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Temporal and spatial variation of fish community and their nursery in a tropical seagrass meadow

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Abstract

Fish species composition and spatio-temporal variability of the community were studied in a tropical seagrass meadow located in a lagoon in the eastern part of North Sulawesi. The diversity of fish community in the seagrass meadows was relatively high, with the Shannon-Wiener index ranging from 1.57 to 3.69. The family Apogonidae was the most dominant in abundance (8.27 ind./(100 m^2)) and biomass (28.49 g/(100 m^2)). At the species level, *Apogon lateralis* and *Sphaeramia orbicularis* were the most dominant species in abundance and biomass, respectively. For spatial distribution on species, the end, middle and mouth of the lagoon clustered together as a whole, which may be due to the substrate types found in those zones. The fish species, fish abundance and fish biomass were greater in the dry and wet seasons than in the transition season, which is explained by the strong monsoon, which provides a more suitable environment and food for the fish. The maximum length of 93.10% of the captured species was less than their length at maturity, indicating that seagrass meadows are nursery habitats for many fishes. Therefore, protection of the seagrass meadows is essential for fisheries and sustainable resource utilization.

Key words: seagrass meadows, fish assemblages, nursery function, North Sulawesi

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1 Introduction

Seagrass meadows are the key ecosystems that constitute important fishing grounds and critical nursery habitats for commercial species (Hemminga and Duarte, 2000; Nagelkerken et al., 2000). However, seagrass meadows are under constant threat worldwide. The changes in seagrass coverage may affect fish community structure, as many species utilize these habitats during their vulnerable early life history stages (Sobocinski et al., 2013; Unsworth et al., 2014). In some areas of the Coral Triangle, fauna associated with seagrass contributes at least 50% of fish-based food, in which juvenile fishes can comprise up to 26% of the catch (Unsworth et al., 2007a, 2014). Seagrass meadows support the fishery occurs in three ways: (1) seagrass meadows function as a nursery area for fisheries species, (2) they provide foraging and refuge habitat for the fauna species, and (3) they provide trophic subsidy to fisheries in adjacent and deep-water habitats (Gillanders, 2007; Heck et al., 2008; Lilley and Unsworth, 2014; Nordlund et al., 2018). Thus, it is in both environmental and economic interests to protect and manage seagrass meadows effectively (de la Torre-Castro et al., 2014).

Southeast Asia is a hotspot of biodiversity, with enormous species richness (Sodhi et al., 2004), and the Indonesian coasts in particular harbor exceptionally high seagrass and fish diversity (Vonk et al., 2008, 2010; Pogoreutz et al., 2012). A great number of studies on the community structure of fishes that inhabit in seagrass meadows have been carried out in Indonesia, where living more than 300 species of fish live (Hutomo and Peristiwady, 1996; Manik, 2007; Du et al., 2016). However, these studies have focused only on fish communities in few areas, while the nursery function of seagrass meadows for fishes in North Sulawesi remains poorly described. Although a few studies have been carried out in Tanjung Merah and Tasikoki, near Kema, there is no information on the temporal and spatial variation of seagrass fish in this area. Understanding the nursery function of seagrass meadows is fundamental for interpreting the fluctuations of local stock and community structure (Silvano et al., 2000), which has implications for human food security (Davis et al., 2005; Hsieh et al., 2006). Therefore, considering the ecological and eco-

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nomic importance of seagrass meadows and associated fisheries, it is necessary to understand the temporal and spatial pattern of fish communities and nursery function of seagrass meadows in the Indo-Pacific region. Improving our knowledge about that information is important for their long-term management and sustainability of fish communities, and subsequently for human and ecosystem wellbeing.

2 Materials and methods

2.1 *Study area*

The present study was carried out in Kema, North Minahasa, in the eastern part of North Sulawesi, Indonesia. North Sulawesi has a typical equatorial climate, the mean sea surface temperatures are uniform, varying by only a few degrees throughout the region and the year (between 20°C and 28°C). Tides in this area are mixed and mainly semi-diurnal, and they fluctuate slightly with an annual range of 2.4 m. In the seagrass meadows, *Enhalus acoroides* (Linnaeus f.) Royle and *Thalassia hemprichii* (Ehrenberg ex Solms) Asch are the dominant species, with about 65% coverage. The lagoon is 2.0 km long and surrounded by mangrove forest. The mouth area of the lagoon is narrow, about 50 m wide and with sandy substrate. The floor of the middle area, which is also about 50 m wide, is composed of mixed sand and mud. The end area of the lagoon is about 300 m wide and with muddy sediment. The site outside the lagoon has fringing coral reef nearby, with mixed sand and mud. This area is subject to strong influences from the wet northwest monsoon from November to March and the dry southeast monsoon from May to September, with April and October as transition seasons (Aldrian and Susanto, 2003). This present study was carried out during August, October and December, which belong to the dry, transitional and wet seasons, respectively.

2.2 *Field collection*

Samples in the seagrass meadows were collected using a beach seine at four stations (Fig. 1). The wing length and the bucket of the seine were 20 m and 3 m, respectively, whereas the wing depth at the wings at the anterior was 1.5 m and close to the bucket 2 m. The beach seine was laid out at a depth of about 1.5 m and pulled perpendicular to the waterline. All samples were collected during a falling tide. All finfish of every size retained by the seine net were immediately preserved in an icebox. Identification was performed according to Allen (1997), Allen et al. (2005), Kimura and Matsuura (2003), and Peristiwady (2006). The weight and length of each individual were measured, and the length at maturity ($L_{maturity}$) of each species was obtained from Fishbase (Froese and Pauly, 2018). The individual was defined as larva and juvenile if its length was less than $L_{maturity}$.

