Seagrass-fish association in East Bolaang Mongondow, North Sulawesi: Assessing seagrass cover status and evidence to support its conservation

[1]Fione Y. Yalindua, [1]Marenda P. Rizqi, [1]Ayuningtyas Indrawati, [1]Putri S. Ibrahim, [1]Rikardo Huwae, [2]Aser Yalindua

[1] Research Center for Oceanography-BRIN, Ancol Timur, Jakarta Utara, DKI Jakarta, Indonesia; [2] Department of Biology, Faculty of Mathematics and Natural Science, Manado State University, Manado, Indonesia. Corresponding author: F. Y. Yalindua, yukitayalindua@gmail.com

Abstract. Seagrass meadows play a significant role in coastal ecosystems by providing ecosystem services such as supporting biodiversity, ensuring food availability, and serving as shelter for marine life. They also contribute to the reduction of carbon in the ocean. This study assessed the current status of seagrass meadows and their association with fish in East Bolaang Mongondow, North Sulawesi, at six sites. We employed the linear transect method to collect seagrass data and the swept area method to assess fish assemblage. A total of eight seagrass species were identified, with *Enhalus acroides* and *Thalassia hemprichii* found in all sites, exhibiting the highest coverage compared to other seagrass species. The seagrass cover ranged from 12.59 to 38.26%, indicating a poor and unhealthy status overall. We collected fifty-three fish species belonging to 22 families using beach seine. *Siganus canalicullatus* and *Atherinomorus endractensis* were the most abundant fish species observed. Our findings regarding habitat status and trophic groups highlight the crucial role of fish species in seagrass meadows as feeding grounds for visitor fish species, including economically valuable ones. Additionally, these meadows offer protection and serve as permanent habitats for specific fish species, thereby contributing to the fisheries potential in East Bolaang Mongondow Regency. Overall, the low seagrass cover in East Bolaang Mongondow highlights the necessity for monitoring and conservation of seagrass in this area, notwithstanding the importance of this area as a nursery ground.
Key Words: ecological index, fish assemblages, Indonesia, seagrass meadows.

Introduction. Seagrass beds play several essential roles in fish life, including as nursery grounds, feeding grounds, and protective areas. According to Horinouchi (2007), in several experiments, the efficiency of predation or the ability of predators to hunt is reduced in seagrass habitats, particularly in those with high seagrass density; the efficiency of predation or the ability of predators to track is reduced. As a result, fish seeking shelter in seagrass habitats have a higher chance of survival. One of the physical functions of seagrass beds is as a natural wave absorber in coastal areas creating a calm and shady marine environment that is highly favored by various types of marine organisms, mainly fish (Riniatsih 2016). This habitat also has secondary productivity and significantly supports abundance and diversity (Larkum et al 2006). It offers various ecosystem services and food availability for marine life (Du et al 2020) and also plays a significant role in carbon sequestration by storing and retaining carbon for extended periods, capturing approximately 70% of the total organic carbon in the ocean (Macreadie et al 2014). Furthermore, seagrass ecosystems have been shown to increase fish biomass and economic value per ha when close to mangrove and tidal swamp areas (Jänes et al 2020).

Seagrass beds in East Bolaang Mongondow Regency are ecosystems with high biodiversity in shallow sea areas that can support the existing resources, including fisheries. Local fishermen use the coastal waters as fishing grounds. Some fish associated with seagrass ecosystems have high economic value, particularly those from the families Siganidae, Carangidae, and Lutjanidae. East Bolaang Mongondow is composed of several small islands, including Racun Island/Pinonaguan, Kumeke Island, Bombuyanoi Island/Nenas, Ibantong Island, Laga Besar Island, Laga Kecil Island and Flesko Island. These islands play a vital role in the establishment of a comprehensive coastal ecosystem encompassing mangroves, seagrass, and coral reefs. This integrated ecosystem supports a wide array of economically valuable marine organisms that serve as a food source and help tourism due to their unique appeal.

Ecological evidence highlights the high dependency of 20% of economically important fish on seagrass habitats during specific stages of their life cycle (Ambo-Rappe et al 2013). Furthermore, there is evidence that seagrass fish also play an essential role in the sustainability of seagrass ecosystems. Large-scale fishing and environmental stressors in seagrass areas can disrupt food web components, resulting in the loss of large predators and an increase in medium-sized predators (intermediate predators). This leads to a decline in the abundance of small organisms that eat epiphytes attached to the seagrass, ultimately reducing the seagrass habitat (Reynolds 2018; Moritz et al 2018). The state of seagrass beds and seagrass fish in East Bolaang Mongondow remains largely unknown, although this ecosystem plays a vital role in supporting coastal water communities that rely heavily on fishing. Additionally, the tremendous underwater tourism potential in this area is strongly influenced by the ability of seagrass coastal habitats to support it as a nursery area for coral fish juveniles (Moussa et al 2020).

In this study, we assess the health index of the seagrass ecosystem, richness, composition and structure community of seagrass fishes and the habitat residency and trophic group of fishes in the ecosystem of seagrass. Additionally, this study can also provide data to support the management of the coastal environment in East Bolaang Mongondow Regency, North Sulawesi, Indonesia.

Material and Method

Description of the study sites. Data were collected at each site for nine days (14-22 September 2020) in the vegetated seagrass area of East Bolaang Mongondow waters, North Sulawesi Province (Figure 1). The determination of the research locations is based on preliminary observations of seagrass conditions. By establishing the location point, the ecological conditions may be represented (Table 1). The observation sites include seagrass beds located between the mangroves and corals areas.

