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Seagrass-associated fish species' richness: evidence to support conservation along the south coast of Lombok Island, Indonesia

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Abstract. *Syukur A, Al-Idrus A, Zulkifli L. 2021. Seagrass-associated fish species' richness: evidence to support conservation along the South Coast of Lombok Island, Indonesia. Biodiversitas 22: 988-998.* The concept of seagrass conservation at a global scale tends to be less appropriate with regard to the environmental conditions at the regional and local scales, and thus, there is a need for scientific studies at the regional and local scales to support conservation measures. This research aimed to describe the importance of seagrass conservation based on the species richness of seagrass-associated fish. Data were collected from seven seagrass locations using surveys and observation. Data on the fish species present were collected with the gear used by small-scale fishermen to catch fish in the seagrass area and the surrounding waters. Data analysis was descriptive; the statistical analyses performed included calculation of the Shannon-Wiener index of diversity (H '), the Simpson evenness index (E), and the Morisita species richness index (D) as well as cluster analysis. All statistical analyses were performed in IBM SPSS Statistics 25. We found 104 fish species belonging to 38 families. Leiognathidae, Apogonidae, Clupeidae, Carangidae, Channidae, Sillaginidae, and Mullidae are families with high abundance, and 16 fish species have an abundance of individuals above the average value (192 individuals) of the total number of individuals (20,352). Meanwhile, 94.37% of the fish families are the target catch of small-scale fishermen (commercial fish). The diversity of fish species associated with seagrass in the study location is evidence of the survival of seagrass provision services at the local scale for fish. Therefore, scientific evidence of the species richness of fish, species yang domina, and its importance for small-scale fisheries at each seagrass bed in the study location can be used as a source of information for increasing and improving seagrass conservation efforts at the local scale.

Keywords: Ecological index, local scale, seagrass conservation, species richness

INTRODUCTION

Seagrass is a higher plant that thrives in oligotrophic environments (Anton et al. 2020) and plays a vital role in human wellbeing (Ambo-Rappe 2010; Nordlund et al. 2010; Cullen-Unsworth et al. 2014), especially in fishery production at the global, regional, and local scales (de la Torre-Castro et al. 2014; Nordlund et al. 2018; Unsworth et al. 2019). Conversely, essential services provide habitats and food to diverse marine life (Du et al. 2019; Moussa et al. 2020). However, seagrass status and protection rarely come under the spotlight as compared to other ecosystems in coastal areas, such as mangrove ecosystems and coral reefs (Larkum et al. 2018; Waycott et al. 2009). Meanwhile, ecological evidence indicates that 20% of commercial fish species are dependent on seagrass during their life cycle (Ambo-Rappe et al. 2013), as permanent, temporary, regular, or irregular residents. Furthermore, seagrass cover and canopy structure positively correlate with fish species' abundance (Susilo et al. 2018). Meanwhile, areas vegetated by seagrass can increase fish biomass, and the economic value per hectare has been estimated to be higher compared to areas with mangrove vegetation and tidal swamps (Jänes et al. 2020).

Seagrass is currently threatened with destruction in many places, and seagrass beds in Indonesia are under widespread threat. The implications of this can significantly impact local food supply as well as global fishery production, carbon cycling, and biodiversity conservation (Unsworth et al. 2018). The usual source of the threats is anthropogenic activity (Syukur et al. 2017), and the danger of damage is a significant challenge in conservation efforts. Obstacles in seagrass conservation efforts are as follows: (i) affirmation must be provided so that the community realizes or recognizes the importance of seagrass; (ii) data and information on the current status and condition of seagrass are not yet regular; (iii) management actions at the local scale have not taken the appropriate steps; (iv) efforts are needed to balance human needs and survival; (v) there is limited scientific research output to support conservation actions; (vi) conservation efforts are increasingly difficult in the era of climate change (Unsworth et al. 2019). Nevertheless, seagrass conservation efforts at a local scale can be achieved through affirmation and optimizing the participation of the fishing community (Jayabaskaran et al. 2018; Syukur et al. 2018). However, the available information related to seagrass damage on a local scale is minimal and inadequate.

Seagrasses, which have a vital function in supporting food security, are still widely underappreciated. This is a factor in the difficulty of preventing seagrass degradation. Another factor is the incomplete understanding of the ecosystem services provided by seagrass habitats,

particularly those related to management in the fisheries sector. Meanwhile, the integration of bad planning on the part of the jurisdiction and sectoral management often causes the continual degradation of biodiversity and ecosystem values due to anthropogenic activities and climate change (Griffiths et al. 2020) Therefore, policies that are oriented toward the protection of fish resources and their ecosystems are urgently needed. The alternative is to provide scientific information, especially relating to local specifics (ecology, economy, and culture). In this regard, local specific components are the primary factors for success in integrated management for seagrass conservation and restoration purposes (de la Torre-Castro 2006; Newmaster et al. 2011).