2.3 *Statistical analyses*

Fish were counted and weighed in the laboratory. The surface area of the seine was used to calculate biomass and abundance. Ecological indices, namely species richness index (d), Shannon-Wiener diversity index-based $\log_e H'$, and Pielou's evenness index (J'), were used to evaluate the species diversity of each sample. To evaluate the distribution pattern of seagrass fish, the data from the four stations collected in the three seasons were computed using a cluster analysis to elucidate the relative similarities among the samples. Species abundance in each sample was used to calculate Bray–Curtis similarities before the clustering analyses. The Primer 5 was used during clustering analyses (Clarke and Gorley, 2015). For the analysis of saturation of most diverse fish families, data were arranged into species × site matrices and analyzed using the software EstimateS 9.1.0 (Colwell, 2013). The abundance-based coverage estimator (ACE) and incidence-based coverage estimator (ICE) were used as estimators of total species richness.

3 Results

3.1 *Species composition*

A total of 3 837 individuals belonging to 87 species in 44 families were collected from the seagrass meadows (Table A1), 81 of which were found only in larvae and juvenile stages. The abundance of seagrass fish in Kema was 15.03 ind./(100 m^2), and the biomass was 118.02 g/(100 m^2). Family Apogonidae accounted for ten species, and four species belonged to the Carangidae, Gobiidae, and Tetraodontidae. The most common species at each station were *Acreichthys tomentosus*, *Ambasis* sp. 1, *Hypoatherina temminckii*, *Pseudomonacanthus peroni*, *Siganus canaliculatus*, *Sphaeramia orbicularis*, *Sphyraena barracuda*, *Syngnathoides biaculeatus*, and *Tylosurus melanotus*.

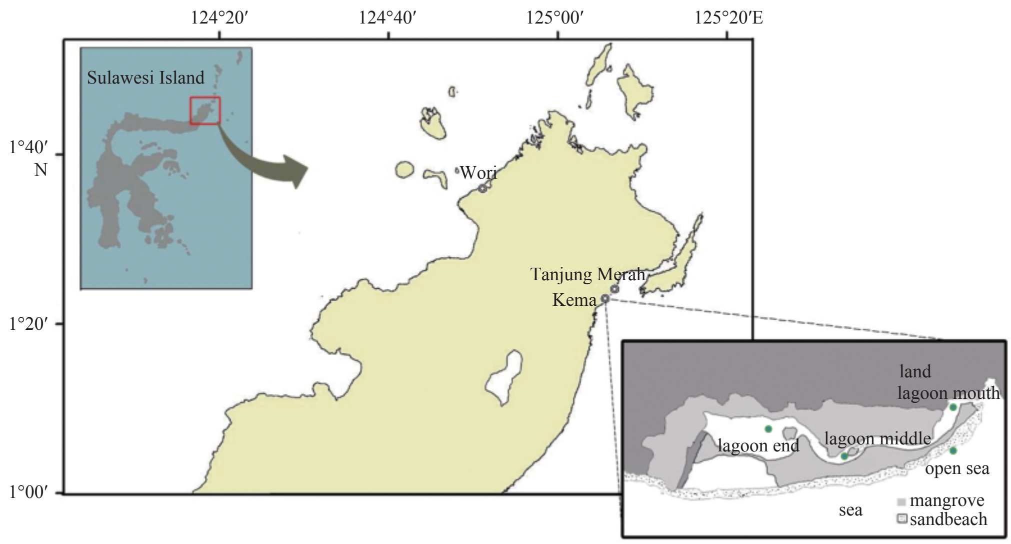

Fig. 1. Study area, showing the location and the survey stations along the east coast of North Sulawesi.

Family Apogonidae was the most dominant with 8.27 ind./(100 m^2) and 2 188 ind. in total, followed by the Ambassidae (1.36 ind./(100 m^2), 463 ind.) and Monacanthidae (1.06 ind./(100 m^2), 230 ind.) (Table A1). *Apogon lateralis* was the most dominant species, accounting for 22.56% of the total abundance, followed by *Sphaeramia orbicularis* (14.26%) and *Apogon* sp. (8.84%) (Fig. 2).

Family Apogonidae was also the most abundant in terms of biomass (28.49 g/(100 m^2)), followed by the Siganidae (11.28 g/(100 m^2)) and the Belonidae (10.40 g/(100 m^2)) (Table A1). *Sphaeramia orbicularis* was the most dominant species, accounting for 14.62% of the total biomass, followed by *Siganus canaliculatus* (8.81%) and *Tylosurus melanotus* (8.81%) (Fig. 3).

3.2 *Temporal and spatial variation*

At all stations, each species' abundance was higher in the dry and wet season than during the transition season. At the end and middle zones of the lagoon, the abundance was higher during the dry season than in the wet season. However, at the lagoon mouth and outside the lagoon, the abundance was higher during the wet season than the dry season (Fig. 4).

The average abundance in the lagoon was higher than that outside the lagoon. At all the stations, the abundance in the wet and dry season was higher compared with that during the transition season. In the end and mouth areas of the lagoon, the abundance was higher during the wet season than during the dry season, but this pattern was reversed in the middle of the lagoon and the right open sea outside the lagoon (Fig. 5).

The average biomass inside the lagoon was higher than that outside the lagoon. At all the stations except in the middle of the lagoon, the biomass in the wet and dry seasons was higher than that during the transition season. In the end and mouth zones of the lagoon, the biomass was higher during the wet season than the dry season, but this was reversed in the middle of the lagoon and the right open sea (Fig. 6).