Data Collection. Using an underwater camera, the visual census method was used to determine the ecological conditions of seagrass, corals, and others. Seagrass fish data were collected with an exploratory descriptive method with a survey as a basis for policymakers and further research. The exploratory descriptive approach aims to illustrate the present state or condition of ecology, utilizing various methods. In this study, we used beach seine methods.

The beach seine was operated using the swept area method during the day when the water had a depth of 1 m. The samplings were repeated until no new species were obtained. The time required for netting ranged from 1-3 hours at each site depending on the species found. The fish caught were counted individually, placed in plastic containers and labeled. The tools used are underwater cameras, GPS, roller meters, iron stakes, buoys and identification books (Kuiter & Tonozuka 2001; Kimura & Matsuura 2003; Peristiwady 2006; Allen & Erdmann 2012; White et al 2013).

The quadratics transect method was used to measure seagrass beds condition by placing a 0.5x0.5 m PVC pipe frame divided into four squares of 0.25x0.25 m each. Determination of the sampling point was done by placing a 100 m rope perpendicularly to the shoreline. Transects were placed at each point, 10 m apart, so that ten sampling points were obtained at each location, and repeated three times at each location. Seagrass observations were conducted when the seawater receded between 20-150 cm. The family and species of each type of seagrass found on the transect were recorded, together with the inventory. The existing seagrass bed density in each observation square was calculated.

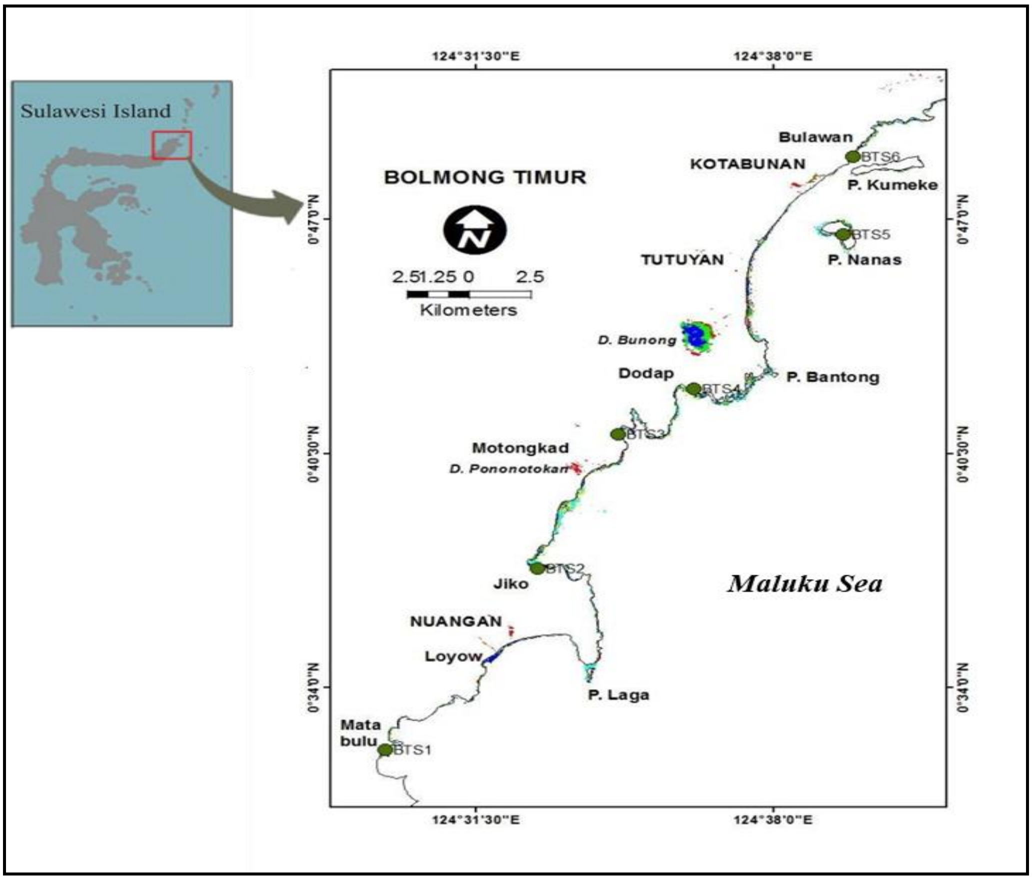

Figure 1. Map of Seagrass Research Sites in East Bolaang Mongondow Regency, North Sulawesi, Indonesia.

Table 1

Location site of seagrass and fish data collection

No	*Site*	*Location*	*N*	*E*	*Substrate*
1	BMTS1	Matabulu, Kec. Nuangan	0.53795	124.492	Mud, sand, rubble
3	BMTS2	Jiko, Kec Motongkad	0.6217	124.5475	Sand, rubble
2	BMTS3	Jiko Tehi, Kec. Tutuyan	0.68391	12457698	Mud, sand, rubble
4	BMTS4	Tg Dodap, Kec. Tutuyan	0.70497	124.6045	Mud, sand
5	BMTS5	P. Nenas, Kec. Kotabunan	0.70497	124.6045	Mud, sand, rubble
6	BMTS6	Bulawan, Kec. Kotabunan	0.81238	124.6619	Sand, rubble

Seagrass data analysis. Seagrass samples were identified according to Philips & Menez (1988). Seagrass beds condition were analyzed by calculating the percentage of seagrass cover at each research location and the dominance of each type of seagrass in each plot/sampling point. The data obtained was analyzed using the MS Excel program to determine the condition of seagrass on the transect, using the formula:

Seagrass cover = [Seagrass cover value (4 squares)/4] x 100

The average seagrass cover in each square frame (0-10) was used to determine the percentage of seagrass cover on the transect. The dominance of each type of seagrass was analyzed using the following formula:

Seagrass cover per species = (Number of each species cover/10) x 100

The cover per seagrass species results serve as a reference to rank the percentage cover of each species, to determine which seagrass species have the highest percentage of cover and the most dominant species on the transect. The results were then analyzed and categorized based on the Decree of the Minister of the Environment. No. 200 of 2004 (KLHK 2004) about standard criteria for damage and guidelines for determining the status of seagrass beds, which are as follows: a - seagrass coverage ≥60%, good/healthy condition; b - seagrass coverage between 30-60%, damaged/unhealthy condition; c - seagrass coverage under 30%, poor condition.

