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Threats to Seagrass Ecology and Indicators of the Importance of Seagrass Ecological Services in the Coastal Waters of East Lombok, Indonesia

[1]Abdul Syukur, [2]Yusli Wardiatno, [2]Ismudi Muchsin and [2]Mohammad Mukhlis Kamal

[1]Department of Sciences Education,
Faculty of Teacher Training and Education, Mataram University, Indonesia
[2]Department of Aquatic Resources Management,
Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Indonesia

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Corresponding Author:
Abdul Syukur
Department of Sciences Education, Faculty of Teacher Training and Education, Mataram University, Indonesia
Email: syukur_unram@ymail.com

Abstract: Seagrass ecology contributes to the preservation of fish and other biota diversity and is also an important livelihood source for fishermen and local communities. The purpose of our research was (1) to determine the source of the threats toseagrass ecology and to the ecological services it provides for the sustainability of fish resources and (2) to determine the main indicators defining the conservation needs of seagrass in the study area. Data were collected through direct observation, questionnaires, interviews and discussions. Data for fish in the seagrass bed research sites were obtained using mini-trawlers belonging to local fishermen. All data were analyzed using descriptive statistical analyses. The results showed that seagrass beds play an important role in fish ecology and that local livelihoods were highly dependent on small-scale fishing. However, fishermen and local communities also constituted the two main threats to the preservation and sustainability of fish and other biota in the area. Our results found, too, that there is a scarcity of some types of biota: some fish species, mollusks, crabs, see-urchin and some types of sea cucumber were very difficult to find in the seagrass beds that were the focus of our study. Our conclusion is that, given the scarcity of fifteen species of fish, as well as of other biota and the lack of diversity in fish food in our study area, it is imperative that seagrass conservation becomes an important priority for conservation interventions.

Keywords: Resources Threats, Seagrass Ecology Systems, Conservation of Seagrass

Introduction

Seagrass beds are an important habitat in the tropical marine environment. The global species diversity of seagrasses is low (<60 species), but are a key component of ecological systems in the coastal environment and can form extensive meadows supporting high biodiversity (Short *et al*., 2007). Many of the smaller fish species and invertebrates and other animals (e.g., gastropods, bivalves and polychaetes) are found in seagrass beds (Shokri *et al*., 2009; Maheswari *et al*., 2011; Satumanatpan *et al*., 2011) and they support the productivity and fish biodiversity of coral reefs (Bosire *et al*., 2012; Unsworth and Cullen, 2010). *Tripneustes gratilla, Leptoscarus vaigiensis,Chelonia midas* and *Dugong dugong* have all been found to have a high dependence on seagrass (Mamboya *et al*., 2009) and thirteen fish of commercial importance were identified as being recruitment enhanced in seagrass habitat, twelve of which were associated with sufficient life history on seagrass beds in southern Australia (Blandon and zu Ermgassen, 2014) and the artificial seagrass could play a vital role as a nutrient rich habitat for marine fishes (Shahbudin *et al*., 2011). Seagrass beds provide feeding habitats for some life-stages of fish and contribute to stabilizing our climate and support food security (Verweij *et al*., 2006; Unsworth *et al*., 2015), but these impacts have brought about accelerated the decline in seagrass habitats globally (Waycott *et al*., 2009).

Storms and prolonged rain (which affect water clarity) have had a significant impact on seagrass beds in the coastal areas of Indonesia. Declines were associated with storm and cyclone activity and similar to other nearby seagrass areas and natural disturbances such as weather changes affect seagrass populations (Ahmad-Kamil *et al*., 2013; Mckenna *et al*., 2015) and productivity were expected to decrease with decreasing water clarity (van Tussenbroek *et al*., 2014). Our research found that a combination of these factors has resulted in significant damage to hundreds of meters of seagrass beds (Orth *et al*., 2006; Short *et al*., 2006; Brigitta *et al*., 2014). From the review of 45 case studies worldwide for a total loss of 21.023 ha of seagrass vegetation (Erftemeijer and Lewis, 2006) and the coastal nature of Philippine demography, development and facilities, have caused eutrophication of marine waters, which, along with habitat loss, is a major long-term threat to seagrass ecosystems (Fortes, 2011).