The highest H' was observed in the right open sea during the

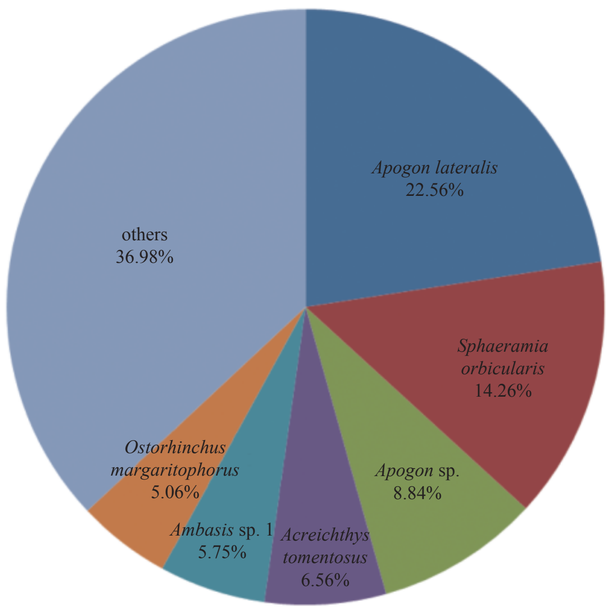

Fig. 2. Percent abundance of seagrass fish in Kema.

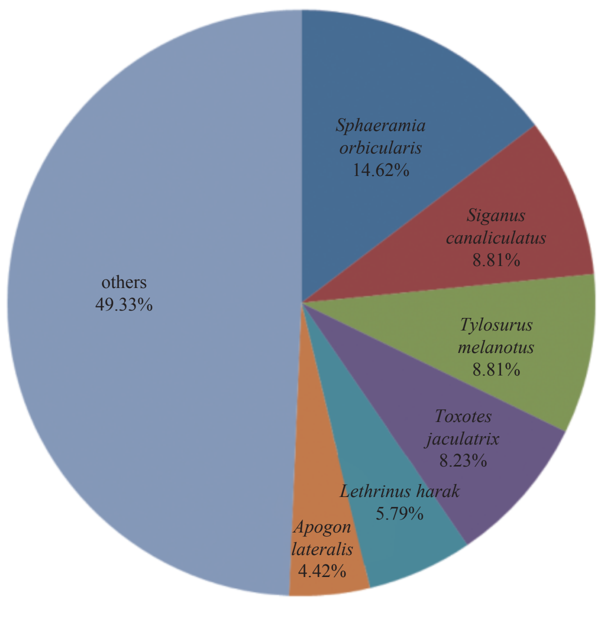

Fig. 3. Percent biomass of seagrass fish in Kema.

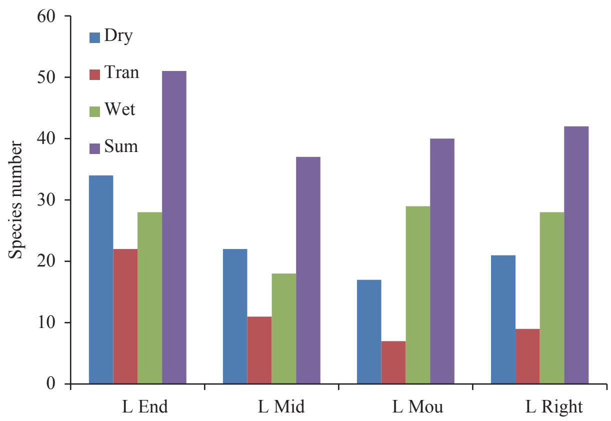

Fig. 4. Seagrass fish species in Kema. Dry represents dry season; Tran transitional season; Wet wet season; Sum sum of dry season, transitional season and wet season; L End the end of the lagoon; L Mid the middle of the lagoon; L Mou the mouse of the lagoon; and L Right the right open sea outside the lagoon.

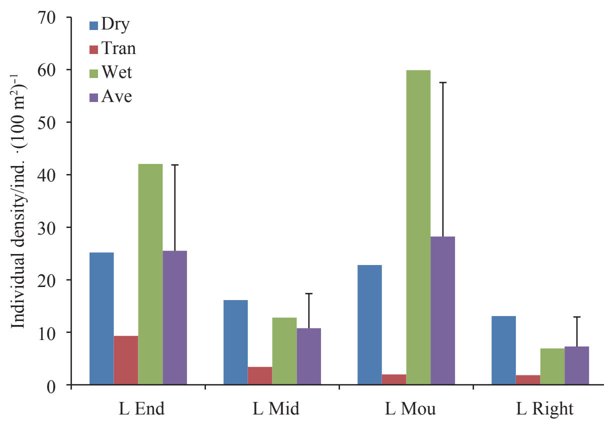

Fig. 5. Seagrass fish abundance in Kema. Dry represents dry season; Tran transitional season; Wet wet season; Ave average of dry season, transitional season and wet season; L End the end of the lagoon; L Mid the middle of the lagoon; L Mou the mouse of the lagoon; and L Right the right open sea outside the lagoon.

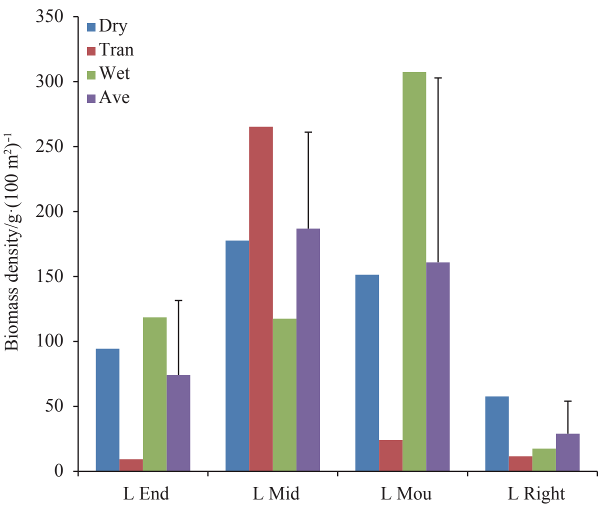

Fig. 6. Seagrass fish biomass in Kema. Dry represents dry season; Tran transitional season; Wet wet season; Ave average of dry season, transitional season and wet season; L End the end of the lagoon; L Mid the middle of the lagoon; L Mou the mouse of the lagoon; and L Right the right open sea outside the lagoon.

wet season, while the lowest *H*′ was observed in the right open sea during the dry season. The highest *J*′ was observed in the middle of the lagoon in the transition season, and the lowest *J*′ was observed in the right open sea during the dry season (Table 1).