Seagrass fish data analysis. The Simpson Dominance Index (C) was used to determine the dominance of fish species within the ecological community. The Shannon-Wiener Diversity Index (H') was utilized to measure the abundance of the community, considering the number of species and the number of individuals of each species at a particular location. The Evenness Index (E) was used to determine the similarity of individual distribution among different species by comparing the diversity index to its maximum value (Krebs 1989). The sampled fish were categorized into two groups based on their swimming ability and habitat residency: visitors and permanent residents (Simanjuntak et al 2020; Espadero et al 2020). Additionally, the fish were classified according to their feeding behavior using published dietary data, including benthivores, herbivores, detritivores, piscivores, and omnivores (Nakamura et al 2003; Horinouchi et al 2012). The Dominance index (C), Diversity Index (H') and Evennes Index (E) were performed using IBM SPSS Statistics 25 employing aggregate functions for data analysis.

Results and Discussion

Seagrass coverage. The results of monitoring the seagrass condition at all sites revealed a total of eight species of seagrass: *Enhalus acoroides, Thalassia hemprichii, Cymodocea serrulata, C. rotundata, Syringodium isoetifolium, Halophila ovalis, Halodule pinifolia,* and *H. uninervis*. The highest number of species was observed at site 1 (Matabulu), site 5 (P. Nenas), and site 6 (Bulawan), each with six species. In contrast, site 4 (Tg Dodap) exhibited the lowest species richness, with only two species (Table 2). Overall, seagrass coverage ranged from 12.59 to 38.26% (Table 2), categorized as poor (<29%) at four sites (Jiko, Jiko Tehi, Dodap and Bulawan) and unhealthy (30-59.9%) at two sites (Matabulu and Nenas Island) (KLHK 2004).

The dominant seagrass species, *E. acroides* and *T. hemprichii,* were found across all sites, exhibiting the highest coverage among the seagrass species. East Bolaang Mongondow Regency has a greater diversity of seagrass species, totaling eight species identified compared to Ratatotok, Southeast Minahasa, Lembeh Bitung Island, and Talise, where there were seven species reported (Takaendengan and Azkab 2010; Rustam et al 2015; Kusumaningtyas et al 2016). A lower number of species (six) was also reported in Bahoi Villages (Fahruddin et al 2017). However, Boltim Regency was classified as having the poorest seagrass cover and health condition compared to other regions in North Sulawesi according to the result of this study.

Table 2

The number of seagrass species and the percentage of seagrass cover

Site	*Number of species*	*% of cover*	*Ea*	*Th*	*Cr*	*Cs*	*Si*	*Ho*	*Hu*	*Hp*	*Status*
BMTS1	6	35.42	16.86	10.61	3.41	2.65	0.00	0.00	1.13	0.75	Unhealthy
BMTS2	4	13.64	8.33	1.52	0.00	2.84	0.95	0.00	0.00	0.00	Poor
BMTS3	4	24.81	12.97	8.71	0.00	0.85	2.27	0.00	0.00	0.00	Poor
BMTS4	2	12.59	12.22	0.38	0.00	0.00	0.00	0.00	0.00	0.00	Poor
BMTS5	6	38.26	17.61	9.75	6.53	2.37	0.00	0.38	0.00	1.61	Unhealthy
BMTS6	6	17.90	5.87	3.88	4.73	0.00	1.52	0.19	1.70	0.00	Poor

Note: *Ea - Enhalus acoroides*; *Th - Thalassia hemprichii*; *Cr - Cymodocea rotundata*; *Cs - Cymodosea serrulata*; *Si - Syringodium isoetifolium*; *Ho - Halophila ovalis*; *Hu - Halodule uninervis*; *Hp - Halodule pinifolia*.

Species composition and relative abundance of seagrass fish. Based on the data collection results for seagrass fish using the swept area method, 742 individual seagrass-dwelling fish were found, representing 53 species from 22 families and ten orders. The most abundant fish species were *Siganus canalicullatus* or commonly known as baronang (42%), *Atherinomorus endractensis* or stonehead fish (22%) and *Halichoeres papilionaceus* or seagrass koja fish (8%). The remaining seagrass fish species accounted for less than 5% of the total abundance. Some seagrass fish species were represented by a single individual, with a relative abundance value below 1% (Figure 2).

