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Evaluation of seagrass beds as a foraging and nursery habitat based on the structure of the fish community in Nusmapi Island, West Papua, Indonesia

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Abstract. *Manangkalangi E, Sembel L, Tebaiy S, Manuputty A, Rumayomi MR, Musyeri P, Sawaki D, Orissu D, Manumpil AW, Kaber Y. 2022. Evaluation of seagrass beds as a foraging and nursery habitat based on the structure of the fish community in Nusmapi Island, West Papua, Indonesia. Biodiversitas 23: 5539-5550.* Seagrass beds are one of the ecosystems inhabited by various coastal aquatic fauna, including fish. However, information on the temporal role of this ecosystem for fish fauna, particularly diurnal and nocturnal, is still limited. Therefore, this study was conducted to describe daily variations in the fish species composition, their ecological index, developmental stages, and trophic groups in a seagrass bed on Nusmapi Isl., Manokwari. The species composition differed between day and night sampling periods based on the results obtained from 40 species of fish belonging to 21 families and 7 orders. Furthermore, fish species consisted of three trophic groups (omnivores, carnivores, and herbivores), with omnivores and carnivores dominating during the day and at night by 48.6% and 87.5%, respectively. Species found in seagrass beds majorly consisted of juvenile stage individuals (65.9%). Individual abundance varied from day to night and was mainly found among group-forming species, such as *S. spinus, S. trilineata, S. punctatissimum,* and *M. pralinia*. The index of diversity, evenness, and dominance at the two relatively similar sampling times described the overall stability of fish communities in seagrass beds. The results indicate that seagrass beds serve as foraging and nursery grounds for many fish species in coastal waters. In addition, the management and protection of fish biodiversity and coastal fishery resources are affected by the ecosystem function.

Keywords: Coastal ecosystem, diurnal, nocturnal, nursery habitat, trophic

INTRODUCTION

The fish fauna is a component of the ecosystem in coastal waters. Fish migration from one ecosystem to another for reproduction and food can alter species composition and trophic interactions over time (Davis et al. 2014; Nagelkerken et al. 2015). Therefore, it is essential to understand how a species utilizes various ecosystems when migrating for food or completing its life cycle (ontogenetic habitat shift), as well as to assess ecosystem function comprehensively (Abrantes et al. 2015; Nagelkerken et al. 2015; Espinoza et al. 2016; Lee et al. 2019).

In tropical coastal waters, various types of ecosystems are found, such as seagrass beds, mangroves, and coral reefs. The complexity and connectivity of various ecosystems in coastal waters will increase biodiversity and productivity (Olds et al. 2012; Watanabe et al. 2018). Seagrass beds are one of the most important ecosystems in coastal areas due to their high productivity and biodiversity, including benthic fauna and fish (Leopardas et al. 2014; Lin et al. 2018; Lee et al. 2021; Syukur et al. 2021). Benthic fauna is abundant in these areas and serves as an important food source for many fish species (Unsworth et al. 2007; Kwak et al. 2015). Seagrass beds are commonly referred to as nursery areas for fish fauna due to their complex vegetation structure and thus serve as a refuge for juvenile and small fish, as well as a foraging area for herbivores and carnivores (Nakamura et al. 2012; Fitrian et al. 2017; Lee et al. 2019; Zarco-Perello and Enríquez 2019; Simanjuntak et al. 2020).

The ecological function of seagrass beds, particularly as shelters from predators and foraging sites, is generally assessed through data from fish community structures and trophic interactions obtained during the day (Ambo-Rappe et al. 2013; Simanjuntak et al. 2020). However, during the foraging cycle, many organisms associated with seagrass are known to have varied patterns. Different patterns of diel activity may imply different resource use or different levels of vulnerability to predation (Kronfeld-Schor and Dayan 2003). As a food source, the diversity and abundance of macroinvertebrate groups in seagrass beds vary between day and night periods (García-Sanz et al. 2016). Previous research state that variations in the structure of fish communities and the level of fish predation in seagrass beds during the day and night (Kinoshita et al. 2012; Shoji et al. 2017). This is related to effectiveness in foraging. Diurnal animals usually use sight for predation, while nocturnal animals use the senses of touch, smell, and hearing (Kronfeld-Schor and Dayan 2003). For example, fish species belonging to the carnivorous group tend to be active at night (Harvey et al. 2012; Masuda et al. 2012). Many fish and invertebrates may be more susceptible to capture at night, either because of more significant activity (such as foraging) or because they enter a dormant state (Mattila et al. 1999). In some instances, increasing migration coral reef habitat to seagrass beds has been carried out at night (Mattila et al. 1999; Unsworth et al. 2007). Therefore, data collected during these two times becomes necessary to evaluate the ecological function of the habitat.

Information on the ecological function of seagrass beds as a place for foraging and protection of fish fauna in Indonesian waters is still relatively scarce (Unsworth et al. 2007; Latuconsina and Ambo-Rappe 2013). This research aims to describe the daily variations in fish community structure (species composition, abundance, and ecological index), developmental stages, and trophic groups in seagrass beds on Nusmapi Isl., Manokwari. It also aims to provide an overview of the function of seagrass beds as nurseries and foraging grounds for fish communities. Therefore, the information obtained can have implications for the ecosystem management of seagrass and other coastal water.