3.3 *Fish clustering*

Seagrass fish assemblage analysis based on Bray–Curtis similarities showed variations in community structure. In terms of spatial distribution, the mouth of the lagoon clustered with the middle of the lagoon, and the two then cluster with the end of the lagoon, and finally with the zone outside of the lagoon (Fig. 7). For the abundance cluster, the dry and wet season clustered together, and then the two formed a group with the transition season (Fig. 8).

4 Discussion and conclusions

4.1 *Species composition*

Total species richness for the lagoon was estimated to be 110 and 120 species calculated from the value of ACE and ICE, respectively, based on species accumulation curves. Based on the 87 species sampled in the study, the actual number of species collected was estimated between 72% and 79% of the total species (Fig. 9), indicating that most of the species in the study area were sampled. These results corroborate other studies on Indonesian seagrass meadows reporting around 80 associated fish species (Hutomo and Martosewojo, 1977; Kuriandewa et al., 2003; Unsworth et al., 2007b).

Table 1. The ecological indices of seagrass fish in Kema

	S	*N*	*d*	*J*′		$\log_2 H'$	$\log_e H'$	
Dry-L End	34.00	25.20	5.97	0.61	unstable	3.12	2.16	high
Tran-L End	22.00	9.33	4.63	0.75	stable	3.36	2.33	high
Wet-L End	28.00	42.04	4.47	0.37	oppressed	1.78	1.23	low
Dry-L Mid	22.00	16.13	4.13	0.63	unstable	2.80	1.94	moderate
Tran-L Mid	11.00	3.40	2.84	0.88	stable	3.06	2.12	high
Wet-L Mid	18.00	12.80	3.50	0.76	stable	3.16	2.19	high
Dry-L Mou	17.00	22.80	2.95	0.53	unstable	2.17	1.50	moderate
Tran-L Mou	7.00	2.00	2.00	0.80	stable	2.25	1.56	moderate
Wet-L Mou	29.00	59.90	4.38	0.64	unstable	3.09	2.14	high
Dry-L Right	21.00	13.10	4.10	0.36	oppressed	1.57	1.09	low
Tran-L Right	9.00	1.83	2.75	0.54	unstable	1.73	1.20	low
Wet-L Right	28.00	6.95	6.37	0.77	stable	3.69	2.56	high

Note: *S* represents number of species, *N* number of individuals (ind./(100 m^2)), *d* species richness index, *J*′ evenness index, and *H*′ species diversity index (Shannon-Wiener).

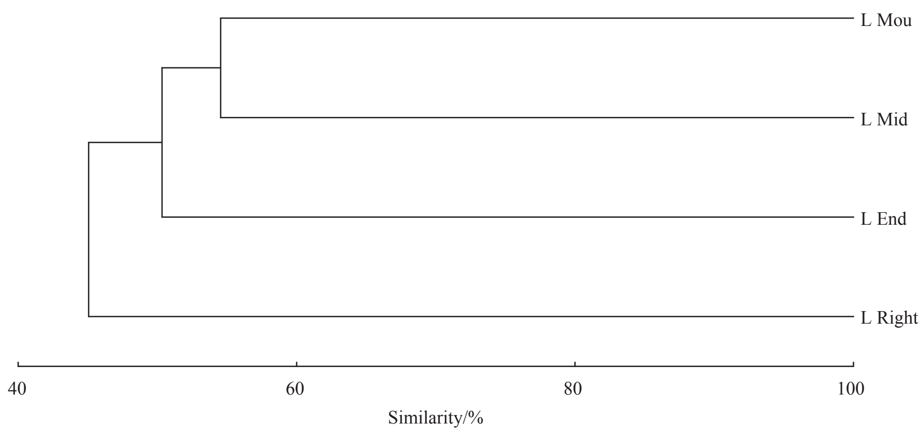

Fig. 7. Seagrass fish spatial cluster in Kema. L End represents the end of the lagoon, L Mid the middle of the lagoon, L Mou the mouse of the lagoon, and L Right the right open sea outside the lagoon.

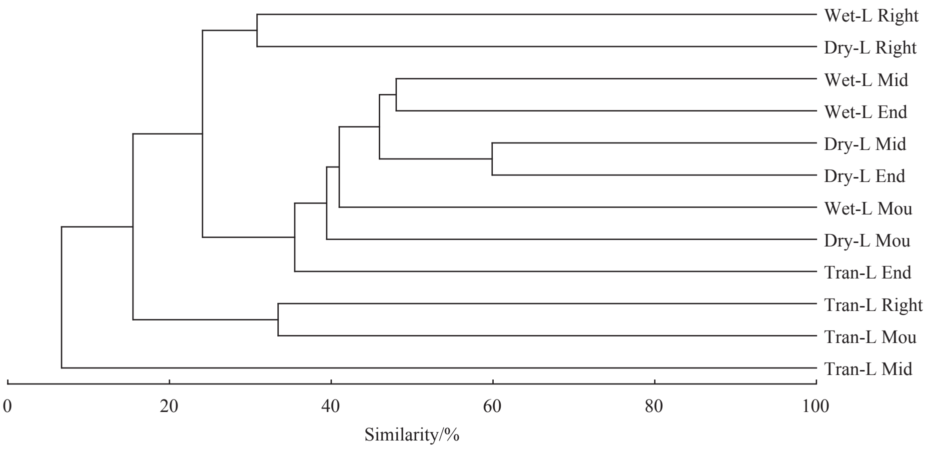

Fig. 8. Seagrass fish abundance cluster in Kema. L End represents the end of the lagoon, L Mid the middle of the lagoon, L Mou the mouse of the lagoon, and L Right the right open sea outside the lagoon.

