their marine habitats. The Lethrinidae family is represented by two species: *Gymnocranius euanus* and *G. grandoculis*. These two species within the *Gymnocranius* genus demonstrate subtle yet discernible interspecific differences, particularly in head profile and body markings. *Gymnocranius euanus* displays a more pronounced blue-grey mottling across its body, with distinct blotches.

In contrast, *G. grandoculis* appears to have a more uniform silvery-grey body with less prominent patterning, and a proportionally larger eye, as implied by its specific epithet. The representation of both families underscores the importance of visual taxonomic keys for species identification, particularly in regions where these fish contribute clearly to marine biodiversity and fisheries. Comparative morphological analysis, as initiated by these visual examples, is fundamental for understanding evolutionary relationships and ecological roles within complex aquatic ecosystems. The relationship between the Lethrinidae family and seagrass, including *T. hemprichii* species, has been established in a previous study conducted by Manangkalangi et al. (2022).

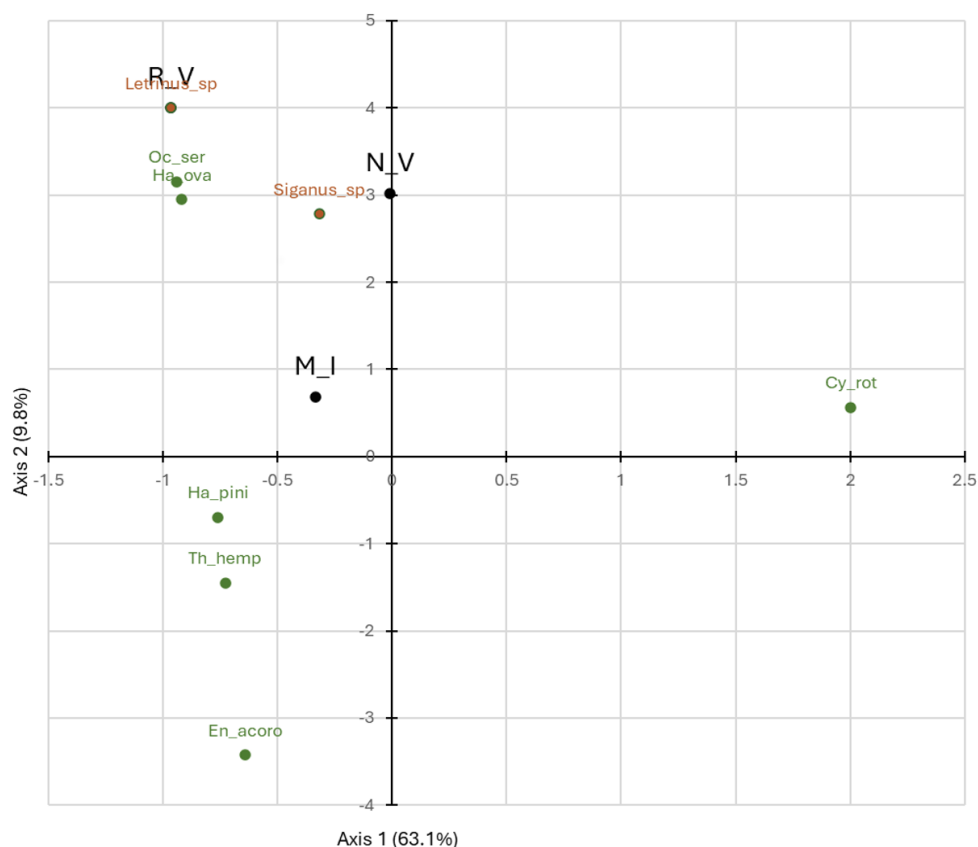


Figure 6. The relationship locations, seagrass species, and fish using CCA in Aruri Islands, Papua Province, Indonesia, where the symbols of R_V: Rayori Village, N_V: Nyambarai Village, M_I: Munsaki Island, Cy_rot: *Cymodocea rotundata*, Oc_ser: *Oceana serrulata*, En_acoro: *Enhalus acoroides*, Ha_ova: *Halophila ovalis*, Ha_pini: *Halodule pinifolia*, Th_hemp: *Thalassia hemprichii*