MATERIALS AND METHODS

Time and location

Fish sampling was carried out in June and July of 2020. This research was conducted in seagrass beds of Nusmapi Isl., Doreri Bay, Manokwari, West Papua, Indonesia. Furthermore, sample analysis was carried out at the Aquatic Resources Laboratory (SDA) of the Faculty of Fisheries and Marine Sciences, University of Papua, Manokwari, West Papua, Indonesia. The location of the fish sampling is shown in Figure 1.

Collection and handling of fish samples

To obtain a representative sample, three locations (left, center, and right) and at different times (day and night), representing seagrass beds and fish activity, respectively, were involved. A net measuring 50 m in length, 1.5 m in height, and mesh sizes of 0.5 and 1.5 inches was laid out in a semicircle on the seaward section in the seagrass bed to collect fish samples. Subsequently, it was left momentarily to allow the fish to return to their natural habitat after being disturbed while the net was being set up. The net was only used at a distance of 10 m perpendicular to the beach because the seagrass beds rarely reach the sea, which was about 18 m away. Furthermore, the two ends of the net were connected by continuously pulling towards the center until all parts of the net reached thes shore, as shown in Figure 2. The total area swept by the net was 557.3 m^2 and the catchment area was 1672.0 m^2 because it was designed from three locations (left, middle, and right) on the seagrass bed.

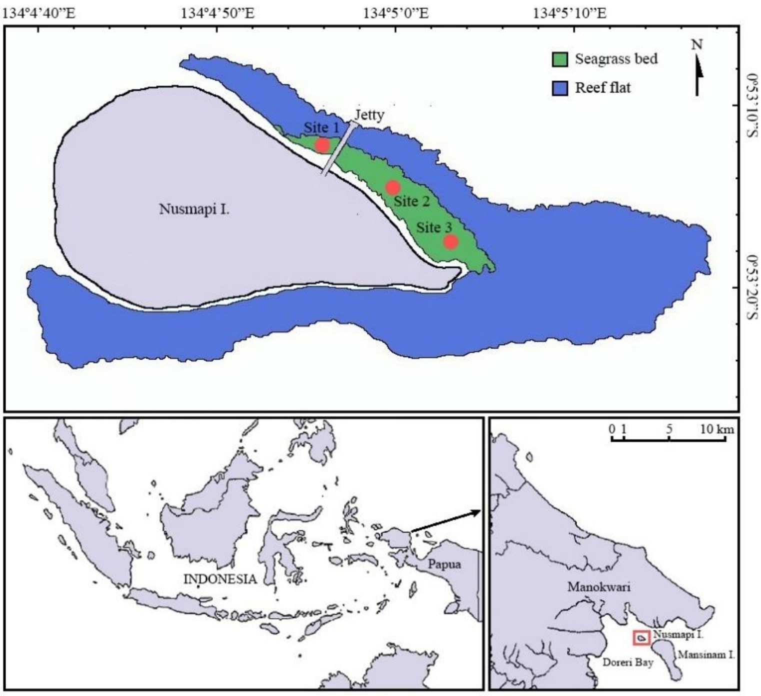

Figure 1. Map of research sites on Nusmapi Isl., Doreri Bay, Manokwari, West Papua Province, Indonesia

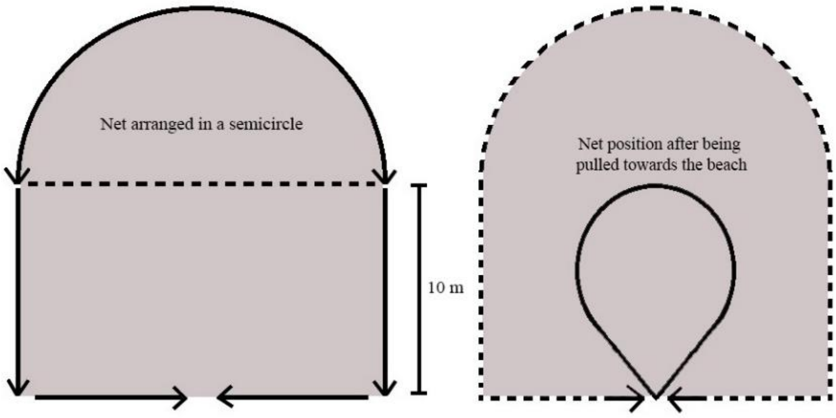

Figure 2. Setting up nets for fish sample collection

The collected fish samples were placed in a coolbox containing a chunk of ice for preservation of the sample before being brought to the Laboratory of Aquatic Resources (LAR). Each fish sample was then identified and trophically determined in the laboratory. Furthermore, species identification and trophic determination were carried out based on Allen and Erdmann (2012) and Froese and Pauly (2022). In each sample, the total length (TL) and standard length (SL) were measured using a caliper with an accuracy of 0.01 mm. The size at first sexual maturity (Lm) was used to classify each fish into juvenile or adult categories. Measurements of sexual maturity were obtained from Fishbase (Froese and Pauly 2022) or through empirical equations with Lmax and L (Froese and Binohlan 2000).