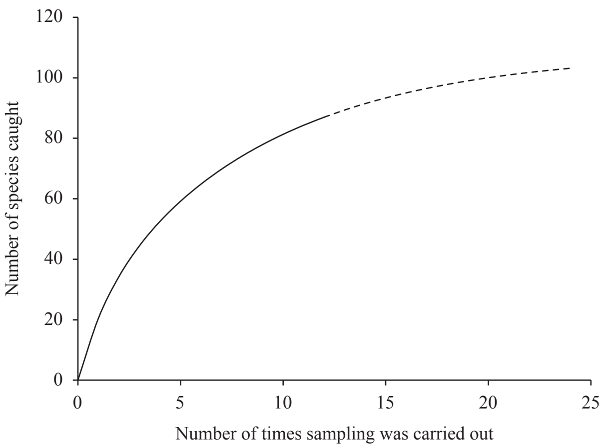

Fig. 9. Fish species accumulation curves for the study area. The solid line indicates the actual sampling times and number of species. The dashed line refers the saturation sampling times and number of species.

The most abundant fish in the investigated seagrass meadows were *Apogon lateralis* (3.39 ind./(100 m^2)) and *Sphaeramia orbicularis* (2.14 ind./(100 m^2)). Meanwhile, in South Sulawesi, the most abundant species were the omnivorous argus wrasse *Halichoeres argus* (21.9 ind./(100 m^2)) and the predominantly herbivorous *Siganus canaliculatus* (18.6 ind./(100 m^2)) (Pogoreutz et al., 2012), but these two species made up only 0.02 ind./(100 m^2) and 0.31 ind./(100 m^2) in North Sulawesi, respectively. Fish species with the highest abundance were small juvenile *Atherinomorus lacunosus*, *Calotomus spinidens*, *Leptoscarus vaigiensis*, *Siganus canaliculatus*, *Cheilio inermis*, *Gerres oyena*, *Pomacentrus adelus*, and *Stethojulis strigiventer* in Bone Batang in Southwest Sulawesi (Vonk et al., 2010). Seven species were present in Bone Batang at abundances greater than 10 ind./(100 m^2): *Atherinomorus lacunosus*, *Cheilio inermis*, *Halichoeres argus*, *H. chloropterus*, *Pentapodus bifasciatus*, *P. trivittatus*, and *Siganus canaliculatus* in South Sulawesi, but none of those species were as abundant as in North Sulawesi. This difference in abundance may be due to the underwater visual census method and longer survey period used in South Sulawesi versus the methods we used in North Sulawesi. In particular, the tidal cycle may be an important factor that changes seagrass fish assemblages (Lee et al., 2014).

The number of species and families in this study area were lower than in some places but higher compared with those in others (Sobocinski et al., 2013; Koagouw et al., 2015; Phinrub et al., 2013) (Table 2), although these comparisons may be affected by variable sampling or fishing practices. For example, 97 taxa in 48 families in the Sikao Bay, Trang Province, Thailand, were observed for one year using gill nets with three different mesh sizes on a monthly basis (Phinrub et al., 2013), whereas our survey was

Table 2. Species and family information of seagrass fish in other reference

Species number	Family number	Individules	Location	Net type	Station	Month	Reference
113	41	1 158	Lembeh Strait and adjacent area	beach seine and trap net	7	May	Koagouw et al. (2015)
107	36	–	Bone Batang	snorkelling	4	Oct. and Nov.	Pogoreutz et al. (2012)
97	48	10 596	Sikao Bay	gillnets	4	Jan. to Dec.	Phinrub et al. (2013)
89	30	–	Barang Lompo	snorkelling	1	Oct. and Nov.	Pogoreutz et al. (2012)
87	44	3 837	Kema	beach seine	4	Aug., Oct. and Dec.	this study
42	25	555	Kema	beach seine and trap net	1	May	Koagouw et al. (2015)
38	–	–	Chesapeake Bay	otter trawl	5	Sep. 1976 to Nov. 1977, Jul. 2009 to Aug. 2011	Sobocinski et al. (2013)
19	18	95	Tanjung Merah, Bitung	beach seine and trap net	1	May	Koagouw et al. (2015)

only conducted over three months. Moreover, there is a positive relationship between seagrass biomass or length and total fish abundance and species richness (Hutchinson et al., 2014). Increased information on seagrass like coverage, species, would enable further analysis. The comparison of our findings with those reported for the Lembeh Strait and surroundings (Koagouw et al., 2015), the Apogonidae were the most abundant family at both sites, while the second most abundant family is different (Ambassidae and Monacanthidae in Kema; Pomacentridae and Labridae in the Lembeh Strait). Meanwhile, *Apogon lateralis* was the most dominant species in Kema, versus *Apogon margaritophorus* in the Lembeh Strait. Specific ecological factors, such as the location and type of seagrass meadows, environment factors, and hydrology, may cause the distribution of families and species to vary in different areas.