Eutrophication of the coastal estuaries is profoundly altering the primary producer, carbon and nitrogen storage capacity of coastal ecosystems at local and regional scales (Schmidt *et al*., 2012). Nevertheless, the increasing human impacts associated with eutrophication and it is possible that could exacerbate seagrass loss (Coll *et al*., 2011; Stoner *et al*., 2014). This indicates that, the anthropogenic factors that negatively influenced over the abundance and distribution of seagrass, through fluvial channels, urban and commercial development, the anchoring of motorized and non-motorized boats, diverse fishing techniques and the dumping of solid waste (Pitanga *et al*., 2012), as though, seagrass in the Western Pacific are showing signs of stress and decline due to human impacts, despite the vastness of the ocean area and relatively low development pressure (Short *et al*., 2014).

Indonesia, the most serious and direct threats to coastal and marine biodiversity are the conversion of the coastal habitats (e.g., mangroves, seagrass beds and estuaries) into man-made land use, such as tambak, industrial estates, settlement; and of coastal and marine resources (Hutomo and Moosa, 2005). Seagrass meadows in Indonesia have also lost their trophic balance due to overexploitation, placing their resilience to poor water quality at risk (Unsworth *et al*., 2015). Anthropogenic activities, particularly port development, livestock grazing, land conversion and over-exploitation by fishermen and local communities have had a major impact, too. Examples of areas where extensive damage has occurred include Gerupuk and Kuta South Lombok and the coastal waters of East Lombok (Syukur *et al*., 2012).

Conservation measures urgently need to be implemented in order to preserve and maintain the remaining seagrass beds and to protect them from these threats and the word's seagrass species under the Categories and Criteria of the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (Short *et al*., 2011). Seagrass conservation monitoring protocols are based on conceptual models that link: (1) light and nutrient availability on the seagrass condition (2) physicomechanical stressors, (3) habitat quality resilience bioindicators and (4) environmental change (Dunton *et al*., 2011; Di Carlo and McKenzie, 2011). Furthermore, by classifying the attributes of the species present, meadow structure and their possible drivers into a framework to assist ongoing monitoring and management decision-making (McKenzie *et al*., 2016). Other factors indicative of the importance of seagrass bed conservation include its role in maintaining water quality, for example in interventions in Chesapeake Bay, USA and the numbers of coral reef fish that migrate to them. This has been important in the expansion of the Great Barrier Reef protection area in Australia (Larkum *et al*., 2006).

The conservation of seagrass in the coastal waters of Indonesia is particularly important because of the vital functions seagrass plays in the life of fish, especially as nursery grounds and for feeding. However, the concept of conservation as a method of achieving sustainability goals for fish resources is not yet understood by the majority of Indonesian people, including some government officials (Nadiarti *et al*., 2012). The roots of the problems of the seagrass conservation in Indonesia are the following factors (e.g., rapid population growth and poverty; lack of implementation policy and poor enforcement; lack of awareness, lack of political will; lack of recognition of "adat" (local tradition); lack of integrated approaches; lack of capable human resources; lack of information as a basis for rational and optimal marine resource management and poor system to access available information (Hutomo and Moosa, 2005) and the worse threat for seagrass conservation might be the lack of information that its importance for coastal ecosystem health, its distribution and poor conservation status (Cunha and Serrão, 2011).

The importance of seagrass resources are highly underestimated and its conservation has thus not been prioritized in conservation management policies at the national level. This is despite studies showing that seagrass and therefore its conservation is key to the sustainability of small-scale fishermen's livelihoods (Syukur *et al*., 2016). The objective of this study is therefore to determine the sources of threat to seagrass and the impact this has had on fish and other biota associated with seagrass and its ecological services. Our intention is that this research will inform seagrass conservation strategies and thus contribute to the sustainability of fish resources in the study area.

Methods

This study was conducted from April to August 2011 in the coastal areas of East Lombok Regency

West Nusa Tenggara Province, with geographic coordinates of 116°.37'-116°.45' east longitude and 8°17'-8°18' south latitude (Fig. 1). Seagrass beds in the study sites covered 154.21 ha and nine species of seagrass were found: *Halophila ovalis*, *Halophila minor*, *Halophila spinulosa*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halodulle pinifolia*, *Thalassia hemprichii*, *Syringodium isotifolium* and *Enhalus acoroides* (Syukur *et al*., 2012).