Data analysis

MS Excel 2010 was used to analyze the data obtained, which include abundance, diversity index, evenness, and dominance. Abundance was calculated based on Krebs (1989), as follows:

$$K = \frac{ni}{A}.$$

Where: K: density, ni: number of individuals in the ith species, and A: area. The diversity index was analyzed by the Shannon-Wiener index (Krebs 1989), as follows:

$$H' = -\sum_{i=1}^{s}(p_i)(\ln p_i).$$

Where: H': diversity index, pi or ni/N: the proportion of individuals in the ith species to the total number of individuals in all species, N: the total number of individuals of all species, and s: the total number of species. Evenness was calculated using the following Shannon-Wiener formula (Krebs 1989):

$$J' = \frac{H'}{H'_{max}}.$$

Where: J': evenness index ranging from 0 to 1, H': Shannon-Wiener diversity index, and H'max: maximum value of H' (ln S). Dominance is calculated based on the Simpson index (Krebs 1989), as follows:

$$D = \sum_{i=1}^{s} {p_i}^2.$$

Where: D: Simpson's index, and pi: proportion of the ith species in the community

RESULTS AND DISCUSSION

Species composition and size

The fish species collected in this research comprised 40 species belonging to 21 families and 7 orders, as shown in Table 1. The species were mainly dominated by members of the Holocentridae, Mullidae, Pomacentridae, Labridae, and Siganidae families. The families of fish found in seagrass beds vary, but member species of all four families (ie, Mullidae, Pomacentridae, Labridae, and Siganidae) are common among the dominant fish communities found in seagrass beds as reported by previous studies (Pogoreutz et al. 2012; Ambo-Rappe et al. 2013; Latuconsina and Ambo-Rappe, 2013; Susilo et al. 2018, Syukur et al. 2021), except for the Holotridae which were found at night in this study. These five dominant families are taxonomically diverse and also members of this family mainly inhabit coastal waters, including seagrass beds (Nelson 2006; Allen and Erdmann, 2012; Froese and Pauly, 2022).

The number of species during the day was more than at night when compared based on sampling time. This is thought to be related to the activities of the fish community in foraging for food. In general, trophic groups of omnivores, herbivores, and carnivores are active during the day looking for food using visuals, while groups of carnivores that are nocturnal require special adaptations to limited light conditions. So that during the day, the trophic groups are more diverse (omnivores, herbivores, and carnivores) and have implications for species diversity. According to Mason et al. (2005) and Cadotte et al. (2011), functional diversity reflects the diversity of species niches through species-specific characteristics.

The number of fish species found in this research was relatively small when compared to previous research, however, the species composition varied by location, as shown in Table 2, This is believed to be due to the use of seagrass beds as fish habitats. The diversity of fish and seagrass species was influenced by expanse, cover, and density (Pogoreutz et al. 2012; Ambo-Rappe et al. 2013; McCloskey and Unsworth, 2015; Ambo-Rappe, 2016; Ho et al. 2018; Susilo et al. 2018; Darmawaty et al. 2022). It is also influenced by the presence of the surrounding ecosystem. There is a relationship between seagrass and other ecosystems in coastal waters, such as coral reefs (Latuconsina et al. 2014; Ho et al. 2018). According to Unsworth et al. (2007), most reef fish species migrate daily to seagrass beds in search of food. These include several members of the family Holocentridae (such as *Myripristis pralinea, Neoniphon samara,* and *Sargocentron punctatissimum*) that forage for food at night and hide in crevices at the bottom of coral formations during the day (Allen and Erdmann 2012). In addition, diversity is likely related to the sampling method and sampling area (Zarco-Perello and Enríquez 2019; French et al. 2021a,b), as shown in Table 2.

The number of species found slightly differed between day (23 species) and night (20 species) but with different species compositions, as shown in Table 1. This is believed to be related to the foraging activities of each species found. The trophic group comprised three main groups, namely herbivores, omnivores, and carnivores, as shown in Figure 3.A. During the day, omnivores, mainly algae eaters, zoobenthos, zooplankton, and fish predominated (48.6%) and herbivores (algae eaters), as well carnivores such as zoobenthos (23.6%) were also present. However, carnivores (87.5 %), mainly zoobenthos and fish-eating groups predominated at night, as shown in Figure 3.B. Unsworth et al. (2007) found that carnivores (invertebrates and fish eaters) and omnivores dominated the fish community during the day, and only carnivores dominated at night in fish communities in Wakatobi seagrass beds. The dominance of carnivorous groups at night is mainly related to their effectiveness in foraging for food. The effectiveness of this group in foraging is mainly related to the ability of their eyes to see in low light conditions (scotopic vision). Schmitz and Wainwright (2011) showed that the eye diameter of nocturnal carnivorous species is 1.4 times larger, the lens and pupil diameter are large and round, thereby increasing the amount of light transmitted and further increasing the brightness of the retinal image and better scotopic vision. Previous research by Unsworth et al. 2007 revealed that seagrass beds are a foraging habitat for herbivores and groups of carnivorous fish that feed on zoobenthos from coral reefs. At high tide, seagrass beds in the intertidal zone provide a large enough space for herbivores and carnivores to use as a temporary shelter and foraging place (Lee et al. 2014). The movement of these fish can facilitate trophic subsidies between seagrass beds and coral reef habitats (Shantz et al. 2015).