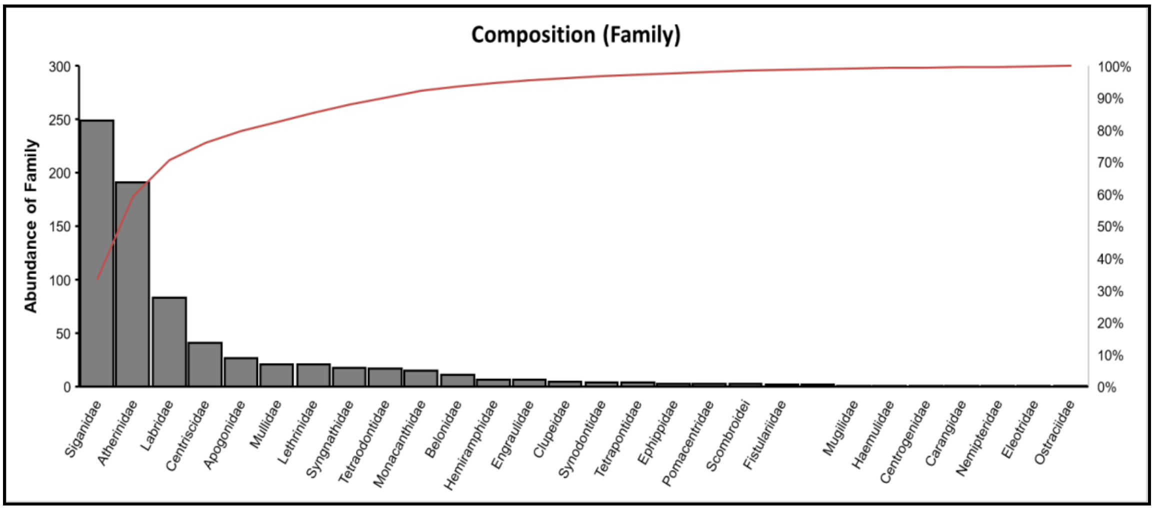

Figure 2. The abundance and composition of seagrass fish in East Bolaang Mongondow, North Sulawesi, Indonesia.

Based on site comparison, site 2 (Jiko Village) exhibited the highest abundance with a total of 491 individuals, while site 4 (Dodap) had the lowest relative abundance, with only 36 individuals (Figure 3).

The high abundance at site 2 (Jiko Village) can be attributed to the dominance of *S. canalliculatus* and *A. endractensis* in their juvenile phase. Multispecific seagrass species influence the dominance in this location, where several seagrass species of varying sizes coexist. According to Ambo-Rappe et al (2013), seagrass ecosystems with multispecific habitats tend to support higher fish abundance, and as the fish mature, they gradually migrate to areas with denser seagrass cover that exhibit a monospecific nature (dominated by a single species). Regarding the composition of fish species, site 2 displayed the highest species richness, with a total of 23 species. In contrast, the lowest number of species was observed at site 6 (Bulawan Village) and site 5 (Nenas Island), with only ten and eleven species, respectively (Figure 4).

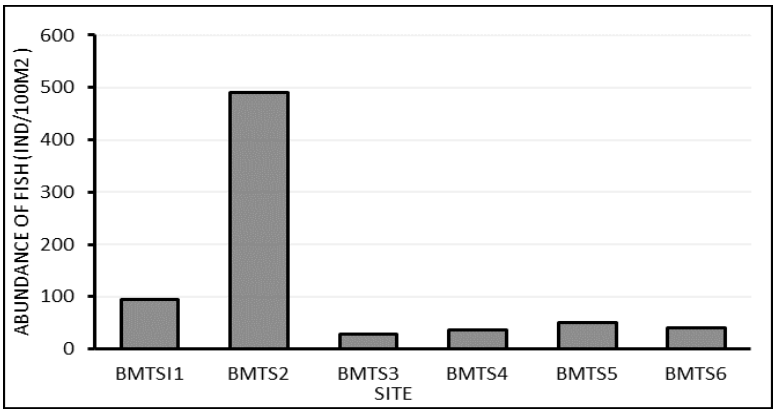

Figure 3. The abundance of seagrass fish in each site per area (100 m^2).

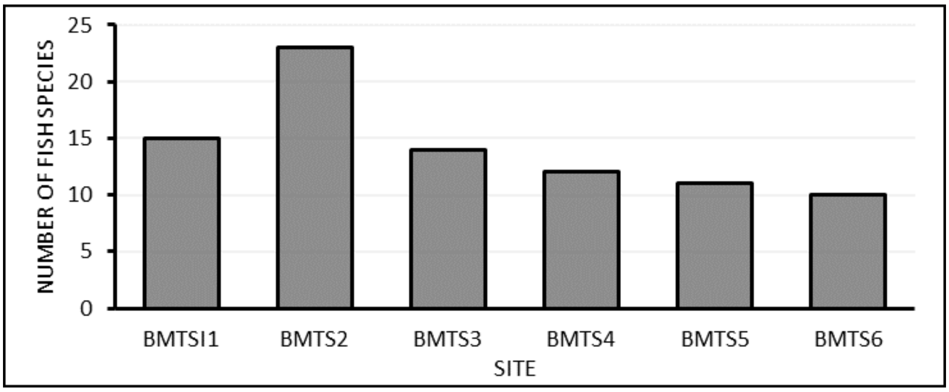

Figure 4. The number of seagrass fish species in each site.

The seagrass ecosystem plays a vital role in supporting fisheries potential in the area, as it is interconnected with coral reef ecosystems and provides crucial habitat and refuge for juvenile fish, thereby ensuring their high survival rate in natural settings. Through the collection of data from multiple sites, several economically important fish species in their juvenile stage have been identified, including Baronang (Siganidae), ikan biji nangka (Mullidae), lencam (Lethrinidae), sako (*Strongylura*), and various other families (Figure 2).