Data regarding the biota targets of small-scale fishing enterprises (of fish, mollusks, crabs, sea-urchins and sea cucumbers) in seagrass beds was obtained through the use questionnaires, interviews and focus group discussions. Our criteria for the selection of research participants were that they: (1) Had a minimum of 20 years'experience as fishermen; (2) fished more than 70% of their time around the seagrass beds; (3) had a knowledge of seagrass; (4) were aware of the changing conditions of the biota groups they targeted in the seagrass bed sites; and (5) had some knowledge regarding the dependence of the target group of organisms on seagrass bed habitats. From these criteria we selected 50 fishermen as respondents (Aswani, 2010). The data generated from interviews were substantiated by focus group discussions (Galappaththi and Berkes, 2014). Collection of fish in the seagrass bedlocations was carried out at night during full tides (the spring tides), using the fishermen's mini-trawlers, with 70 m long nets with wing mesh sizes of 1.25 inches, 1 inch, 0.75 inches and 0.625 inches and mesh bags of 0.5 inches. The nets were dragged by the boats at an average speed of 5 m/minutes. The fish caught were placed in containers we provided and were sorted into family and species. The number of individuals of each species were counted and measured (cm). The trophic status of fish in the seagrass bed sites was determined using secondary data (Syukur *et al*., 2014). The data were analyzed using descriptive statistics and fish diversity was established using the Shanon-Weiver Index (Ludwig and Reynolds, 1988) and dominance index (Odum, 1983) with formula:

$$H' = -\Sigma(pi \ln pi)$$

where, pi is the proportion of all individuals counted that were of species i.