Table 3 shows the size compositions of the fish found in this research. As shown in Figure 4, the proportion of individual fish collected at the juvenile stage, was 65.9%. A larger proportion (>90%) of juveniles in seagrass beds was also reported by Du et al. (2018) and Simanjuntak et al. (2020). This shows how several fish species found in this research use seagrass as a foraging and nursery habitat. Some of the species found may also use this habitat as temporary nursery areas before moving to other ecosystems at a later stage of development.

Honda et al. (2013) and Moussa et al. 2020 found that several species, including *Lutjanus fulviflamma, Scolopsis lineata, Lethrinus harak, Parupeneus barberinus, Siganus fuscescens,* and *Siganus guttatus,* showed ontogenetic habitat shifts from seagrass beds as nursery habitat to coral reef areas in the mature phase. The role of seagrass beds as nursery habitats for reef fish groups was also reported by Sambrook et al. 2019. Due to the structural complexity of the habitat, its use by juvenile fish is strongly influenced by various factors that affect their survival, including habitat structure, food sources, competition, and predation risk (Kimirei et al. 2013). Seagrass beds in the tropics are typically composed of mixed vegetation (Hemminga and Duarte 2000), however, Nusmapi Isl. consists of three to six types (Leatemia et al. 2017; Pattipeilohy et al. 2020). Invertebrate abundance has also been reported in these seagrass beds (Leatemia et al. 2017). According to Du et al. (2016), these results are due to seagrass and its epiphytes being the primary food source for macroinvertebrates (69.4%) and some fish fauna. Carnivorous fish in their early stages of development, including reef fish that use this habitat as a foraging ground, use macroinvertebrates as a food source (Nakamura et al. 2012; Kimirei et al. 2013; Lee and Lin 2015). Variations in morphology, size, density, and canopy height of seagrass vegetation contribute to the structural complexity of this habitat, thereby providing more surface area and intermediate space for the protection of prey species and juveniles (Ho et al. 2018; Jones et al. 2021). Therefore, habitat selection at the juvenile stage is a strategy for achieving a trade-off between food availability and predation risk (Nakamura et al. 2012; Kimirei et al. 2013) and reducing the potential for competition (Kwak et al. 2015).

Abundance

Abundance of fish species found at the research location varied based on species and the day-night period, as shown in Table 4. During the day, the most abundant species were *S. trilineata* and *S. spinus* ranging from 0.33-0.81 ind.100 m^{-2}. Meanwhile, at night, different fish species including *M. pralinia, N. samara*, and *S. punctatissimum* (Holocentridae family) ranging from 0.27-0.36 ind.100 m^{-2} were found. Two other species were also found to be quite abundant at night, namely *M. vanicolansis*, and *S. spinus* (0.18-0.21 ind.100 m^{-2}). Other species were found with lower abundance (0.09 ind.100m^{-2}). Furthermore, several species were found in abundance in groups, such as *Siganus spinus, Stethojulis trilineata, S. punctatissimum,* and *M. pralinia* (Allen and Erdmann 2012).

Fish abundance also varies temporally and spatially. As shown in Table 3, temporal variation is represented by variation in the two sampling periods. It was found that the abundance during the day was higher than that at night. Similar results were also reported by Pattipeilohy et al. (2020). This is thought to be related to the use of seagrass beds for food. This can be seen in the more diverse trophic groups during the day than at night, as shown in Figure 4.

Meanwhile, the condition of seagrass beds (area and density or percentage of cover), as well as the presence or condition of the surrounding ecosystem (coral reef ecosystem) influence the abundance of fish spatially. McCloskey and Unsworth (2015) and Ho et al. (2018) showed significantly higher diversity and abundance of fish at higher percentages of seagrass cover, demonstrating the role of habitat for this fauna. Furthermore, fish density and species richness in seagrasses are also positively correlated with distance to adjacent coral reefs (Ho et al. 2018), suggesting that these conditions may be related to daily migration between adjacent ecosystems (Unsworth et al. 2007).

Table 1. Fish species composition in seagrass beds of Nusmapi Isl., Manokwari, West Papua, Indonesia based on sampling time (day-night) and trophic groups