When compared to studies conducted in the same region of North Sulawesi, the richness of seagrass-associated fish species in East Bolaang Mongondow was found to be higher than in Talise Island, North Sulawesi (34 species) (Manik 2012) and Bolaang Mongondow (50 species) (Ibrahim et al 2021). However, it was lower when compared to other studies conducted in Tandurusa (61 species) (Huwae et al 2022) and Kema, North Minahasa (87 species) (Du et al 2018). These variations can be attributed to differences in the physical conditions of the seagrass meadows, such as coverage, as well as variations in sampling methods and timing (Yalindua et al 2020). According to Henderson et al (2017), the richness and abundance of seagrass-associated fish are greatly influenced by the significant variability of coastal environments, including variations in habitat characteristics such as seagrass length, density, and proximity to mangroves. Moreover, their study indicated that patchy seagrass meadows exhibit lower diversity indices compared to meadows with more continuous coverage. This finding is consistent with the condition of seagrass meadows in East Bolaang Mongondow, where the seagrass coverage is relatively poor, but supports a considerable diversity of seagrass species (8 species), thus providing adequate support for seagrass-associated fish in the area.

The relationship between seagrass cover and the abundance of seagrass fish species. According to Tebaiy et al (2014), substrate characteristics significantly influence seagrass distribution and rooting patterns. Rahmawati et al (2012) revealed that non-vegetated communities predominantly occur in sandy substrates, while the absence of seagrass communities is attributed to high turbidity and strong water currents. The abundance and diversity of fish species within seagrass areas are closely linked to the composition of seagrass species (Larkum et al 2006).

There is no significant correlation between the abundance and species composition of seagrass-associated fish and the type and coverage of seagrass at each site. This is evident at Site 2 in the village of Jiko, where the highest number of individuals and species were observed (Figures 3 and 4). Despite the high abundance of seagrass-associated fish in the rare category (13.64%) within the seagrass ecosystem (Table 2), Horinouchi (2007) suggests that schooling species and temporary resident fish species typically dominate high fish abundance in degraded seagrass habitats. In this study, it appears that the species abundance is primarily influenced by large schoolings of fish such as *A. endractensis*, *S. canaliculatus*, and *Centriscus scutatus*, as well as economically valuable juvenile fish genera (*Siganus, Lethrinus, Upeneus, Therapon*). Moreover, the proximity of seagrass habitats to human settlements and the presence of beach seine fishing gear indicates that local communities also exploit seagrass areas, attracting seagrass-associated fish with bait composed of food remnants. Under these circumstances, continuous seagrass reduction may result in the gradual disappearance of the existing fish species, leading to the loss of nursery areas and a decline in recruitment sources for mid-water fish species and economically valuable fish. However, some sites , such as Site 4, exhibit the lowest number of individuals and fish species (Figures 3 and 4) and the lowest seagrass coverage percentage (12.59%), with only two seagrass species present (Table 2). Conversely, Site 3, with the highest abundance of individuals and fish species, features a low seagrass coverage percentage and consists of only three seagrass species. This may be attributed to various factors, including structural complexity, density, species composition, physical parameters (waves and currents), and interactions among fish species at different growth stages. Further investigation is warranted to elucidate the relationship between seagrass habitats with distinct characteristics, the corresponding fish species, and their abundances (Ambo-Rappe et al 2013).

Habitat residency and trophic group. Based on the habitat residency status, seagrass fish in this study are categorized into two groups: visitors and residents. Visitors in this study include fish species that utilize seagrass as a temporary habitat during specific life stages, such as larvae or juveniles seeking refuge in seagrass until they mature and migrate to larger habitats. They also include species that use seagrass as a feeding ground, taking advantage of the tidal cycle for feeding intentions (Lee et al 2014). On the other hand, residents are small and cryptic fish species that reside in seagrass habitats throughout their life cycle (Gillanders 2006).

The majority of fish species found in the six sites of Bolaang Mongondow are dominated by visitor species, accounting for 63.6 to 78.6% of the total, while the remaining percentage consists of resident fish species, ranging from 21.4% to 36.4% (Figure 5). These findings align with the study conducted by Simanjuntak et al (2020) in Karang Congkak, who also reported a high proportion of visitor species within seagrass communities, including regular visitors, temporary residents, and occasional visitors. Similarly, Ariza et al (2012) found that approximately 59% of seagrass fish species belonged to the visitor category, while 22% were cyclical (temporary residents), and the remaining 19% were classified as permanent residents.

These patterns can be attributed to several factors. The sampling locations were primarily in the intertidal zone exposed during low tide. This condition favors the presence of visiting species with roving behavior, such as *Strongylura strongylura, Sphyraena barracuda* and *Halichoeres miniatus* (Nakamura & Tsuchiya 2008). In contrast, permanent resident species tend to seek shelter under the seagrass canopy during low tide (Unsworth et al 2007), and their cryptic nature poses challenges for effective collection due to sampling limitations.

The benthivores comprised the highest proportion of the trophic group in this study, ranging from 41.7 to 72.7% of the total fish species (Figure 5). The lowest proportion was observed at Site 4 (Tanjung Dodap), while the highest was found at Site 5 (Pulau Nenas). These results indicate that the majority of fish species in this study are benthic-invertebrate feeders, dominated by species such as *A. endractensis, Halichoeres papilionaceus, Halichoeres melanurus, Parupeneus barberinus, C. scutatus*, and others, which primarily feed on invertebrates. These findings align with previous research highlighting the dominance of benthic-invertebrate feeders within seagrass meadows (Unsworth et al 2007; Espadero et al 2021).

The presence of seagrass and its epiphytes as primary food sources for macroinvertebrates (Du et al 2016), as well as the abundance of organic detritus in seagrass meadows supporting benthic invertebrates (Chiu et al 2013) contribute to the high abundance of invertebrates within seagrass habitats (Leatemia et al 2017). This, in turn, provides a significant food resource, especially for juvenile fish, making seagrass meadows crucial nursery and refuge habitats.