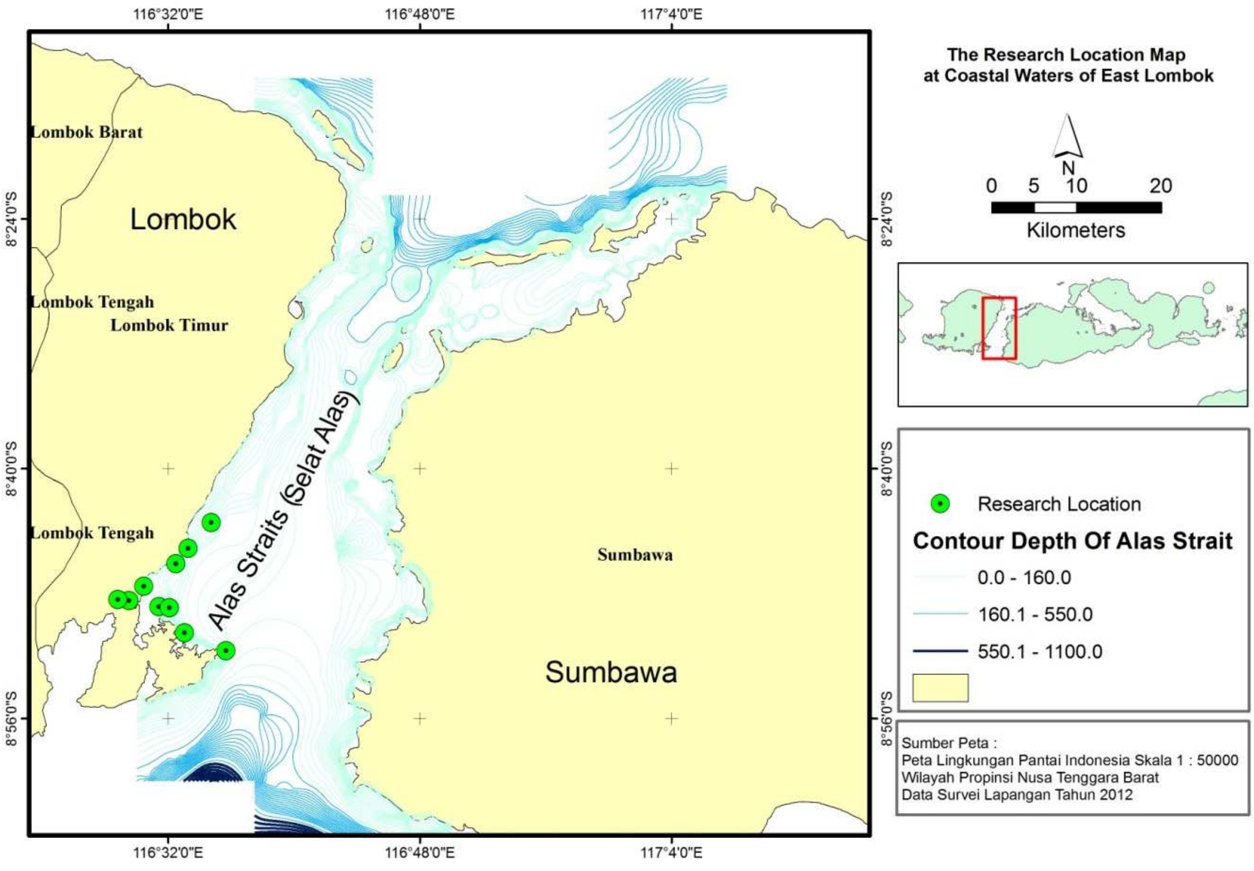

Fig 1. Research location of seagrass bedas and surrounding areas of small fishing in East Lombok

Simpson dominance index with formula:

$$C = \sum_{i=1}^{n} \left[\frac{n_i}{N} \right]^2$$

Where:
C = Dominance index
n_i = The value of importance of each species
N = The total value of important of all species

Results

Small-scale fishing communities live in small villages scattered along the shoreline of our study area. Livelihoods are based on the extraction of natural resources, such as plants, fish and other animals. Small-scale fishing constitutes some 84.33% of livelihoods in the local communities in the study area. We divided small-scale fishermen into categories based on the type of equipment they used and their catchment area, as shown in Table 1.

All categories of fishermen (Table 1) were dependent on seagrass beds as the main target area for catching fish and other biota that have economic and/or consumption value. The most common fish targeted were Carangidae, Leiognathidae, Haemullidae, Scaridae, Siganidae, Mugilidae and Lethrinidae. Crabs, *Portunus pelagicus* and *Portunus sanguinolentus,* were commonly targeted too.

Interview results showed that 64% of respondents stated that areas of seagrass habitat were very important for the sustainability of fish resources. Thirty percent stated they were quite important and only 6% said they were not very important. Respondents also stated that several species of fish and other biota had become considerably less abundant in recent years and that their catch often no longer met the needs of their families. Local residents themselves were a considerable threat to the sustainability of the ecological functions of seagrass in the study area. Activities such as gathering mollusks, crabs, sea cucumbers, see-urchins, fruit and other consum able biota were common. Our observations found that a large number of local people visited the seagrass sites, as is shown in Table 2.

The intensity of the utilization of seagrass areas by fishermen and local communities helps explain the level of exploitation of fish resources and other biota at the study sites. Such continuous exploitation can have a negative impact on the preservation of fish resources and other biota and can cause damage to the shoot density of seagrass. The implications of this over-exploitation can be gauged through our respondents' resource assessment results (Fig. 2). Some groups of marine organisms such as mollusks, crabs, sea-urchins and sea cucumber populations have declined significantly. Moreover the flagship groups *Syngnathoides biaculeatus* and *Synodus dermogenys* of the family Syngnathidae were very difficult to find during the study period.

118 fish species and 16049 individuals were found during the sampling period. The location with the highest number of species was Gili Kere, while the location with the highest number of individuals was Kampung Baru. The location with the lowest number of species and individuals was Gili Maringkik (Table 3). The results of the analysis of the abundance of species in each sampling site showed great differences in the numbers of individual species abundance and frequency. The fish community structure in Gili Kere had 72 species. *Archamia goni, Leiognathus equulus, Leiognathus bindus, Ambassis buruensis, Plectorhinchus flavomaculatus, Sphyraena barracuda, Upeneus vittatus, Sardinella lemuru, Sardinella gibbos and Gerres filamentosus*a all had above average numbers of individuals. The total number of individuals counted at Gili Kere was 4080. The species with the highest abundance was *Archamia goni* (32.79%), followed by *Leiognathus equulus* (16.66%), *Leiognathus bindus* (3.62%) and *Gerres filamentosus* (1,9%). There were 62 species with a below average number of individuals and one species, *Syngnathoides biaculeatus* of the family Syngnathidae.