Taxa			Local name	Sampling		Trophic guild*
Ordo	Family	Species		Day	Night	
Anguilliformes	Muraenidae	*Gymnothorax pictus*	Karabas (Biak)		√	C (Zb-Fi)
		Gymnothorax sp.	Karabas (Biak)		√	C (Zb-Fi)
Aulopiformes	Synodontidae	*Saurida gracilis*	Manggaraurau (Biak), Kumiri (Serui)		√	C (Zb-Fi)
		Synodus dermatogenys	Manggaraurau (Biak), Kumiri (Serui)		√	C (Zb-Fi)
Beloniformes	Belonidae	*Tylosurus crocodilus*	Imbekwa (Biak)		√	C (Fi)
Beryciformes	Holocentridae	*Myripristis pralinia*	Indur (Biak)		√	C (Zp)
		Neoniphon argenteus	Indur (Biak)		√	C (Zb)
		Neoniphon samara	Indur (Biak)		√	C (Zb-Fi)
		Sargocentron punctatissimum	Indur (Biak)		√	C (Zb-Fi)
		Sargocentron praslin	Indur (Biak)		√	C (zp)
Scorpaeniformes	Scorpaenidae	*Scorpaenoides venosa*	Kinof (Biak), Ripariurui (Serui)		√	C (Zb-Fi)
Perciformes	Apogonidae	*Apogon guamensis*	Insabus (Biak)		√	C (Zb-Fi)
	Lutjanidae	*Lutjanus fulviflamma*	Imbarpekem (Biak)		√	C (Zb-Fi)
	Gerreidae	*Gerres oyena*	Inggower (Biak)	√		C (Zb)
	Lethrinidae	*Lethrinus harak*	Indur (Biak), Mantona (Serui)	√		C (Zb-Fi)
	Nemipteridae	*Scolopsis lineata*	Inamsor (Biak)	√	√	C (Zb-Fi)
	Mullidae	*Mulloidichthys vanicolansis*	Inmarsyum (Biak)		√	C (Zb)
		Parupeneus barberinus	Inmarsyum (Biak)	√	√	C (Zb)
		Parupeneus multifasciatus	Inmarsyum (Biak)	√		C (Zb)
		Parupeneus trifasciatus	Inmarsyum (Biak)	√		C (Zb)
	Chaetodontidae	*Chaetodon vagabundus*	-	√		O (Al-Zb)
	Pomacentridae	*Abudefduf vaigiensis*	Badikois (Biak)	√		O (Al-Zb-Zp)
		Pomacentrus opisthostigma	Inarweken (Biak), Diang goropang (Serui)	√		O (Al-Zb)
		Stegastes nigricans	Inarweken (Biak), Marai (Serui)	√		O (Al-Zb)
		Dacyllus melanurus	Inarweken (Biak), Diang bajukos (Serui)	√		O (Al-Zb-Zp-Fi)
	Labridae	*Halichoeres scapularis*	Insis (Biak)	√		C (Zb)
		Haliochoeres trimaculatus	Insis (Biak)	√		C (Zb-Fi)
		Stethojulis bandanensis	Insis (Biak)	√		C (Zb)
		Stethojulis strigiventer	Insis (Biak)	√		C (Zb)
		Stethojulis trilineata	Insis (Biak)	√		O (Al-Zb-Zp-Fi)
	Scaridae	*Scarus psittacus*	Indawen (Biak)	√		H (Al)
	Blenniidae	*Salarias alboguttatus*	Masadikor (Biak)	√		H (Al)
	Siganidae	*Siganus fuscescens*	Insarek (Biak)	√		H (Al-Sg)
		Siganus guttatus	Indos (Biak)		√	H (Al)
		Siganus lineatus	Indos (Biak)		√	H (Al)
		Siganus spinus	Insarek (Biak)	√	√	H (Al)
	Acanthuridae	*Acanthurus triostegus*	Imbran (Biak)	√		H (Al)
Tetraodontiformes	Balistidae	*Rhinecanthus verrucosus*	-	√		C (Zb-Zp)
	Monacanthidae	*Pervagor janthinosoma*	-	√		O (Al-Zb)
	.Tetraodontidae	*Arothron manilensis*	Nus (Biak)		√	C (Zb)
Total				**23**	**20**	

Notes**:** * Allen and Erdmann (2012), Froese and Pauly (2022), C: carnivore, O: omnivore, H: herbivore, Zb: zoobenthos, Zp: zooplankton, Fi: fish, Al: algae, Sg: seagrass

Table 2. Composition and sampling method of fish in seagrass beds at several locations

Location	No. of species (family)	No. of sampling location	Sampling method	Source
Nusmapi Isl., Doreri Bay, Manokwari	40 (21)	1	Bottom gill net with 0.5 and 1.5 inches mesh size, two sampling periods, day and night time sampling	*This study*
North Oba, Tidore Island	25 (14)	4	Beach trawl	Darmawaty et al. (2022)
Wael Beach, Kotania Bay, West Seram	44 (28)	1	Bottom gill net with 1,5 inches of mesh size, day and night time sampling	Latuconsina et al. (2014)
Doreri Bay	56 (26)	5	Gill net, one period sampling, day and night time sampling	Pattipeilohy et al. (2020)
Tanjung Tiram-Inner Ambon Bay	72 (35)	1	Beach seine net with 0.5 inches of mesh size, three sampling periods, day and night time sampling	Latuconsina and Ambo-Rappe (2013)
South coast of Lombok	104 (38)	7	Mini trawl with four mesh sizes (0.5-1,25 inch), five sampling periods	Syukur et al. (2021)