The results of this study on habitat status and trophic groups reveal that the fish inhabiting the seagrass meadows in East Bolaang Mongondow utilize this habitat for various purposes. These seagrass meadows serve as crucial feeding grounds for visitor fish species, including economically important species, while also providing refuge for juvenile fish and serving as permanent habitats for specific fish species.

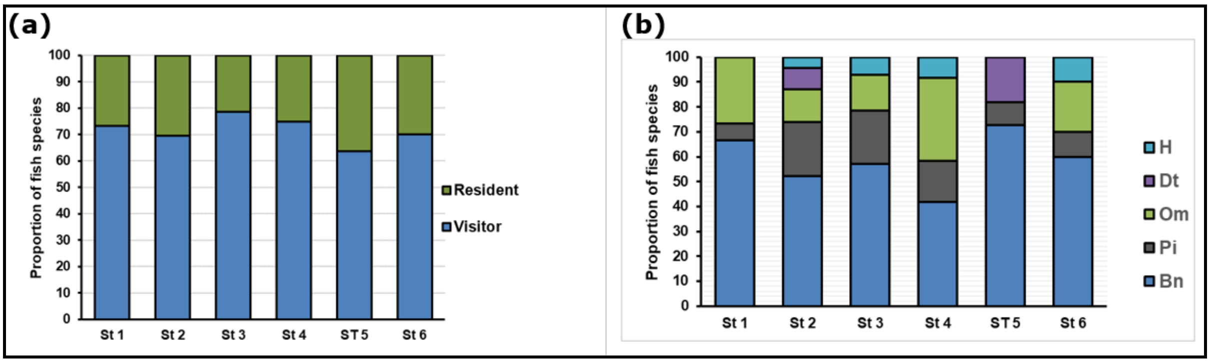

Figure 5. a - the proportion of residents and visitors seagrass fish in each site; b - seagrass fish trophic group proportion in each site; H - herbivores; Dt - detritivore; Om - omnivore; Pi - piscivores; Bn - benthivores.

The community structure of seagrass fishes. The diversity index, evenness index, and dominance index indicate the balance in the distribution of the number of individuals of each species and show species richness (Odum 1983). The results of the fish community structure found during the study include the dominance, diversity, and evenness of species, as presented in the Table 3.

Table 3

Diversity index, dominance index and evenness index in each site in East Bolaang Mongondow, North Sulawesi, Indonesia

Index	*St 1*	*St 2*	*St 3*	*St 4*	*St 5*	*St 6*	*Average*
H (Diversity)	2.128	1.535	2.395	2.223	1.832	1.385	1.91±0.40
D (Dominance)	0.168	0.340	0.115	0.128	0.226	0.407	0.23±0.11
E (Evenness)	0.786	0.489	0.907	0.895	0.764	0.601	0.74±0.16

Based on the diversity, evenness, and dominance indices, it can be inferred that the distribution of individuals among species is balanced and the species richness is high (Odum 1983). The diversity index values ranged between 1.385 to 2.395, with the highest value recorded at site 3 (Jiko Tehi), falling in the moderate category. This is due to the even distribution of fish species, with no dominant species (stable community structure). Therefore, the evenness index falls into the high category. The relatively isolated and unpressured seagrass conditions at Jiko Tehi, categorized as multispecific, may have contributed to this result. The lowest diversity index value was observed at site 6 (Bulawan village), with a value of 1.385, in the low category, supported by a moderate dominance index and a labile evenness index. Additionally, this site had the fewest number of fish species among all sites. Anthropogenic pressure plays a significant role in the seagrass ecosystem at Site 6. Destructive coral behavior, such as the presence of broken and dead coral, and direct discharge of household waste into the sea affects the fish diversity and homogenization of species observed during some surveys. Generalist species dominance and a lack of unique/rare species are also notable outcomes.

Apart from Site 6, the other sites with low diversity index values were Sites 2 (Jiko village) and 5 (Nenas Island). Site 3 had a low dominance index, while the evenness index was suppressed. Site 5 had a low dominance index, while the evenness index was stable. Sites 1 (Matabulu) and 4 (Dodap) fell into the moderate category for diversity index values, with a low dominance index and stable evenness index. Overall, the fish species diversity in the seagrass ecosystem of East Bolaang Mongondow Regency falls into the low category, with index values below 2. The dominance index is low, with values below 0.5, and the evenness index falls into the labile to the stable category, with index values below 0.75.

Conclusions. Based on the analysis of species composition, most fish found in seagrass ecosystems in East Bolaang Mongondow Regency are in the juvenile stage, confirming their role as nurseries and sanctuaries for fish. The findings on habitat status and trophic groups indicate that fish species in the seagrass meadows play a significant role as feeding grounds for visitor fish species, including economically important ones. Additionally, they provide shelter for juvenile fish and serve as permanent habitats for specific fish species, thus supporting the fisheries potential in East Bolaang Mongondow Regency. The health status of seagrass in East Bolaang Mongondow Regency reveals poor and unhealthy conditions. The seagrass fish community structure analysis shows a low species diversity index, low dominance index, and a labile to stable uniformity index. Therefore, conservation efforts need to be implemented, especially in seagrass areas with high anthropogenic pressures such as Pulau Nenas and Bulawan village, to maintain high fish biodiversity associated with seagrass and ensure species conservation.

Acknowledgements. The authors are grateful to Mochtar Djabar for assisting in data collection. This research is funded by Priority Research LIPI 2020 (The potential for developing and conserving the biodiversity of coastal ecosystems in the East Bolaang Mongondow region and its surroundings) no. B-2485/IPK/HK.01.03/2020.

Conflict of Interest. The authors declare that there is no conflict of interest.