Table 1. Fishermen categorized by equipment and catchment area

No	Category of fishermen	Equipment	Catchment area
1	Mixed	Mini trawler	Open waters, seagrass beds and estuaries
2	Drag net	Beach seine	Seagrass beds and estuaries
3	Fishermen catching shrimp and crab	Nets	Seagrass beds, estuaries and coral reefs

Table 2. Numbers of local people visiting the seagrass beds

No	Location of the seagrass	Number of local people visiting the seagrass beds more than five days /month: April	May	June	The average number of local people visiting the seagrass sites per day
1	Gili Kere	648	637	669	130
2	Poton Bakau	1156	907	968	202
3	Kampung Baru	187	155	136	31
4	Lungkak	226	208	214	43
Total	2217	1933	1987	406	

Table 3. Fish families, species and total number of fish in the study area

No	Location	Number of families	Number of species	Number of individuals	Width of seagrass beds (ha)	Number of Individuals/ha
1	Gili Kere	35	72	4080	46	89
2	Kampung Baru	29	60	4108	4	1027
3	Lungkak	28	48	2147	5,6	383
4	Poton Bakau	31	67	3975	55	72
5	Gili Maringkik	28	47	1739	32	54

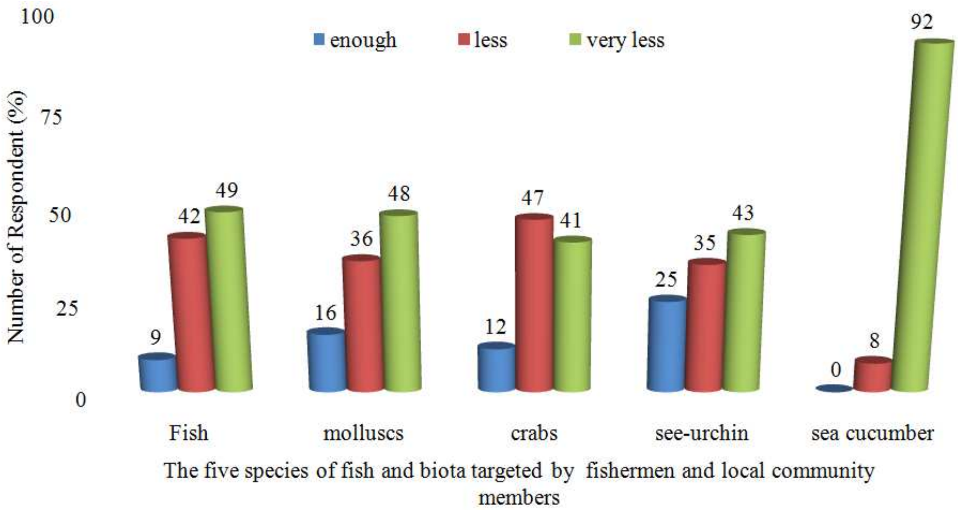

Fig. 2. Status of fish and marine life at the seagrass sites in the study area, n = 50

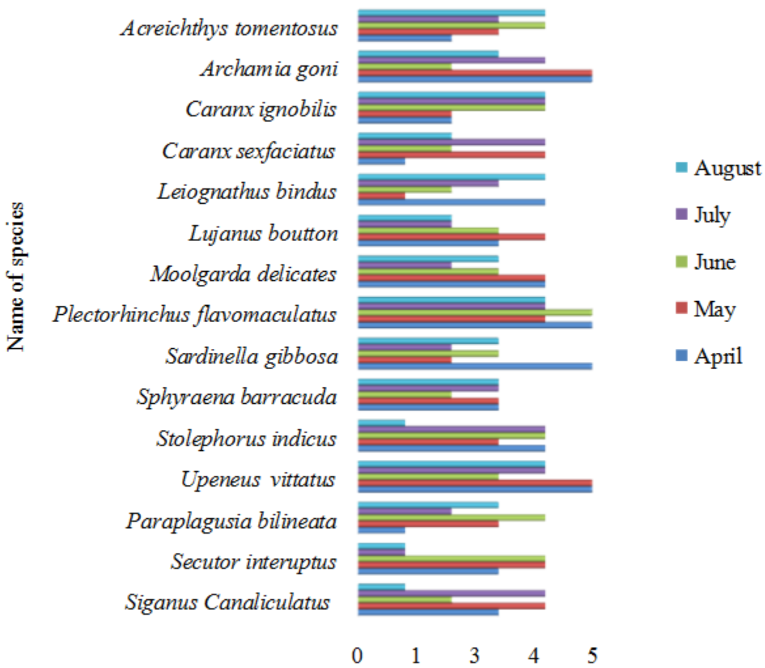

Fig. 3. The fifteen species of fish with the highest abundance during the study period