Furthermore, the objective of seagrass conservation or management is the preservation of fish resources and their ecosystems. In this case, the indicators of fish species diversity that are considered can include fish abundance, population, fish size, and the number and diversity of fish species in seagrass areas, such as marine protected areas (Segiwati et al. 2015; Yuliana et al. 2019). Scientific facts support the contention that seagrass beds are very important for fishery production and play an essential role in the productivity and biodiversity of coral reefs and other ecosystems in coastal waters (Unsworth and Cullen 2010). However, research efforts to inform policy and practice in this regard are still minimal. From 1,122 articles on seagrass published from 1973 to 2016 in the Asian region (including China), 77% is high and thus inappropriate, and only 23% are about science (Fortes 2018). However, there has been little research related to seagrass fisheries resources, fish stocks, or fish communities, particularly to support conservation or management policies at the local and regional scales, such as at the study site. Therefore, this research was conducted to obtain scientific information on the diversity of fish species associated with seagrass. The aim was to provide detailed scientific knowledge as a basis for seagrass conservation efforts at the local scale. The results of this research can serve as a source of information for seagrass conservation policies in the study location, not only for the fisheries sector but also for the development of seagrass beds as natural tourism spots.

MATERIALS AND METHODS

Site location

The study was conducted from April to August 2020 at seven locations (Figure 1) in Lombok Island, West Nusa Tenggara Province, Indonesia, i.e. East Lombok District (Gili Kere, Tanjung Luar, Lungkak, and Poton Bakau) and Central Lombok District (Kute, Gerupuk, and Awang). The seagrass species reported at the locations in Central Lombok are as follows: Kute Bay (11 species), Grupuk Bay (10 species) (Kiswara and Winardi, 1994), and Teluk Awang (seven species) (Sari et al. 2020). Meanwhile, nine seagrass species have been reported from the four sampling locations in East Lombok (Syukur et al. 2017). In terms of the environmental conditions around the seagrass areas, some sites—such as Lungkak, Poton Bakau, and Awang—were close to the mangrove ecosystem.

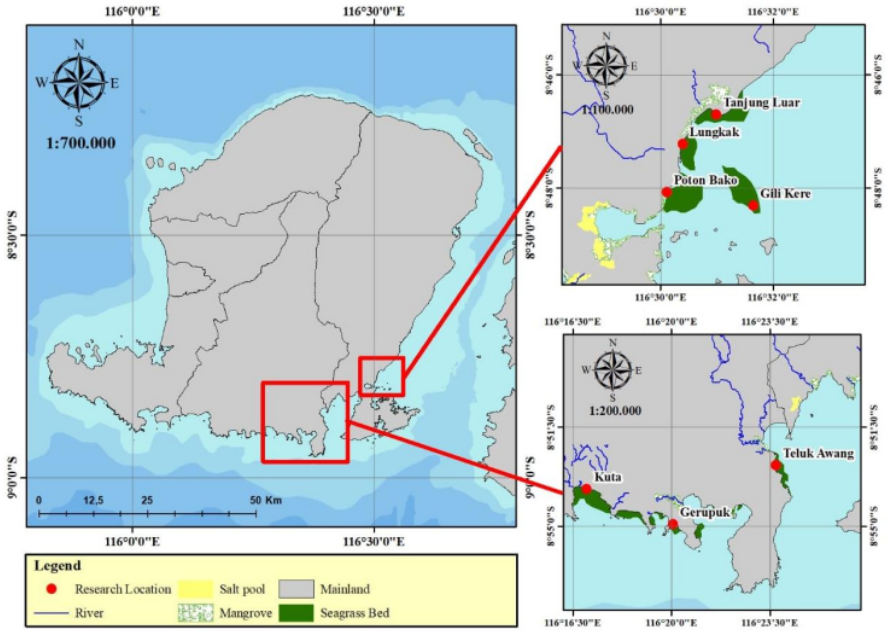

Figure 1. A map of Lombok Island, Indonesia, showing the seven research locations

Most of the mangrove vegetation along the coast around the research locations is the result of replanting efforts in the early 1990's (Idrus et al. 2019). While the seagrass area at Tanjung Luar is adjacent to the Fish Landing Site, the seagrass sites in Gili Kere, Gerupuk, and Kute are adjacent to coral reef ecosystems, and the latter three seagrass locations have become nature tourism destinations on the southern coast of Lombok Island (Syukur et al. 2020).

Data collection and analysis

Primary data was collected through surveys and observation at the seven predetermined locations. The data on fish species at each location was collected using fishing gear belonging to the fishers who generally catch fish in the seagrass area. Furthermore, data collection was carried out by the research team, assisted by the fishermen. The fishing gear used was a kind of mini-trawl. The specifications were as follows: net length 80 m with 1.25", 1", 0.75", and 0.625" mesh-size, and 0.5" mesh at the cod end. The nets were towed by fishing boats at an average speed of 5m/minute, with each tow lasting around two hours. Data was collected every month, during the full moon phase (days 14-16 of the lunar phase) from April to August 2019. The fish caught were placed in a container that had been provided.

The fish caught in each sampling tow were grouped and separated according to family and species. The identification of the fish species employed a standard identification reference (Tsukamoto et al. 1997). The data collected was tabulated and analyzed using descriptive statistics. The diversity and composition of the fish community were evaluated using three indices: the Shannon-Waiver diversity index (H ') (Ludwig and Reynolds, 1988), the Simpson evenness index (E), and the Morisita distribution index of species richness (D). Furthermore, a cluster analysis was performed based on the ecological index values (H ', E, and D). All statistical analyses were performed in IBM SPSS Statistics 25.