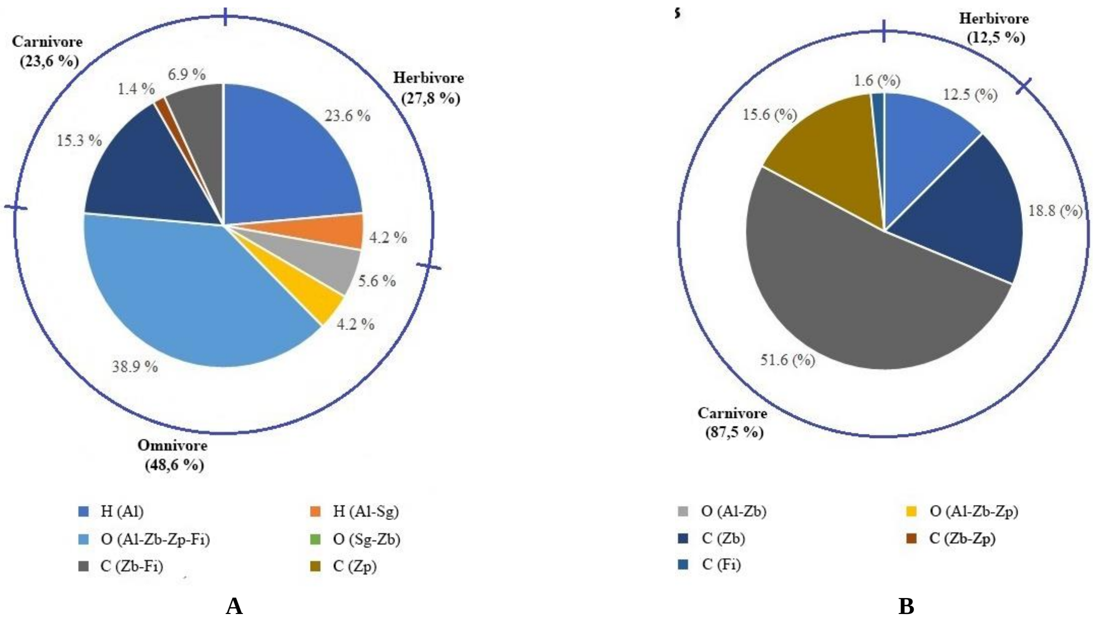

Figure 3. Trophic groups of fish in seagrass beds based on sampling periods (A) during the day, and (B) at night. Notes: H: herbivore, O: omnivore, C: carnivore, Al: algae, Sg: seagrass, Zb: zoobenthos, Zp: zooplankton, Fi: fish

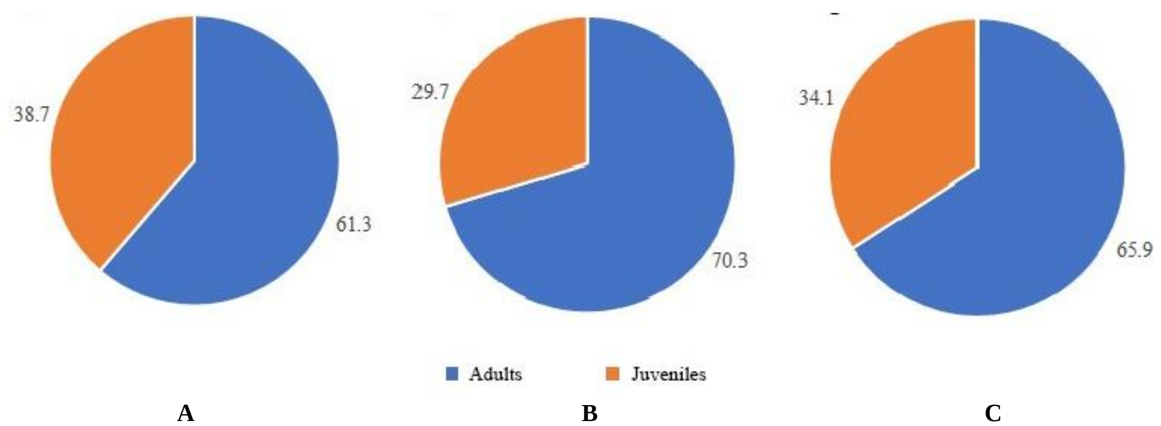

Figure 4. Individual proportions between juvenile and adult stages of fish communities in seagrass beds on Nusmapi Isl., Manokwari, West Papua, Indonesia. A. daytime, B. Night, C. overall

Table 3. Body length, length of first sexual maturity, and stage of development of fish communities in seagrass beds of Nusmapi Isl., Manokwari, West Papua, Indonesia