In Kampung Baru there were sixteen species with an above average number of individuals and twelve species with high frequency values. The species with the highest number of individuals was *Sardinella gibbosa* and the species with the highest frequency value were *Stolephorus indicus* and *Plectorhinchus falvomaculatus.*

At the seagrass site in Gili Maringkik there were fourteen species which had an above average number of individuals and nine species with a high frequency value. The species with the highest number of individuals was *Leiognathus equulus* and the species with the highest frequency value were *Cheilio inermis*, *Acreichthys tomentosus* and *Siganus guttatus*. At this location the species with the most individuals was *Upeneus vittatus* and the species with the highest frequency value were *Stolephorus indicus*, *Leiognathus oblongus*, *Moolgarda delicates* and *Upeneus vittatus*.

In the seagrass beds in Poton Bakau there were thirteen species with above average numbers of individuals and twelve species with a high frequency value. *Archamia goni* had the most individuals and the species with the highest frequency value were followed by *Stolephorus indicus*, *Plectorhinchus falvomaculatus*, *Moolgarda delicates* and *Upeneus vittatus*.

Seagrass ecology has a strong relationship with fish species abundance. Of the 118 species of fish found in the study area, 15 species had an abundance value of more than 50% (Fig. 3). 103 species (87.28%) had a frequency below 50% of the total sampling. The prevalence of these species indicates the importance of the ecological value of seagrass at the study site. Furthermore, fish species with a frequency value between 6-12 can be found in (Appendix 1). However, in their group, namely *Leiognathus equulus* (48%), *Gerres filamentosus* and *Sardinella clupeid* (44%), *Trichiurus lepturus* and *Upeneus sulphureus* (40%) is a fish species with high abundance. The group had a frequency value between 1-5 (Appendix 2) and comprised 80 species (70%) of the total number of species, 77.66% of the number of fish species with a frequency value below 50%. Thirteen species (11.01%) were found during the study period at each of the seagrass bed sites (Appendix 3) and 12 species (10.26%) were found at only four of the sites (Appendix 4).

Fish diversity in seagrass beds is an important way of assessing the ecological role of seagrass beds in the conservation of fish resources. Diversity index values and dominance index values are good indicators to illustrate the importance of seagrass beds for the diversity of fish species. The diversity index value offers a different perspective to that of the dominance index value (Table 4). For our study these two values provided information on fish community structure at each seagrass bed site in the study area. The diversity of fish associated with seagrass is indicative, too, of how seagrass beds provide ecological services which lead to fish seeking them out. We observed the stomach contents of seventeen species of fish and these showed that 85% were from a carnivorous fish group (Appendix 5). This indicates that carnivorous fish were the dominant group in the structure of the fish communities.

Table 4. The value of the diversity index and dominance index of species of fish at each seagrass bed site in the study area

No	Location	Diversity index (H')	Dominance index (D)
1	Gili Kere	2.448	0.164
2	Kampung Baru	2.948	0.083
3	Lungkak	2.606	0.148
4	Poton Bakau	2.797	0.131
5	Gili Maringkik	2.942	0.077

Discussion

Threats to the Sustainability of the Ecological Functions of Seagrass

Seagrass meadows provide important ecosystem services; primary production, nursery habitat for juveniles and human food from seagrass associated species (Ambo-Rappe *et al*, 2013; Buapet *et al*., 2013; Cullen-Unsworth *et al*., 2014; Jackson *et al*., 2015; Giakoumi *et al*., 2015). Others ecological services of seagrass are an estimated $1.9 trillion per year in the form of nutrient cycling and the significant enhancement of coral reef fish productivity and they provide a habitat for thousands of fish, birds and invertebrate species and are a major food source for the endangered dugong, manatee and green turtle (Waycott *et al*., 2009). Furthermore, seagrass beds are the most significant daily income source for fishermen and also provide the main sources of animal protein. Local communities use them, too, for harvesting traditional medicines, fertilizers and for other aesthetic, instrumental, spiritual and religious purposes (Kenworthy *et al*., 2007) and key ecosystems supporting small-scale fisheries (de la Torre-Castroa *et al*., 2014), but in many areas, they are also threatening a way of life for those people closely associated with the system either directly or indirectly (Cullen-Unsworth *et al*., 2014), Therefore, better understanding of which ecosystem services areas sociated with specific seagrass genera and bioregions is important for improved coastal management and conservation (Nordlund *et al*., 2016).