RESULTS AND DISCUSSION

Composition of fish in the study area

The results reveal that 20,352 individual fish (specimens) were identified as belonging to 38 fish families and 104 species (Table 1). Meanwhile, in this study, 16 fish species contributed an above-average number of individuals (more than 192 specimens) to the total sample; they include *Archamia goni* (19.045%), *Leiognathus equulus* (11.100%), *Leiognahus bindus* (8.658%), *Sardinella gibbosa* (6.761%), *Ambassis buruensis* (4.756%), *Scomberoides lysan* (2.457%), *Leiognathus splendens* (2.241%), *Sillago macrolepis* (2.069%), *Apogonichthys ocellatus* (2.034%), *Acreichthys tomentosus* (2.010%), *Sillago sihama* (1.911%), *Leiognathus oblongus* (1.695%), *Gazza rhombea* (1.322%), *Leiognathus daura* (1.125%), *Caranx ignobilis* (1.110%), and *Plectorhinchus flavomaculatus* (1.037%). However, 84% of the species had below-average values. Furthermore, in the category of species with the number of individuals below the average, 20 species had number of individuals between one and 10, and the fish species with the lowest number of individuals were *Gerres erythrourus* from the family Gerreidae and *Abudefduf sexfasciatus* from the family Pomacentridae. Meanwhile, it was found that seven of the 38 families' contribution was above the average of the total number of individuals/families (more than 536): Leiognathidae (27.78%), Apogonidae (21.41%), Clupeidae (11.61%), Carangidae (8.03%), Channidae (4.75%), Sillaginidae (4.57%), and Mullidae (2.97%). Meanwhile, the species composition by fish family (Figure 2) showed that Leiognathidae was the most speciose family, with 10.377% of species, followed by Carangidae and Tetraodontidae (both contributing 7.547%), Pomacentridae (6. 604%), and Apogonidae (5.660%). Therefore, the existence of these seven families is very important in the structure of the fish community in the study location. However, the presence of other families contributes to the species' richness value of the fish communities associated with seagrass in the study location.

Other studies on the number of fish families found in seagrass beds recorded 35 families in the Jordanian coast (Khalaf et al. 2012), 35 families in Ban Pak Klong, Thailand (Phinrub et al. 2014), 41 families in Gazi Bay, Kenya (Musembi et al. 2019), 26 families in Karang Congkak Island, Kepulauan Seribu National Park, Indonesia (Simanjuntak et al. 2020), 24 families in Jervis Bay Marine Park, New South Wales, Australia (Kiggins et al. 2019), 44 families in the seagrass ecosystem of Minicoy Atoll, Lakshadweep, India (Prabhakaran et al. 2013), and 38 families in the inner Ambon Bay, eastern Indonesia (Ambo-Rappe et al. 2013). Furthermore, at twenty-two seagrass beds, there were differences in the number of fish families (Ambo-Rappe 2020). Thus, different locations of seagrass beds, including the study locations, possess different attractions for the fish. This can be influenced by habitat characteristics or habitat structure variability (Bijoy et al. 2013; Vieira et al. 2020), whether the habitat's adjacent to seagrass (mangroves, coral reefs, and other habitats), fragmentation of the seagrass habitat (Hyndes et al. 2018), and the diversity of the seagrass species' morphology (Ambo-Rappe et al. 2013). Furthermore, the existence of fish species in seagrass is useful for assessing the level of species diversity (Short et al. 2007).

The presence of a dominant fish species is another parameter that explains the difference in the composition of fish communities between locations. For instance, in the Quirimba Archipelago, Northern Mozambique, the dominant fish species were *Siganus sutor*, *Leptoscarus vaigiensis*, *Lethrinus variegatus*, *Lethrinus lentjan*, and *Gerres oyena* (Gell and Whitting 2002), while in Pak Klong Ban, Thailand, they were *Sillago sihama*, *Leiognathus jonesi*, and *Gerres erythrourus* (Phinrub et al. 2014). With respect to some other sites in Indonesia, at Muara Binuangeun, Lebak Banten, the dominant species were *Moolgarda sp* and *Istiblennius edentulus* (Kholis et al. 2017), while *Spratelloides gracilis*, *Stenatherina panatela*, *Siganus canaliculatus*, *Gerresoyena* sp., and *Siganus spinus* were the dominant species in the seagrass

beds of Karang Congkak Island, Kepulauan Seribu National Park, Indonesia (Simanjuntak et al. 2020). In Youtefa Bay, Jayapura, Papua, the dominant species were *Scolopsis lineata*, *Apogon ceramensis*, *Parupeneus barberinus*, *Aeliscus strigatus*, *Siganus fuscescens*, and *Siganus canaliculatus* (Tebaiy et al. 2017). Fish species that gather on seagrass with dominant indicators of species richness and species constit the main value of seagrass as a fish habitat (Nordlund et al. 2018). Therefore, in this study, the species richness and dominant fish species are important information that provides a scientific basis for protecting or conserving seagrass.