References

Allen G. R., Erdmann M. V., 2012 Reef fishes of the East Indies. Volumes I–III. Conservation International Foundation, 1292 p.

Ambo-Rappe R., Nessa M. N., Latuconsina H., Lajus D. L., 2013 Relationship between the tropical seagrass bed characteristics and the structure of the associated fish community. Open Journal of Ecology 3(5):331-342.

Ariza A. L. A., Núñez P. J. G., Ruiz L., Mendez de E. E., 2012 [Fish biodiveristy of seagrass meadows of the northwest coast of the Gulf of Cariaco, Venezuela]. Revista de Biologia Tropical 60(2):635-648. [In Spanish].

Chiu S. H., Huang Y. H., Lin H. J., 2013 Carbon budget of leaves of the tropical intertidal seagrass *Thalassia hemprichii*. Estuarine, Coastal and Shelf Science 125:27-35.

Du J., Wang Y., Peristiwady T., Liao J., Makatipu P. C., Huwae R., Ju P., Loh K. H., Chen B., 2018 Temporal and spatial variation of fish community and their nursery in a tropical seagrass meadow. Acta Oceanologica Sinica 37(12):63-72.

Du J., Xie M., Wang Y., Chen Z., Liu W., Liao J., Chen B., 2020 Connectivity of fish assemblages along the mangrove-seagrass-coral reef continuum in Wenchang, China. Acta Oceanologica Sinica 39(8):43-52.

Du J., Zheng X., Peristiwady T., Liao J., Makatipu P. C., Yin X., Hu W., Koagouw W., Chen B., 2016 Food sources and trophic structure of fishes and benthic macroinvertebrates in a tropical seagrass meadow revealed by stable isotope analysis. Marine Biology Research 12(7):748-757.

Espadero A. D. A., Nakamura Y., Uy W. H., Horinouchi M., 2021 Tropical intertidal seagrass beds as fish habitat: Similarities between fish assemblages of intertidal and subtidal seagrass beds in the Philippines. Estuarine, Coastal and Shelf Science 251:107245.

Espadero A. D. A., Nakamura Y., Uy W. H., Tongnunui P., Horinouchi M., 2020 Tropical intertidal seagrass beds: An overlooked foraging habitat for fishes revealed by underwater videos. Journal of Experimental Marine Biology and Ecology 526:151353.

Fahruddin M., Yulianda F., Setyobudiandi I., 2017 [Density and the coverage of seagrass ecosystem in Bahoi village coastal waters, North Sulawesi]. Jurnal Ilmu dan Teknologi Kelautan Tropis 9(1):375-383. [In Indonesian].

Gillanders B. M., 2006 Seagrassess, fish, and fisheries. In: Seagrassess: Biology, ecology and conservation. Larkum A. W. D., Orth R. J., Duarte C. M. (eds), Springer, pp. 503-536.
Henderson C. J., Gilby B. L., Lee S. Y., Stevens T., 2017 Contrasting effects of habitat complexity and connectivity on biodiversity in seagrass meadows. Marine Biology 164(5):117.
Horinouchi M., 2007 Review of the effects of within-patch scale structural complexity on seagrass fishes. Journal of Experimental Marine Biology and Ecology 350(1):111-129.
Horinouchi M., Tongnunui P., Furumitsu K., Nakamura Y., Kanou K., Yamaguchi A., Okamoto K., Sano M., 2012 Food habits of small fishes in seagrass habitats in Trang, Southern Thailand. Fisheries Science 78(3):577-587.
Huwae R., Patty S. I., Akbar N., Paembonan R. E., 2022 [Composition of types and structure of the fish community in the seaweed ecosystem Tandarusa Beach, Bitung]. Jurnal Ilmu Kelautan Kepulauan 5(1):542-551. [In Indonesian].
Ibrahim P. S., Yalindua F. Y., Indrawati A., Huwae R., 2021 [Community structure of seagrass fishes in Bolaang Mongondow waters, North Sulawesi]. Bawal Widya Riset Perikanan Tangkap 13(2):71-76. [In Indonesian].
Jänes H., Macreadie P. I., Ermgassen P. S. E. Z., Gair J. R., Treby S., Reeves S., Nicholson E., Ierodiaconou D., Carnell P., 2020 Quantifying fisheries enhancement from coastal vegetated ecosystems. Ecosystem Services 43:101105.
Kimura S., Matsuura K., 2003 Fishes of Bitung: Northern tip of Sulawesi, Indonesia. Ocean Research Institute, University of Tokyo, Tokyo, 244 p.
Krebs C. J., 1989 Ecological methodology. NY Harper and Row Publishers, 654 p.
Kuiter R. H., Tonozuka T., 2001 Pictoral guide to Indonesian reef fishes Part 1. Eels-Snappers, Muraenidae-Lutjanidae. Zoonetics, Australia, 302 p.
Kusumaningtyas M. A., Rustam A., Kepel T. L., Ati R. N. A., Daulat A., Mangindaan P., Hutahaean A. A., 2016 [Ecology and structure of seagrass communities in Ratatotok Bay, Southeast Minahasa, North Sulawesi]. Jurnal Segara 12(1):1-10. [In Indonesian].
Larkum A. W. D., Orth R. J., Duarte C. M., 2006 Seagrasses: biology, ecology and conservation. Springer International Publishing, 691 p.
Leatemia S. P. O., Pakilaran E. L., Kopalit H., 2017 [Macrozoobenthos abudance in the vegetated (seagrass) and un-vegetated areas of Doreri Bay Manokwari]. Jurnal Sumberdaya Akuatik Indopasifik 1(1):15-26. [In Indonesian].
Lee C. L., Huang Y. H., Chung C. Y., Lin H. J., 2014 Tidal variation in fish assemblages and trophic structures in tropical Indo-Pacific seagrass beds. Zoological Studies 53:56.
Macreadie P. I., Baird M. E., Trevathan-Tackett S. M., Larkum A. W. D., Ralph P. J., 2014 Quantifying and modelling the carbon sequestration capacity of seagrass meadows - A critical assessment. Marine Pollution Bulletin 83(2):430-439.
Manik N., 2012 [Fish diversity in seagrass beds on the west coast of Talise Island, North Sulawesi]. Oseanologi dan Limnologi di Indonesia 3:307-314. [In Indonesian].
Moritz C., Vii J., Long W. L., Tamelander J., Thomassin A., Planes S., 2018 Status and trends of coral reefs of the Pacific. Global Coral Reef Monitoring Network, 220 p.
Moussa R. M., Bertucci F., Jorissen H., Gache C., Waqalevu V. P., Parravicini V., Lecchini D., Galzin R., 2020 Importance of intertidal seagrass beds as nursery area for coral reef fish juveniles (Mayotte, Indian Ocean). Regional Studies in Marine Science 33:100965.
Nakamura Y., Horinouchi M., Nakai T., Sano M., 2003 Food habits of fishes in a seagrass bed on a fringing coral reef at Iriomote Island, Southern Japan. Ichthyological Research 50(1):15-22.
Nakamura Y., Tsuchiya M., 2008 Spatial and temporal patterns of seagrass habitat use by fishes at the Ryukyu Islands, Japan. Estuarine, Coastal and Shelf Science 76(2):345-256.
Odum E. P., 1983 Basic ecology. CBS College Publishing, 325 p.
Peristiwady T., 2006 [Economically important marine fishes in Indonesia: Identification