There are not many alternative sources of livelihoods for local communities in the study area. Many of our respondents were aware that their actions have caused a significant reduction in the fish populations that they target, as well as to another biota in and around the neighborhood of the seagrass beds. The dependency on fishing, however, makes it very difficult to implement effective strategies to prevent over-exploitation by fishermen and local communities and this has resulted in the decline of fish populations and other biota associated with seagrass. Other studies, too, have reported that small-scale fishing activities have had a negative impact on seagrass and other biota associated with seagrass in East Lombok (Satyawan *et al*., 2014), in reef flats and seagrass bed areas has reduced the population of the biota in the coastal waters (McCloskey and Unsworth, 2015) and high rates of exploitation mean that stocks generally cannot sustain expected levels of economic return (Aheto *et al*., 2012) and a relationship between the significant decline in catches in Indonesian waters and damage to seagrass beds (Unsworth *et al*., 2010). Furthermore, many of seagrass habitats damage caused to from community activities, commercial fishing and aquaculture (Brigitta *et al*., 2014). Similarly, our study found that the two main sources of continual threat to the ecological functions of seagrass were small-scale fishing operations and the local community. We believe it is essential that local government understands this and initiates strategies for the management of seagrass at a local level, not least in order to protect and conserve fish stocks for the economic and social benefit of fishermen and local communities.

The Abundance and Diversity of Fish as Indicators of Seagrass Conservation

The richness in numbers of fish species associated with seagrass highlights: (1) The ecological importance of seagrass for the sustainability of fish resources; (2) the abundance of fish species that use seagrass habitats to survive; and (3) that the distribution of fish speciesis an indicator of ecological health, of the scale of seagrass damage and of the importance of its conservation for fish sustainability. Some fish species found in the study area had higher numbers than at other seagrass bed sites, such as at the Marine National Park at Wakatobi where there were 81 species (Unsworth *et al*., 2007).

Of those 118 species, 13 species were found at all the seagrass bed sites (Appendix 3) and 12 species were found at four sites (Appendix 4). Three species had a high abundance value: *Plectorhinchus flavomaculatus (*88%), *Upeneus vittatus* (84%) and *Archamia goni* (76%). Of these *Archamia goni* is a permanent seagrass resident. Nevertheless, families Apogonidae using seagrass as an alternative habitat and reef as the main habitat, including *Archamia goni* (Bosire *et al*., 2012). Of fish that gather on seagrass, 87.5% come from other habitats, such as coral reefs, estuarine and other locations around seagrass beds and over 90% of these fish species used multiple habitats, such as mangrove, seagrass and coral reef (Honda *et al*., 2013). Furthermore, *Stolephorus indicus* and *Sardinella gibbosa* are both in the pelagic fish group on seagrass in the study area. Another study states that, *Sardinella gibbosa* is a pelagic fish that can be found in coastal waters dominated by mangrove and in turn contributes to regional offshore fisheries (Khatoon *et al*., 2014; Kumar *et al*., 2016; Swapna *et al*., 2016) and *Stolephorus indicus* is belonging pelagic-neritik and become the target of a small fishing catch (Asha *et al*., 2014). Consequently, the abundance of fish species diversity in seagrass beds highlights the importance of seagrass for these fish to survive and is an important factor to considered in conservation strategies for seagrass in the study area.

Several studies of fish associated with seagrass beds, especially in Southeast Asia. *Atherinomorus duodecimalis*, *Sillago sihama* and *Pelates quadrilineatus* dominant species in seagrass meadows at Sikao Bay, Trang Province, Thailand (Phinrub *et al*., 2015) and *Sillago aeolus*, *Sillago sihama* and *Gerres erythrourus* the highest of occurrence frequency in seagrass beds at Ban Pak Klong, Trang Province, Thailand (Phinrub *et al*., 2014). Furthermore, *Siganus canaliculatus*, *Aeoliscus strigatus*, *Syngnathoides biaculeatus*, *Acreichthys tomentosus* and *Paracentropogon longispinis* dominant species in Ambon Bay Indonesia (Ambo-Rappe *et al*., 2013) and the Engraulidae family and *Lethrinus harak*, the most abundant being from in the Marine National Park at Wakatobi, Indonesia (Unsworth *et al*., 2007) and *Chromis sp*. and *Pomacentrus sp.* was dominant in the artificial seagrass area in Sepanggar Bay at Northern Kinabalu Malaysia (Shahbudin *et al*., 2011). In this respect, the abundance of different species with several other locations as we mentioned above, I believe this is a unique kinds of fish abundance at the study location, so it can be a major argumentation of seagrass conservation and sustainable fisheries in the study area.