Table 1. The total number and species composition of the sampled fish associated with seagrass at the seven study locations.

Family	Species	No. of specimens/species	Percentage of specimens/species
Apogonidae	*Apogonichthys ocellatus*	414	2.03
	Archamia goni	3876	19.04
	Archamia zosterophora	14	0.07
	Cheilodipterus macrodon	51	0.25
	Foa brachygramma	3	0.01
Atherinidae	*Atherinomorus duodecimalis*	2	0.01
	Atherinomorus lacunosus	30	0.15
Blenniidae	*Alticus saliens*	72	0.35
	Andamia tetradactylus	5	0.02
	Petroscirtes variabilis	89	0.44
Bothidae	*Bothus pantherinus*	30	0.15
Channidae	*nbassis buruensis*	968	4.76
Carangidae	*Atule mate*	153	0.75
	Caranx ignobilis	226	1.11
	Caranx melampygus	108	0.53
	Caranx sexfasciatus	393	1.93
	Scomberoides tala	40	0.20
	Selar crumenophthalmus	142	0.70
	Scomberoides lysan	500	2.46
	rachinotus blochii	73	0.36
Clupeidae	*Sardinella gibbosa*	1376	6.76
	Sardinella lemuru	987	4.85
Cynoglossidae	*Paraplagusia bilineata*	28	0.14
	Paraplagusia blochi	29	0.14
Diodontidae	*Diodon liturosus*	6	0.03
Engraulidae	*Stolephorus commersonii*	54	0.27
	Stolephorus indicus	268	1.32
	Thryssa setirostris	9	0.04
Ephippidae	*Platax boersii*	20	0.10
Fistulariidae	*Fistularia commersonii*	38	0.19
Gerreidae	*erres abbreviatus*	53	0.26
	Gerres erythrourus	1	0.00
	Gerres filamentosus	370	1.82
	Gerres oyena	44	0.22
Haemulidae	*Plectorhinchus celebicus*	54	0.27
	Plectorhinchus flavomaculatus	211	1.04
Hemiramphidae	*Hemiramphus far*	144	0.71
Labridae	*Halichoeres papilionaceus*	2	0.01
	Thalassoma hardwicke	3	0.01
Leiognathidae	*nbassis urotaenia*	27	0.13
	Gazza achlamys	15	0.07
	Gazza minuta	92	0.45
	Cynoglossus puncticeps	18	0.09
	Gazza rhombea	269	1.32
	Leiognathus daura	229	1.13
	Leiognathus ulus	2259	11.10
	Leiognathus bindus	1762	8.66
	Leiognathus rapsoni	56	0.28
	Leiognathus splendens	456	2.24
	Leiognathus oblongus	345	1.70
	Secutor interruptus	127	0.62
Lethrinidae	*Gymnocranius elongatus*	64	0.31
	Lethrinus variegatus	24	0.12
Lutjanidae	*Lutjanus argentimaculatus*	108	0.53
	Lutjanus boutton	103	0.51
	Lutjanus erythropterus	64	0.31
	Lutjanus	91	0.45
Mugilidae	*Moolgarda delicates*	109	0.54
Mullidae	*Pempheris oualensis*	22	0.11
	Upeneus sulphureus	84	0.41
	Upeneus tragula	24	0.12
	Upeneus vittatus	476	2.34
Monacanthidae	*Acreichthys tomentosus*	409	2.01
	Acreichthys sp.	68	0.33
Plotosidae	*Plotosus lineatus*	3	0.01
Polynemidae	*Filimanus xanthone*	162	0.80
	Polynemus plebeius	9	0.04
Pomacentridae	*Abudefduf notatus*	16	0.08
	udefduf vaigiensis	11	0.05
	Abudefduf sexfasciatus	1	0.00
	Abudefduf septemfasciatus	6	0.03
	Amphiprion frenatus	11	0.05
	Neopomacentrus azysron	55	0.27
	Pomacentrus lepidogenys	5	0.02
Scaridae	*Calotomus spinidens*	24	0.12
	Leptoscarus vaigiensis	33	0.16
Scianidae	*Johnius amblycephalus*	7	0.03
	Johnius borneensis	2	0.01
	Johnius macropterus	6	0.03
Scorpaenidae	*Ablabys taenianotus*	4	0.02
Serranidae	*Epinephelus bontoides*	66	0.32
Siganidae	*ganus argenteus*	12	0.06
	Siganus canaliculatus	62	0.30
	Siganus guttatus	42	0.21
Sillaginidae	*Sillago chondropus*	121	0.59
	Sillago sihama	389	1.91
	Sillago macrolepis	421	2.07
Soleidae	*Cynoglossus lingua*	22	0.11
Sphyraenidae	*Sphyraena barracuda*	25	0.12
Syngnathidae	*Syngnathoides biaculeatus*	2	0.01
	Synodus dermatogenys	4	0.02
Synodontidae	*Saurida gracilis*	2	0.01
	Saurida nebulosa	47	0.23
	hyraena flavicauda	46	0.23
Tetraodontidae	*Arothron immaculatus*	179	0.88
	Arothron manilensis	118	0.58
	Canthigaster compressa	51	0.25
	Chelonodon patoca	51	0.25
	Lagocephalus gloveri	8	0.04
	Lagocephalus ivheeleri	12	0.06
	Lagocephalus lunaris	3	0.01
	Takifugu radiatus	2	0.01
Triacanthidae	*Triacanthus nieuhofi*	36	0.18
Trichiuridae	*Trichiurus lepturus*	89	0.44
	Total	20352	100