4.2 *Temporal and spatial variation*

In total, the common species at each station and each season included only *Acreichthys tomentosus*, *Pseudomonacanthus peroni*, *Siganus canaliculatus*, *Sphyraena barracuda*, and *Syngnathoides biaculeatus*. Seagrass fish species can be classified into four residential types: permanent residents that stay throughout their whole life in the seagrass habitat; temporary residents that visit only seasonally or during a part of their life cycle; regular visitors that migrate on a diurnal basis from other habitats to nearby seagrass meadows; and occasional visitors that visit the meadows occasionally (Kikuchi, 1966; Hemminga and Duarte, 2000). Eighteen species were common during each season: *Acreichthys tomentosus*, *Arothron manilensis*, *Aurigequula fasciata*, *Butis butis*, *Cheilio inermis*, *Halichoeres papilionaceus*, *Lethrinus harak*, *Meiacanthus grammistes*, *Monodactylus argenteus*, *Petroscirtes variabilis*, *Pseudomonacanthus peroni*, *Scolopsis ciliata*, *Siganus canaliculatus*, *Siganus guttatus*, *Sphyraena barracuda*, *Syngnathoides biaculeatus*, *Toxotes jaculatrix*, and *Zenarchopterus dispar*. These species may be permanent residents or regular visitors. Meanwhile, *Aeoliscus strigatus* could be classed as a permanent resident, because the adult individuals of this species could be found both in coral reef and seagrass, but the specimens in seagrass environment were greenish-yellow with diffused stripe (Froese and Pauly, 2018). *Apogon margaritophorus* was only recorded during the wet season, and may belong to the temporary residents (Kuiter and Tonozuka, 2001). Although the specimens of *Cheilio inermis* we collected were adults, juveniles often hide in seagrasses (Kuiter and Tonozuka, 2001). The specimens of *Syngnathoides biaculeatus* included both juveniles and adults and were found at all stations during all three seasons, and thus, this species was considered a permanent resident in accordance with a description by Gell and Whittington (2002).

The spatial distribution cluster analysis grouped the mouth, the middle, and the end of the lagoon together, and the three zones then clustered with the zone outside the lagoon (Fig. 7). This pattern may be caused by the different substrate types—sand in the mouth, sand and mud in the middle, and mud in the end of the lagoon, and mixed sand and coral in the zone outside the lagoon. For each site, the fish species, fish abundance, and fish biomass of the dry and wet seasons were higher compared with those in the transition season (Figs 4–6, 8). This may be caused by the strong monsoon in August and December, eventually resulting in strong currents, and higher turbidity, and larger tidal ranges, which are more suitable for fish than a quiet sea in October. For example, many fish species, including the *Ilisha megaloptera* and *I. filigera* prefer the wet and dry season (Blaber et al., 1997). Many studies have shown that the wet season is the primary growth and reproductive season for the fishes in tropical areas (Lowe-McConnell, 1987). Furthermore, coastal plankton production is also higher during the wet season, thereby enhancing larval and juvenile growth and survival of the fish (Nagelkerken, 2009).

A diversity index conveys the balance of diversity in the number of individuals of each species. Diversity indices have the greatest value if all individuals are from different species, while smaller values are obtained if all individuals are from just one species (Odum, 1971). Our diversity index and species richness index both showed that the right open sea at wet season had the highest value, while the same station at dry season had the lowest index value.

Koagouw et al. (2015) put forward criteria for the value of seagrass fish community structure: diversity is high when H' is higher than 3, moderate when H' is between 2 and 3, and low when H' is lower than 2. Similarly, the community is stable when J' is higher than 0.75, unstable when J' is between 0.5 and 0.75, and under pressure when J' is lower than 0.5. According to these criteria, the diversity of fish at the end of the lagoon was high during the dry and wet seasons, at the middle of the lagoon during the transitional and wet season, at the mouth of the lagoon during the wet season, and in the right open sea in the wet season. Meanwhile, the diversity of fish was low at the end of the lagoon during the wet season and in the dry and transitional seasons in the right open sea, but moderate in the rest of the stations. The community condition seemed quite different in different season. Overall, the fish community was stable and the diversity was high in the end zone and middle of the lagoon during the transition season, as well as in the middle of the lagoon and right open sea during the wet season. Conversely, the condition of the fish community to the left of the lagoon was less diverse and less rich, but this may have been due to undersampling.

Deeper water during high tides may support more space as temporary refuges for high trophic level carnivores and herbivores in intertidal meadows (Lee et al., 2014). Additionally, daily crepuscular migrations are also common among fishes in tropical marine ecosystems, wherein diurnal reef fish such as Acanthuridae and Chaetodontidae move from their daytime foraging sites to nighttime shelter in cavities of corals or seagrass (Krumme, 2009). Further studies should consider these factors.

4.3 *Nursery function of seagrass meadows for fishes*

One conspicuous feature of seagrass meadows is the high densities of juvenile fish. Based on the spatial separation between juvenile and adult populations, seagrass meadows have been assumed to function as important nursery areas that contribute to adult populations (Parrish, 1989). Three hypotheses have been proposed to explain the attractiveness of seagrass meadows and mangrove for fish assemblages: (1) the food availability hypothesis, suggests that seagrass meadows harbor a high abundance of food; (2) the predation risk hypothesis, suggests that the lower densities of predators and the higher water turbidity lead to a lower predation pressure; and (3) the structural heterogeneity hypothesis, suggests that fish are attracted to the complex structure provided by seagrass shoots (Laegdsgaard and Johnson, 2001; Verweij and Nagelkerken, 2007). Thus, the factors like turbidity and seagrass structure likely contribute to the underlying mechanisms that regulate the nursery-role measures of density, growth, and survival (Nagelkerken, 2009). Considering that the coverage by seagrass is up to 65% and that the lagoon is surrounded by mangrove, the structural heterogeneity of the lagoon is high enough to be a nursery area for fish.