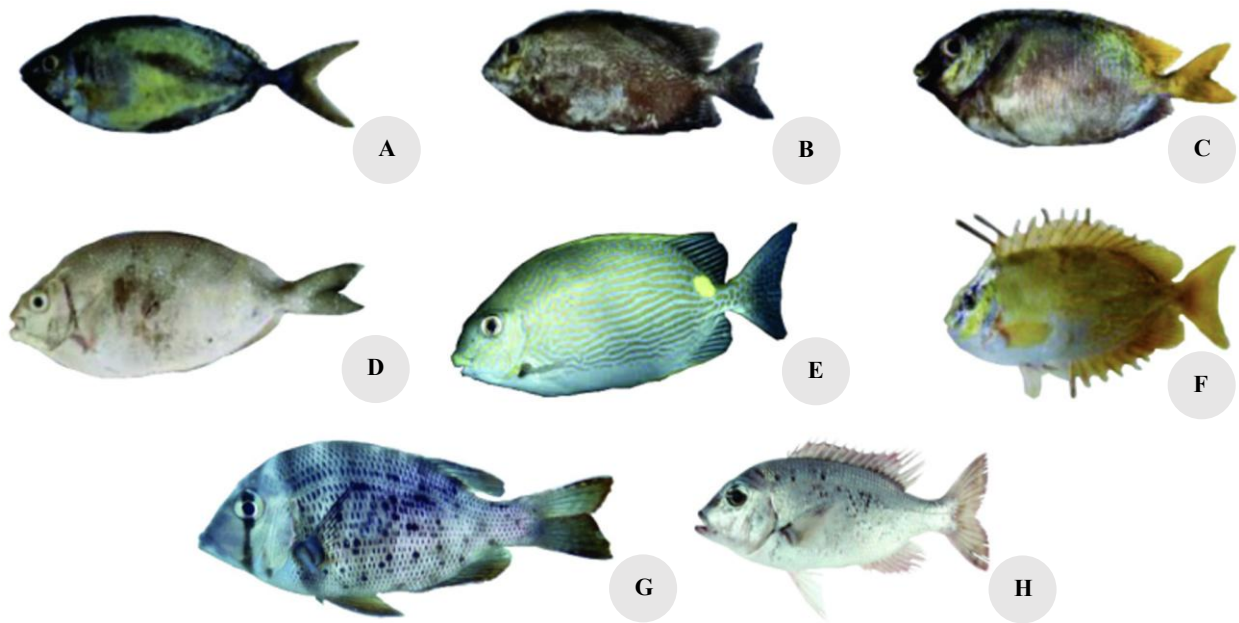


Figure 7. Target fish species representing species from the Families of Siganidae and Lethrinidae found at the study location. Siganidae (A: *Siganus argenteus*, B: *Siganus vermiculatus*, C: *Siganus doliatus*, D: *Siganus canaliculatus*, E: *Siganus lineatus*, F: *Siganus puellus*), Lethrinidae (G: *Gymnocranius euanus*, H: *Gymnocranius grandoculis*). Photo credit: Emmanuel Manangkalangi and Marthin Matulesy

The fish species found in the seagrass beds of Nusmapi Island, Manokwari, consisted of 65.9% juveniles, including *Lethrinus harak*. These showed that ecosystems served as nurseries and feeding grounds for various fish. To sum up, this study revealed six seagrass species in the waters of the Aruri Islands: *H. ovalis*, *C. rotundata*, *O. serrulata*, *E. acoroides*, *H. pinifolia*, and *T. hemprichii*, belonging to two families (Hydrocharitaceae and Cymodoceaceae). The Figure 2 and 3 detailing the composition of the seagrass ecosystem reveals a highly skewed dominance structure across the six identified species: *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule pinifolia*, *Halophila ovalis*, *Oceana serrulata*, and *Thalassia hemprichii*. The community is overwhelmingly characterized by the prevalence of a single species, *Cymodocea rotundata*, which accounts for the largest proportion of the total relative cover at 48%. This near monopoly suggests that *C. rotundata* is the foundational species, dictating the habitat structure and potentially the associated faunal community within this particular meadow. In contrast, the least abundant species is *Halodule pinifolia*, representing only 2% of the total cover. This species, which is typically noted for its pioneering characteristics and tolerance to disturbance, is a minor component of the overall biomass. The disparity between the highest and lowest relative covers is substantial, demonstrating a 24-fold difference (48% vs. 2%). The remaining species occupy intermediate proportions: *Thalassia hemprichii* (25%) and *Enhalus acoroidea* (12%) are significant secondary contributors, while *Oceana serrulata* (10%) and *Halophila ovalis* (3%) are minor constituents. The overall structure indicates a mature, mixed-species meadow strongly influenced by the

dominant presence of *C. rotundata*. The highest seagrass cover was observed at Nyambarai (85.50%), with *E. acoroides* as the dominant species. Meanwhile, Munsaki Island had a cover percentage of 54.67%, predominantly *T. hemprichii*, forming a fairly dense cover. *Siganus canaliculatus* was the most prevalent fish species at the study site, accounting for 71% of the fish community, compared to *Lutjanus* sp., *S. doliatus*, and *Lethrinus* sp., which represented 11%, 5%, and 4%, respectively. Target fish were present at nearly all locations, totaling 139 *Siganus* sp. and 9 *Lethrinus* sp.. The maximum body length recorded was 211.95 mm, with a body weight of 28 grams for *Siganus* sp., while *Lethrinus* sp. reached a body length of 280.65 mm and a body weight of 107 grams. CCA results indicated that the seagrass *T. hemprichii* has a very close relationship with target fish species Siganidae and Lethrinidae, compared to other seagrass species. This suggests that *T. hemprichii* plays a crucial role in establishing and maintaining target fish within seagrass ecosystems. Therefore, the strong association suggests that all target and related fish species exhibit specific preferences for seagrass species.

Furthermore, this study highlighted the critical role of seagrass ecosystems, such as those in the Aruri Islands, where seagrass meadows are ecologically indispensable marine assets warranting immediate and comprehensive conservation. These highly productive ecosystems serve as critical nursery and foraging grounds, significantly enhancing coastal fishery productivity and supporting finfish populations vital for regional food security. Globally, beyond their faunal support, seagrasses contribute substantially to climate mitigation as a key

component of "blue carbon", sequestering and storing organic carbon in their sediments at rates exceeding those of many terrestrial forests. Given this dual role in sustaining marine trophic structures and mitigating atmospheric CO₂ concentration, their formal inclusion and prioritization within national and international conservation programs are essential for achieving both biodiversity and climate resilience objectives.

This study was limited by its short temporal coverage (2 months) and the absence of seasonal replication, which may limit the generalizability of fish-seagrass relationships. Moreover, this research collected data only at the end of 2022, thereby representing only the situation at that time. As a result, this study revealed that the association between fish and seagrasses was dynamic. For future studies, data collection is necessary to represent the period of the year, or at least the variation in variables could be considered to describe where the minimum and maximum values of variables affect the relationship between fish and seagrasses. Future research should span seasons and incorporate physicochemical parameters (e.g., turbidity, nutrient levels) to model habitat suitability and temporal variability. Integrating socioeconomic dimensions, such as fishing effort and local management practices, would further enrich ecosystem-based policy applications.

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