Guide]. LIPI Press, Jakarta, 270 p. [In Indonesian].
Philips R. C., Menez E. G., 1988 Seagrass. Smithsonian Institution Pres, 104 p.
Rahmawati S., Fahmi, Yusup D. S., 2012 [Seagrass and coastal fish communities in Kendari waters, south-east Sulawesi]. Ilmu Kelautan 17(4):190-198. [In Indonesian].
Riniatsih I., 2016 [Community structure of fish larvae in seagrass ecosystems in Jepara waters]. Jurnal Kelautan Tropis 19(1):21-28. [In Indonesian].
Rustam A., Kepel T. L., Kusumaningtyas M. A., Ati R. N. A., Daulat A., Suryono D. D., Sudirman N., Rahyau Y. P., Mangindaan P., Heriati A., Hutahean A. A., 2015 [Seagrass ecosystem as environmental bioindicator in Lembeh Island, Bitung, North Sulawesi]. Jurnal Biologi Indonesia 11(2):233-241. [In Indonesian].
Simanjuntak C. P. H., Noviana, Putri A. K., Rahardjo M. F., Djumanto, Syafei L. S., Abdillah D., 2020 Species composition and abundance of small fishes in seagrass beds of the Karang Congkak Island, Kepulauan Seribu National Park, Indonesia. IOP Conference Series: Earth and Environmental Science 404:012063.
Takaendengan K., Azkab M. H., 2010 [Structure community seagrass bed of Talise Island, North Sulawesi]. Oseanologi dan Limnologi di Indonesia 36(1):85-95. [In Indonesian].
Tebaiy S., Yulianda F., Fahrudin A., Muchsin I., 2014 [Fish community structure at seagrass beds habitat in Youtefa Bay Jayapura Papua]. Jurnal Iktiologi Indonesia 14(1):49-65. [In Indonesian].
Unsworth R. K. F., Wylie E., Smith D. J., Bell J. J., 2007 Diel trophic structuring of seagrass bed fish assemblages in the Wakatobi Marine National Park, Indonesia. Estuarine, Coastal and Shelf Science 72(1-2):81-88.
White W. T., Last P. R., Dharmadi, Faizah R., Chodrijah U., Prisantoso B. I., Pogonoski J. J., Puckeridge M., Blaber S. J. M., 2013 Market fishes of Indonesia. ACIAR, 438 p.
Yalindua F. Y., Ibrahim P. S., Manik N., 2020 [Fish diversity in seagrass communities on the coast Kema, North Sulawesi]. Jurnal Enggano 5(3):377-391. [In Indonesian].
*** KLHK, 2004 [The standard criteria for damage and manual for determination of the status of sea grass]. [In Indonesian].
*** Reynolds P. L., 2018 Seagrass and seagrass beds. Smithsonian Ocean Portal. Available at: https://ocean.si.edu/ocean-life/plants-algae/seagrass-and-seagrass-beds

Received: 07 June 2023. Accepted: 19 August 2023. Published online: 12 December 2023.
Authors:
Fione Yukita Yalindua, Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: yukitayalindua@gmail.com
Marenda Pandu Rizqi, Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: mare001@brin.go.id
Ayuningtyas Indrawati, Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: ayun004@brin.go.id
Putri Sapira Ibrahim, Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: putr013@brin.go.id
Rikaro Huwae, Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: rika006@brin.go.id
Aser Yalindua, Department of Biology, Faculty of Mathematics and Natural Science, Manado State University, Jl. Kampus Unima 1, Tondano Selatan, 95619 Sulawesi Utara, Indonesia, e-mail: aseryalindua60@gmail.com

How to cite this article:
Yalindua F. Y., Rizqi M. P., Indrawati A., Ibrahim P. S., Huwae R., Yalindua A., 2023 Seagrass-fish association in East Bolaang Mongondow, North Sulawesi: Assessing seagrass cover status and evidence to support its conservation. AACL Bioflux 16(6):3173-3183.