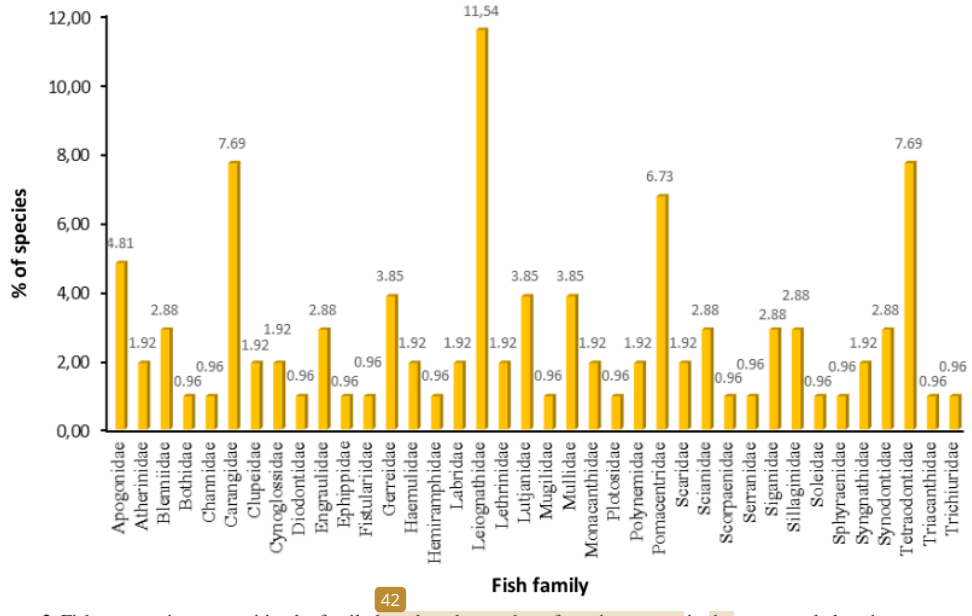

Figure 2. Fish community composition by family based on the number of species present in the seven study locations

Ecological index of fish species associated with seagrass in the seven study sites

The results of the analysis of the diversity index (H '), evenness index (E), and species richness index (D) the seven sampling locations are shown in Figure 3. The results of this study indicate that Tanjung Luar is the location with the highest H ', E, and D values, and Gerupak is the location with the lowest ecological index values for H ', E, and D. Meanwhile, the diversity index value at all seagrass locations was between 2.40 and 2.80, with an average value of 2.61. Meanwhile, the species richness index values were between 2.14 and 8.47, with an average of 7.74, and the evenness index ranged from 0.57-0.69, with an average value of 0.62. In this case, the value of H ' can describe the structure of the fish community at the seven sampling locations. In addition, it can explain the distribution of species based on the number of individuals. However, the value of E, which is below one, indicates that no fish species is very dominant at the seven sampling locations. Ecological indices, in addition to those described above, the next assessment was based on month (Table 2). The results of the analysis show that the average H 'value at the seven sampling locations was 2.35 ± 0.24-2.80 ± 0.19, the average E value was 0.59 ± 0.08-0.78 ± 0.10, and the average D value was 6.30 ± 0.17-8.51 ± 0.35. Meanwhile, the highest H 'value was 2.99 in June in Kute, and the lowest was 2.21 in April in Gili Kere. The highest E value was 0.89 in June, and the lowest was 0.49 in April in Gili Kere. Finally, the highest D value was 8.80 in June in Tanjung Luar, and the lowest was 3.04 in April in Gerupuk. Because of this, the ecological index value of fish species found in the study location can provide environmental evidence that the presence of seagrass is needed by marine organisms to survive, but that fish density in seagrass is often dominated by juvenile fish groups (Dorenbosch et al. 2005; Hylkema et al. 2015). Moreover, it can explain the vital role of seagrass to fish, which includes providing food, rearing, and protection from predators, and especially fish biodiversity (Jackson et al. 2001; Heck et al. 2003; Bertelli and Unsworth 2014; Prasetya and Purwanti 2017; Hidayati and Suparmoko 2018).