Species	n	TL		SL		Lm[a]	Stage
		Range (mm)	Average±SD	Range (mm)	Average±SD		
Muraenidae							
G. pictus	1	710.0		710.0		721.0*	Juvenile
Gymnothorax sp.	1	236.0		236.0		721.0*	Juvenile
Synodontidae							
S. gracilis	1	144.8		122.2		196.0*,[b]	Juvenile
S. dermatogenys	1	153.7		134.4		152.0*	Juvenile
Belonidae							
T. crocodilus	1	358.0		325.0		517.0	Juvenile
Holocentridae							
M. pralinia	9	128.2-157.0	141.8±8.1	99.3-121.9	109.9±7.3	129.0*	Juvenile-adult
N. argenteus	2	93.5-123.4	108.5±21.1	75.5-100.0	87.8±17.3	152.0*	Juvenile
N. samara	12	92.6-141.4	111.7±17.7	74.7-115.0	90.3±14.2	150.0	Juvenile
S. punctatissimum	11	91,1-107.7	98.8±4.3	72.5-86.5	79.0±3.6	146.0*	Juvenile
S. praslin	1	121.0		97.5		196.0*	Juvenile
Scorpaenidae							
S. venosa	1	112.6		90.6		157.0*	Juvenile
Apogonidae							
A. guamensis	1	91.3		67.3		77.0*	Juvenile
Lutjanidae							
L. fulviflamma	1	185.0		143.8		171.0*	Juvenile
Gerreidae							
G. oyena	1	143.7		109.4		185.0*	Juvenile
Lutjanidae							
L. harak	1	83.3		66.0		195.0	Juvenile
Nemipteridae							
S. lineata	5	90.2-170.0	148.7±33.7	71.3-132.2	115.9±25.7	157.0*	Juvenile-adult
Mullidae							
M. vanicolansis	7	195.0-258.0	228.0±20.6	151.8-197.0	180.0±16.1	240.0	Juvenile-adult
P. barberinus	3	159.0-230.0	195.0±35.5	120.5-183.0	152.5±31.3	341.0*	Juvenile
P. multifasciatus	1	112.6		87.7		110.0	Juvenile
P. trifasciatus	2	117.1-160.0	138.6±30.3	91.6-128.9	110.3±26.4	212.0*	Juvenile
Chaetodontidae							
C. vagabundus	1	92.6		77.3		146.0*	Juvenile
Pomacentridae							
A. vaigiensis	3	63.9-97.2	76.2±18.3	45.6-71.7	55.1±14.4	120.0	Juvenile
P. opisthostigma	1	77.7		62.7		48.0*	Adult
S. nigricans	1	70.9		55.3		94.0*	Juvenile
D. melanurus	1	53.0		40.4		57.0*	Juvenile
Labridae							
H. scapularis	2	108.3-128.7	118.5±14.4	94.0-106.6	100.3±8.9	129.0*	Juvenile
H. trimaculatus	2	116.9-124.1	120.5±5.1	95.6-100.6	98.1±3.5	168.0*	Juvenile
S. bandanensis	1	96.1		78.3		100.0*	Juvenile
S. strigiventer	3	103.5-113.1	107.9±4.8	85.2±94.8	89.7±4.8	100.0*	Adult
S. trilineata	27	77.7-113.8	99.5±8.9	63.1-94.8	82.4±7.5	90.0	Juvenile-adult
Scaridae							
S. psittacus	2	85.7-160.0	122.9±52.5	71.9-134.6	103.3±44.3	126.0	Juvenile-adult
Blenniidae							
S. alboguttatus	1	103.9		82.4		64.0*	Adult
Siganidae							
S. fuscescens	3	148.6-149.5	149.1±0.6	120.7-121.5	121.1±0.6	238.0*	Juvenile
S. guttatus	1	337.7		270.0		181.0	Adult
S. lineatus	1	305.0		250.0		254.0*	Adult
S. spinus	17	80.4-162.2	130.2±21.4	67.9-131.1	108.1±17.3	174.0*	Juvenile-adult
Acanthuridae							
A. triostegus	3	93.2-109.3	100.5±8.2	76.8±86.4	80.9±5.0	88.0	Adult
Balistidae							
R. verrucosus	1	109.5		95.4		146.0*	Juvenile
Monacanthidae							
P. janthinosoma	1	113.3		92.1		88.0*	Adult
Tetraodontidae							
A. manilensis	1	173.0		127.5		190.0*	Juvenile

Note: [a] total length (TL), [b] standard length (SL), *estimated based on Lmax and L∞ based on empirical equations (Froese and Binohlan 2000)

Table 4. The abundance of fish species in the seagrass beds of Nusmapi Isl., Manokwari, West Papua, Indonesia based on sampling period