Of the 87 species collected, the maximum length of 81 species was less than their length at maturity (Table A1), suggesting that seagrass meadows serve as nursery habitats for many fish species. This conclusion is in agreement with the widely held hypothesis (Hemminga and Duarte, 2000). The length of some specimens of *Aeoliscus strigatus*, *Apogon margaritophorus*, *Cheilio inermis*, *Sphaeramia orbicularis*, *Syngnathoides biaculeatus*, and *Yarica hyalosoma* exceeded their length at maturity, although most individuals of *Apogon margaritophorus*, *Sphaeramia orbicularis*, and *Syngnathoides biaculeatus* were still less than their adult size. Adult reef fishes utilize seagrasses mainly as nursery grounds. For example, juveniles hide from predators and feed in seagrass, indicating a critical role of seagrass meadows for survival of juvenile snappers in North Sulawesi and in the Banten Bay (Nuraini et al., 2007). This has been similarly demonstrated in both tropical and temperate areas, such as in northern Queensland, Australia estuarine seagrass meadows, where most of the fish were found to be juveniles (Coles et al., 1993), as well as in the Chesapeake Bay (Sobocinski et al., 2013). Thus, the conservation and management of seagrass meadows, as one of the most threatened tropical coastal habitats, is of utmost importance.

4.4 *Summary and conclusions*

This study analyzed the composition and spatio-temporal variation of the fish community in a North Sulawesian seagrass meadow. The diversity of fish assemblage was relatively high, with a Shannon-Wiener index ranging from 1.57 to 3.69. Apogonidae was the most abundant family, with *Apogon lateralis* as the most abundant species. Regarding the spatial distribution, the end, middle and mouth of the lagoon were always found to be clustered together first as a whole because of substrate types in those zones. The greater fish species, fish abundance and fish biomass in the dry and wet season than those in the transition season, was attributed to the strong monsoon, which provided a more suitable environment and sufficient food for the fish. The fact that the maximum length of most of captured species was less than their length at maturity suggests that seagrass meadows are nursery habitats for fishes. It is important to further the research in this topic for conservation of seagrass meadows.

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Appendix:

Table A1. The number and weight of seagrass fish species of each family

Species	Family	Number	Weight/g	Individual density /ind.·(100 m^2)$^{-1}$	Biomass density /g·(100 m^2)$^{-1}$	L_{min}/mm	L_{max}/mm	$L_{maturity}$/mm
Acanthurus xanthopterus	Acanthuridae	3	45.0	0.03	0.51	40.3	45.6	355.0
Acreichthys tomentosus	Monacanthidae	214	1 020.0	0.99	4.16	14.0	70.9	77.0
Aeoliscus strigatus	Centriscidae	14	43.0	0.03	0.08	136.0	142.4	100.0
Aluterus scriptus	Monacanthidae	3	48.7	0.02	0.27	47.1	90.6	583.0
Ambasis sp. 1	Ambassidae	286	625.9	0.86	1.83	8.1	59.5	129.0
Ambasis sp. 2	Ambassidae	177	244.0	0.49	0.67	29.3	56.4	129.0
Amblygobius albimaculatus	Gobiidae	5	77.2	0.03	0.52	59.0	93.2	118.0
Amblygobius phalaena	Gobiidae	1	3.1	0.01	0.02		47.7	100.0
Apogon lateralis	Apogonidae	986	1 401.6	3.39	5.22	15.8	54.0	76.0
Apogon margaritophorus	Apogonidae	70	88.3	0.33	0.44	19.8	90.0	48.0
Apogon sp.	Apogonidae	350	701.6	1.33	3.08	26.0	59.0	70.0
Arothron hispidus	Tetraodontidae	1	201.3	0.00	0.54		150.3	290.0
Arothron manilensis	Tetraodontidae	26	604.7	0.09	1.44	12.9	97.0	190.0
Atule mate	Carangidae	1	1.4	0.00	0.00		39.6	197.0
Aulostomus chinensis	Aulostomidae	2	21.2	0.01	0.12	153.6	216.0	440.0
Aurigequula fasciata	Leiognathidae	26	243.7	0.12	0.97	28.0	78.2	169.0
Balistoides viridescens	Balistidae	3	4.5	0.01	0.02	226.0	308.1	415.0
Bothus pantherinus	Bothidae	11	825.8	0.00	0.00	46.0	66.0	100.0
Brachirus sp.	Soleidae	1	3.1	0.00	0.01		95.0	228.0
Butis butis	Eleotridae	10	29.9	0.08	2.32	29.2	34.0	82.0
Canthigaster compressa	Tetraodontidae	2	55.9	0.01	0.02	82.1	99.0	157.0
Caranx melampygus	Carangidae	1	35.1	0.00	0.08		100.2	513.0
Caranx sexfasciatus	Carangidae	1	3.4	0.00	0.01		461.1	484.0
Caranx sp.	Carangidae	2	11.9	0.01	0.06	58.3	60.1	484.0
Chaetobranchopsis orbicularis	Cichlidae	1	5.2	0.14	0.76		90.1	290.0
Chaetodon sp.	Chaetodontidae	2	13.7	0.01	0.09	38.6	58.8	118.0
Cheilio inermis	Labridae	2	108.7	0.01	0.17	90.1	94.1	88.0
Cheilodipterus quinquelineatus	Apogonidae	13	270.1	0.07	0.49	79.7	155.0	228.0
Chelonodon patoca	Tetraodontidae	7	184.9	0.03	1.69	56.9	91.5	290.0
Cociella punctata	Platycephalidae	1	0.1	0.00	0.00		22.7	88.0
Crenimugil crenilabis	Mugilidae	2	172.8	0.01	0.39	78.7	189.0	341.0
Ctenochaetus striatus	Acanthuridae	6	279.4	0.07	3.48	77.2	107.8	109.0
Dendrochirus zebra	Scorpaenidae	1	1.0	0.00	0.04		26.2	100.0
Diodon holocanthus	Diodontidae	1	275.4	0.00	0.61		153.3	154.0
Dischistodus perspicillatus	Pomacentridae	12	138.2	0.02	1.21	30.4	58.9	64.0
Eubleekeria splendens	Leiognathidae	2	26.2	0.02	0.30	81.0	83.6	86.0
Exyrias puntang	Gobiidae	7	168.5	0.04	1.01	80.0	85.1	107.0
Fibramia lateralis	Apogonidae	37	87.5	0.16	0.16	45.0	50.0	76.0
Fibramia thermalis	Apogonidae	1	5.2	0.01	0.04		53.8	61.0
Fistularia petimba	Fistulariidae	1	20.5	0.01	0.14		240.3	988.0
Fowleria aurita	Apogonidae	38	46.7	0.07	0.27	17.0	48.5	185.0
Gerres filamentosus	Gerreidae	1	46.2	0.01	0.62		116.0	192.0
Gerres oyena	Gerreidae	18	231.2	0.15	0.58	54.0	108.3	559.0
Gymnothorax albimarginatus	Muraenidae	1	146.1	0.05	1.01		380.5	440.0
Gymnothorax sp.	Muraenidae	30	79.9	0.01	0.24	22.1	61.0	82.0
Halichoeres argus	Labridae	3	12.6	0.02	0.06	55.0	61.1	82.0
Halichoeres papilionaceus	Labridae	58	287.4	0.17	0.72	47.7	63.4	119.0
Hippocampus kuda	Syngnathidae	52	207.4	0.02	0.19	40.3	70.4	82.0
Hypoatherina temminckii	Atherinidae	53	93.8	0.50	1.63	27.0	48.0	76.0
Istigobius ornatus	Gobiidae	16	38.9	0.02	0.05	23.0	60.0	76.0
Leptoscarus vaigiensis	Scaridae	1	9.6	0.01	0.02		31.6	212.0
Lethrinus harak	Lethrinidae	35	558.9	0.18	6.83	30.9	80.5	233.0