The results of the one-way ANOVA analysis of the ecological index values (H ', E, and D) are presented in Table 2. H ' and E show no significant differences, with an F_{count} value of 2.689, F_{table} 13.013, and P_{value} 2.93 for H ', and F_{count} 2.758, F_{table} 5.012, and P_{value} 0.004 for E. Meanwhile, the value of D shows that there is a significant difference, with F_{count} 2.758, F_{table} 0.582, and P-value 0.677 (Table 3). This explains that the seven seagrass beds have extremely different species and individuals that are evenly distributed or not. The significant difference in the values of D can be explained through the results of the analysis cluster (Figure 4), where Awang and Lungkak are in one group and have similar characteristics, namely that they are situated close to river estuaries and mangrove ecosystems. Furthermore, Gili Kere and Poton Bakau are in one group because they are in close proximity. Other locations, such as Tanjung Luar, have similarities with Gili Kere and Poton Bakau, Kute has similarities with Lungkak and Awang, and only Gerupk does not belong to the first and second stage grouping. Furthermore, the composition of the fish species at the seven sampling locations consisted 94.37% of the commercial fish or the target fish families caught by fishermen. In this case, more than 20% of the commercial fish species experience a shift in habitat use between

ecosystems adjacent to seagrass (Honda et al. 2013). Therefore, the presence of other ecosystems and commercial fish species has contributed to the differences in fish species richness, such as in the study sites.

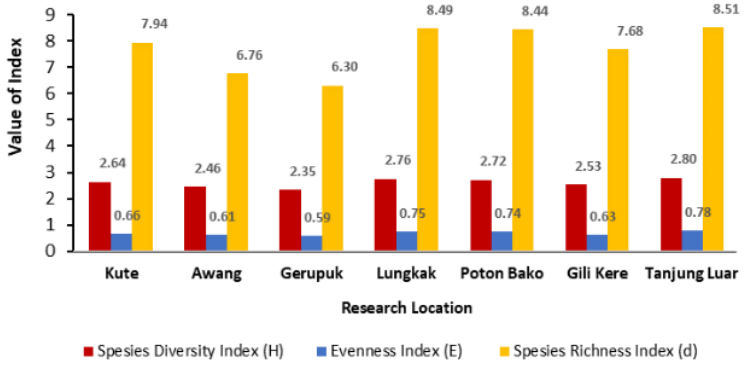

Figure 3. Diversity index, evenness index, and species richness index at the seven survey locations in the study area

Table 2. Ecological index values for seagrass-associated fish species by month at the seven study locations

Location	Index	Month					
		April	May	June	July	August	Mean ±SD
Kute	Species Diversity Index (H ')	2.31	2.52	2.99	2.64	2.76	2.64±0.26
	Evenness Index (E)	0.57	0.65	0.72	0.67	0.69	0.66±0.06
	Species Richness Index (D)	7.56	7.79	8.2	8.04	8.11	7.94±0.26
Awang	Species Diversity Index (H ')	2.11	2.32	2.71	2.46	2.68	2.46±0.25
	Evenness Index (E)	0.51	0.56	0.67	0.62	0.68	0.61±0.07
	Species Richness Index (D)	6.42	6.62	7.09	6.78	6.88	6.76±0.25
Gerupuk	Species Diversity Index (H ')	2.09	2.18	2.64	2.28	2.56	2.35±0.24
	Evenness Index (E)	0.5	0.53	0.69	0.56	0.66	0.59±0.08
	Species Richness Index (D)	6.04	6.26	6.48	6.31	6.41	6.30±0.17
Lungkak	Species Diversity Index (H ')	2.46	2.65	2.99	2.73	2.97	2.76±0.22
	Evenness Index (E)	0.69	0.71	0.82	0.74	0.81	0.75±0.06
	Species Richness Index (D)	8.14	8.23	8.91	8.41	8.76	8.44±0.37
Poton Bako	Species Diversity Index (H ')	2.38	2.43	2.97	2.87	2.93	2.72±0.29
	Evenness Index (E)	0.65	0.67	0.81	0.75	0.81	0.74±0.08
	Species Richness Index (D)	7.93	8.21	8.88	8.49	8.67	8.49±0.33
Gili Kere	Species Diversity Index (H ')	2.12	2.21	3.01	2.59	2.73	2.53±0.37
	Evenness Index (E)	0.49	0.59	0.82	0.59	0.64	0.63±0.12
	Species Richness Index (D)	7.21	7.41	8.11	7.76	7.89	7.68±0.36
Tanjung Luar	Species Diversity Index (H ')	2.51	2.71	2.98	2.93	2.87	2.80±0.19
	Evenness Index (E)	0.65	0.71	0.89	0.81	0.82	0.78±0.10
	Species Richness Index (D)	8.04	8.21	8.80	8.72	8.76	8.51±0.35

Table 3. The results of the one-way ANOVA analysis of the ecological indices for seagrass-associated fish at the seven study locations ($\dot{\alpha} = 0{,}05$)

One-way ANOVA	Source of variation	Diversity index (H ')	Evenness index(E)	Richness index (D)
SS	Between Groups	1.778	0.157	2.194
	Within Groups	1.025	0.196	23.532
df	Between Groups	4	4	4
	Within Groups	30	25	25
MS	Between Groups	0.444	0.039	0.548
	Within Groups	0.034	0.007	0.941
F crit		2.689	2.758	2.758
F *table*		13.013	5.012	0.582
P-value		2.932	0.004	0.677