Species	Daytime sampling periode		Night sampling periode	
	Range	Total	Range	Total
Muraenidae				
G. pictus	-	-	0.06	0.03
Gymnothorax sp.	-	-	0.06	0.03
Synodontidae				
S. gracilis	-	-	0.06	0.03
S. dermatogenys	-	-	0.06	0.03
Belonidae				
T. crocodilus	-	-	0.06	0.03
Holocentridae				
M. pralinia	-	-	0.06-0.48	0.27**
N. argenteus	-	-	0.12	0.06
N. samara	-	-	0.06-0.66	0.36**
S. punctatissimum	-	-	0.66	0.33**
S. praslin	-	-	0.06	0.03
Scorpaenidae				
S. venosa	-	-	0.06	0.03
Apogonidae				
A. guamensis	-	-	0.06	0.03
Lutjanidae				
L. fulviflamma	-	-	0.06	0.03
Gerreidae				
G. oyena	0.06	0.03	-	-
Lethrinidae				
L. harak	0.06	0.03	-	-
Nemipteridae				
S. lineata	0.06	0.06	0.18	0.09
Mullidae				
M. vanicolansis	-	-	0.18-0.24	0.21*
P. barberinus	0.06	0.03	0.12	0.06
P. multifasciatus	0.06	0.03	-	-
P. trifasciatus	0.12	0.06	-	-
Chaetodontidae				
C. vagabundus	0.06	0.03	-	-
Pomacentridae				
A. vaigiensis	0.06-0.12	0.09	-	-
P. opisthostigma	0.06	0.03	-	-
S. nigricans	0.06	0.03	-	-
D. melanurus	0.06	0.03	-	-
Labridae				
H. scapularis	0.06	0.06	-	-
H. trimaculatus	0.12	0.06	-	-
S. bandanensis	0.06	0.03	-	-
Stethojulis strigiventer	0.18	0.09	-	-
S. trilineata	0.72-0.90	0.81**	-	-
Scaridae				
S. psittacus	0.06	0.06	-	-
Blenniidae				
S. alboguttatus	0.06	0.03	-	-
Siganidae				
S. fuscescens	0.18	0.09	-	-
S. guttatus	-	-	0.06	0.03
S. lineatus	-	-	0.06	0.03
S. spinus	0.24-0.42	0.33**	0.12-0.24	0.18*
Acanthuridae				
A. triostegus	0.06-0.12	0.09	-	-
Balistidae				
R. verrucosus	0.06	0.03	-	-
Monacanthidae				
P. janthinosoma	0.06	0.03	-	-
Tetraodontidae				
A. manilensis	-	-	0.06	0.03
Total	2.09-2.21	2.15	1.73-2.09	1.91

Notes: ** most abundant, * quite abundant

Community diversity, evenness, and dominance

The index values of diversity, evenness, and dominance of fish communities in the seagrass beds of Nusmapi Isl. are shown in Table 5. The values of the three indices between day and night were slightly different. In comparison with other research on fish communities in seagrass beds, the diversity index value in the research location was classified as medium, the evenness index was high, and the dominance index was low. These indices are attributes that describe the overall stability of a community. It indicates that fish communities in seagrass beds are relatively stable, with an equal proportion of each species making up the community and no predominant species. As shown in Table 5, the diversity index increases with the increase in the number of species in the community but decreases as the proportion of individuals of each species becomes unequal or one predominates (Krebs 1989).

The stability of the fish community can also be seen in the presence of diverse trophic groups, namely algae, seagrass, zoobenthos, zooplankton, and fish eaters, as shown in Figure 4. High functional diversity indicates efficient resource utilization and higher productivity, which is reflected in species using different resources with complementary niches (Hooper et al. 2012; Duffy et al. 2017). Furthermore, differences in food composition will increase the number of food resources available to the fish community and reduce the potential for competition for food resources (Kwak et al. 2015). High functional diversity is considered to support the function and stability of the ecosystem it inhabits (Hooper et al. 2012; Rasher et al. 2013; Richardson et al. 2017; Brandl et al. 2019). The extent to which these ecosystem functions occur is highly dependent on how different species contribute to specific processes in the ecosystem (Brandl et al. 2019). The relatively stable fish community in the seagrass beds as it continues to support its function, particularly as a nursery and foraging habitat indirectly demonstrates the stability of this ecosystem.

The fish community in seagrass beds of Nusmapi Isl. consisted of various species during the day and night. It was dominated by omnivores during the day and carnivores at night. The fish community was found in juvenile stage, and its condition is relatively stable. Furthermore, seagrass beds serve as habitats for foraging and protection from predators.

The results suggest that seagrass beds are important habitats for coastal fish communities and have real implications for coastal management policies. These results were supported by previous research which revealed that seagrass beds not only provide a habitat for particularly small fish species but also serve as nurseries and foraging grounds for various fish from the surrounding ecosystem. These include large species commercially valuable fish species, such as members of the Siganidae and Lutjanidae families. Therefore, it is important to conserve seagrass beds to maintain fish biodiversity and coastal fishery resources.

Table 5. Index of diversity, evenness, and dominance of fish communities in seagrass beds on Nusmapi Isl., Manokwari, West Papua, Indonesia and several other locations

Location	Sampling period	Number of species (S)	Index			Sources
			H'	J'	D	
Nusmapi Isl., Doreri Bay,	Day	14-16	2.03-2.32	0.77-0.84	0.16-0.22	This study
Manokwari	Night	12	1.91-2.20	0.77-0.89	0.14-0.21	
Tanjung Tiram, Inner	Day	41-44	2.76-2.87	0.71-0.78	0.09-0.13	Latuconsina and
Ambon Bay	Night	38-39	2.13-2.49	0.58-0.69	0.15-0.23	Ambo-Rappe (2013)
Wael Beach, Kotania Bay,	Day	4-11	1.06-1.86	0.66-0.95	0.17-0.43	Latuconsina et al. (2014)
West Seram	Night	5-15	1.38-2.20	0.65-0.86	0.19-0.33	

Notes: H': diversity index, J': evenness index, D: dominance index

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