to be continued

Continued from Table A1

Species	Family	Number	Weight/g	Individual density /ind.·(100 m^2)$^{-1}$	Biomass density /g·(100 m^2)$^{-1}$	L_{min}/mm	L_{max}/mm	$L_{maturity}$/mm
Lutjanus argentimaculatus	Lutjanidae	1	63.7	0.01	0.85		122.0	546.0
Lutjanus fulviflamma	Lutjanidae	6	101.2	0.03	0.26	59.5	119.0	136.0
Lutjanus russellii	Lutjanidae	3	51.7	0.01	0.14	84.0	88.9	290.0
Meiacanthus grammistes	Blenniidae	8	6.9	0.03	0.03	34.0	44.0	76.0
Monodactylus argenteus	Monodactylidae	46	145.6	0.14	0.37	12.6	62.0	169.0
Neoglyphidodon melas	Pomacentridae	6	178.1	0.03	1.98	26.7	40.8	118.0
Ostorhinchus margaritophorus	Apogonidae	318	390.4	0.76	0.94	47.8	93.7	192.0
Parupeneus barberinus	Mullidae	7	128.4	0.05	1.56	47.8	93.7	192.0
Pelates quadrilineatus	Terapontidae	13	39.9	0.06	0.19	34.1	63.0	185.0
Petroscirtes variabilis	Blenniidae	18	25.0	0.07	0.10	36.8	67.4	100.0
Plagiotremus tapeinosoma	Blenniidae	13	14.0	0.04	0.04	27.3	51.4	94.0
Platax boersii	Ephippidae	72	116.4	0.48	0.75	31.2	51.5	238.0
Plotosus lineatus	Plotosidae	14	209.9	0.03	0.47	49.2	170.4	169.0
Pseudomonacanthus peroni	Monacanthidae	13	320.8	0.05	1.27	56.0	125.0	212.0
Rhinomuraena quaesita	Muraenidae	1	21.3	0.00	0.04		470.0	675.0
Sardinella lemuru	Clupeidae	1	2.7	0.00	0.01		54.7	136.0
Saurida gracilis	Synodontidae	3	231.7	0.03	2.83	57.0	119.2	196.0
Scarus ghobban	Scaridae	1	137.6	0.01	1.84		156.4	488.0
Scolopsis bilineatus	Nemipteridae	3	5.2	0.01	0.01	35.4	39.0	157.0
Scolopsis ciliata	Nemipteridae	18	175.9	0.07	1.02	40.0	76.0	157.0
Scolopsis lineata	Nemipteridae	2	58.5	0.01	0.17	50.6	65.7	157.0
Scomberomorus commerson	Scombridae	1	1.0	0.00	0.00		389.2	611.0
Scorpaenodes sp.	Scorpaenidae	1	8.9	0.01	0.06		43.9	82.0
Siganus canaliculatus	Siganidae	64	1 006.4	0.31	10.40	29.3	92.1	102.0
Siganus doliatus	Siganidae	2	4.3	0.00	0.01	38.9	43.8	157.0
Siganus guttatus	Siganidae	25	210.7	0.08	0.87	18.0	52.0	191.0
Sphaeramia orbicularis	Apogonidae	374	2 884.4	2.14	17.25	16.3	70.9	70.0
Sphyraena barracuda	Sphyraenidae	32	1 423.7	0.13	3.46	75.4	233.0	877.0
Syngnathoides biaculeatus	Syngnathidae	48	377.3	0.15	1.12	14.3	259.0	156.0
Terapon jarbua	Terapontidae	2	124.3	0.03	1.66	80.0	81.0	208.0
Toxotes jaculatrix	Toxotidae	10	879.8	0.09	9.71	86.0	139.9	185.0
Tylosurus crocodilus	Belonidae	1	343.5	0.00	0.00		440.5	767.0
Tylosurus melanotus	Belonidae	34	2 148.0	0.17	10.39	154.0	352.0	535.0
Yarica hyalosoma	Apogonidae	1	46.0	0.01	0.61		147.5	112.0
Zenarchopterus dispar	Zenarchopteridae	77	512.1	0.34	2.50	51.0	126.0	146.0