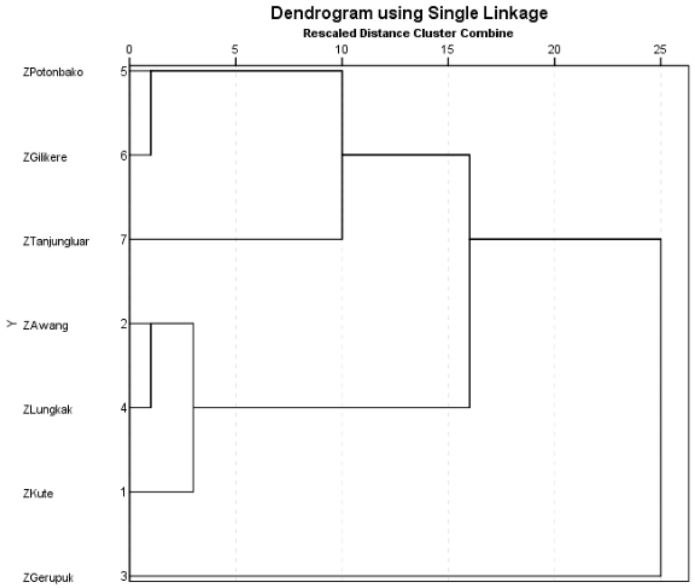

Figure 4. Cluster analysis of the Euclidean distance between seagrass-associated fish communities at the seven study sites

Seagrass conservation

Several research results have proven the importance of intertidal areas, such as mangroves, seagrass beds, and coral reefs, as fish habitats (Unsworth et al. 2009; Honda et al. 2013; Aller et al. 2014; Nagelkerken et al. 2014; Moussa 2018; Moussa et al. 2020). In particular, seagrass beds have contributed to supporting global fisheries' production and local-scale fisheries' sustainability (Nordlund et al. 2018; Unsworth et al. 2019a; Ambo-Rappe 2020). The results of this study indicate the potential to support small-scale fisheries in the study locations. First is the level of distribution of fish species at the seven sampling locations (Table 4); second, 25.96% of fish species can be found at all locations, and only 7.69% are found at one location; third, the richness of fish species at each location is above the average value, i.e., 14.42 out of 104 species at all locations, and the highest number of species is found in Gili Kere (73.08%) and the lowest is in Awang (48.08%) (Figure 5); fourth, 94.73% of fish families are fish groups that are the target catch of small-scale fishermen, and among the families that are not, only 5. Moreover, 26% are from Apogonidae and Cynoglossidae (Table 1). Therefore, the existence of seagrass beds in the study location is very important for the economic sustainability of small-scale fishermen. Meanwhile, the richness of fish species associated with seagrass in the seven sampling locations is a source of the biodiversity of fish resources, which must be protected.

Furthermore, the results of this study can explain the value of the ecological indices H ', E, and D quantitatively (Figure 3 and Table 2) as indicators of the role of seagrass ecological services in providing habitat, food, and shelter from predators. Therefore, the results of this study can become a reference for the design of seagrass conservation plans or seagrass management, worked into an integrated and sustainable management system at the study site. Moreover, the results can become the basis for monitoring and evaluating the changes caused by disturbances or threats, such as species overexploitation, habitat destruction, and other anthropogenic activities as well as climate change. This is very important given the disturbance to biodiversity, especially fish resources, despite conservation efforts, where the loss of biodiversity continues at a regional or global scale in various ecosystems (Mouillot et al. 2013; Villéger et al. 2010). If environmental management is neglected, such as in the study location, it can cause a reduction in the value of biodiversity, particularly fish resources, which will affect the sustainability of ecological processes and the provision of ecosystem services.

The current problem that cannot be resolved is the degradation of seagrass habitats, which can reduce the supply of fish produced by small-scale fishermen. Furthermore, the status of seagrass conditions determines the livelihoods of small-scale fishermen (Cullen-Unsworth et al. 2014; de la Torre-Castro et al. 2014). Therefore, efforts to maintain the condition of the seagrass can be done through conservation. This is very important, as seen by how seagrass conservation through restoration in southern Australia has increased the populations of 15 commercial fish species (Blandon and Zu Ermgassen 2014). Another study explains that the economic value of seagrass beds is dominated by the species *Cymodocea nodosa*, which greatly determines the sustainability of local

fisheries in East Atlantic oceanic islands, especially for fishing and breeding (Tuya et al. 2014). According to the results of this study, 15.73% of the fishermen's target fish group contributed to supporting the sustainability of small-scale fisheries' production. Another extremely important aspect of the results is the value of the ecological indices, where at two sampling locations, the H ' values of 2.53 in Gili Kere and 2.76 in Lungak were higher than in 2017, when the values were 2.448 in Gili Kere and 2.60 in Lungkak (Syukur et al. 2017). However, in two other locations Poton Bakau and Tanjung Luar (Kampung Baru), the values of H ' were lower than in 2017. Therefore, the study of seagrass provisioning services, particularly for fish resources, is produced as scientific information for the management or conservation of local-scale seagrass at the study location.

In connection with the seagrass-associated fish species in the study location, maintaining fish habitats, such as preventing or restraining the damage rate, is crucial. Furthermore, seagrass protection efforts can prevent the degradation or loss of seagrass ecosystem services in the ecosystems of coastal waters, especially for protecting marine biodiversity. Moreover, the damage to seagrass can have negative implications by decreasing the productivity of marine resources, disrupting trophic interactions, and reducing stability in the natural ecosystems in the marine environment (Duffy 2006; Duffy et al. 2015; Best and Stachowicz 2012). In addition, the loss of seagrass vegetation can have a direct effect on fish that need seagrass as a habitat (Patro et al. 2017; Mishra et al. 2019). Therefore, practical initiatives are needed in the conceptualization of pilots to conserve exemplary seagrass beds. In this case, the conservation of seagrass beds can be realized through the participation of fishing communities, especially small-scale fishermen.

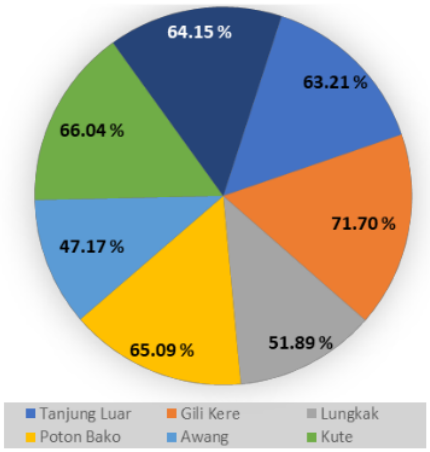

Figure 5. The percentage of all seagrass-associated fish species identified in this study found at each of the seven locations

Table 4. Spatial distribution of the seagrass-associated fish species identified in this study

Spatial distribution	Species present	Number of species
All Locations	*Acreichthys tomentosus, Ambassis buruensis, Archamia goni, Canthigaster compressa, Caranx ignobilis, Caranx melampygus, Caranx sexfasciatus, Chelonodon patoca, Calotomus spinidens, Epinephelus bontoides, Fistularia commersonii, Gazza minuta, Gazza rhombea, Leiognathus bindus, Leiognathus daura, Leiognathus equulus, Leiognathus rapsoni, Lutjanus argentimaculatus, Lutjanus boutton, Lutjanus erythropterus, Moolgarda delicates, Sardinella gibbosa, Saurida nebulosa, Secutor interruptus, Siganus canaliculatus, Sillago sihama, Stolephorus indicus, Upeneus vittatus*	27
Six locations	*Abudefduf vaigiensis, Ambassis urotaenia, Gerres filamentosus, Paraplagusia blochi, Scomberoides lysan, Sillago macrolepis, Stolephorus commersonii, Bothus pantherinus, Sardinella lemuru*	9
Five locations	*Alticus saliens, Arothron immaculatus, Arothron manilensis, Atule mate, Gazza achlamys, Leiognathus oblongus, Platax boersii, Plectorhinchus celebicus, Plectorhinchus flavomaculatus, Selar crumenophthalmus*	10
Four locations	*Abudefduf notatus, Cheilodipterus macrodon, Hemiramphus far, Leiognathus splendens, Siganus guttatus, Sphyraena barracuda, Sphyraena flavicauda, Triacanthus nieuhofi, Upeneus sulphureus*	9
Three Locations	*Abudefduf septemfasciatus, Acreichthys* sp., *Apogonichthys ocellatus, Archamia zosterophora, Atherinomorus lacunosus, Cynoglossus lingua, Cynoglossus puncticeps, Filimanus xanthone, Gymnocranius elongatus, Johnius amblycephalus, Johnius macropterus, Lagocephalus ivheeleri, Lagocephalus lunaris, Leptoscarus vaigiensis, Lethrinus variegatus, Plotosus lineatus, Polynemus plebeius, Pomacentrus lepidogenys, Sillago chondropus, Thalassoma hardwicke, Trachinotus blochii, Trichiurus lepturus, Upeneus tragula*	23
Two Locations	*Amphiprion frenatus, Atherinomorus duodecimalis, Diodon liturosus, Pempheris oualensis, Foa brachygramma, Gerres abbreviatus, Gerrres oyena, Halichoeres papilionaceus, Johnius borneensis, Lagocephalus gloveri, Lutjanus, Paraplagusia bilineata, Petroscirtes variabilis, Saurida gracilis, Scomberoides tala, Siganus argenteus, Synodus dermatogenys*	18
One Location	*Abudefduf sexfasciatus, Andamia tetradactylus, Gerres erythrourus, Neopomacentrus azysron, Syngnathoides biaculeatus, Takifugu radiatus, Thryssa setirostris, Ablabys taenianotus*	8
Total Number of Species		104

In conclusion, the fish communities associated with seagrass in the study sites have two main dimensions in relation to conservation. The first aspect of the diversity of fish species found in the seagrass area of the study location constitutes ecological evidence of the contribution of seagrasses to the sustainability of fish communities. Second, 94.73% of the fish families targeted by small-scale fishermen contribute to supporting the sustainability of small-scale fisheries' production. It is hoped that these two factors can become the primary considerations in the local-scale seagrass management and conservation plan in the study location. Consequently, seagrass conservation efforts at various scales, especially outside protected areas such as the study location and others, are urgently needed to protect and preserve marine biodiversity and economic sustainability for local human communities.

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