The diversity of fish that assembled at our seagrass study sites, whether permanent seagrass residents or species that migrate to find food and shelter from predators, is an important indicator of the ecological services which seagrass beds provide for the sustainability of fish resources. The index value of diversity and dominance (Table 4) illustrates the distribution of the species and the number of individuals within a species or diversity index is a proportion of each species and dominance indices represent the relative number of individuals. The diversity index value of fish found in the study area is relatively equal to the index value diversity of fish with two locations of seagrass beds. The location of seagrass beds both are in Sikao Bay, Trang Province, Thailand with the value of the Shannon-Wiener index (H') = 2.7 (Phinrub *et al*., 2015) and, in Formoso River Estuary-Pernambuco, Brazil (H') = 2.66 (Pereira *et al*., 2010). Nevertheless, have considerable differences with the value of fish diversity on seagrass beds in the Jordanian coast of the Gulf of Aqaba (H') = 1.4 (Khalaf *et al*., 2012).

Other studies have shown, the vegetated habitats such as mangroves and seagrass beds showed higher species diversity (Sichum *et al*., 2013) and species number and abundance were significantly lower in sandy areas and seagrass habitats presenting intermediate values (Giakoumi and Kokkoris, 2013). More of study showed, the species diversity in seagrass beds were higher than those in the bare substrate (Horinouch, 2005) and fish assemblage structure and distribution pattern in *Thalassia hemprichii* and *Enhalus acoroides* were significantly different (Nadiarti *et al*., 2015) and species diversity was significantly higher in high cover seagrass than in low cover seagrass (McCloskey and Unsworth, 2015).

The diversity of value is an ecological indicator that can help evaluate the area for the conservation decisions. The extent that key attributes of biodiversity, including ecological (vegetation structure, species diversity and abundance and ecosystem functioning) and socioeconomic (Wortley *et al*, 2013). Moreover, diversity index as ecological indicators for monitoring environmental changes is reliable and cost-effective (Siddig *et al*., 2016). It is this a useful tool for monitoring and evaluating conservation areas (Nemeth and Jackson, 2007) and informing conservation policy and also provides information about the fish within the habitat. However, the loss of or reduction in the value of biodiversity associated with seagrass fish will ultimately have an impact on the livelihood support to small-scale fisherman and long-term impact on the ecological service of seagrass. Therefore, the value diversity of fish is a very essential as information in seagrass conservation measures for sustainable of fish resource in the study area.

Our analysis of fish food (Appendix 5) showed that seagrass provides a diversity of fish food (e.g., fish, fish larvae, shrimp, crabs, see-urchins, crustaceans and cephalopods) were found in the stomach contents of the other types of fish. Furthermore, a status of fish trophic in the study area was grouped into three categories; herbivores, carnivores and omnivores. carnivores (61,90%) were the most dominant, followed by herbivores and omnivores (19%). In this case, the group of fish is the most dominant carnivores on seagrass beds in the study areas. Similarly, the group of fish carnivores contributed about 70% of the total fish abundance in seagrass beds at Donghsa Island's (Lee *et al*., 2014), but there was differences, the group of fish carnivores (20%) and herbivores (20%) in the Formoso River estuary-Pernambuco, Brazil (Pereira *et al*., 2010). Besides that, (Appendix 6) showed that seagrass provides a diversity of fish food on seagrass in the study area. It is the substantial fact of for preventing the threat of damage seagrass and may be considered in seagrass conservation actions for the sustainability of fish resources in the study area. However, which was related to the greater movement of fish between the seagrass and adjacent habitats to forage and a breakdown in the association with seagrass habitat as a refuge from predation (Jackson *et al*., 2006).

Understanding how fish use seagrass habitatsis beneficial to informing the design of conservation strategies at the level of species, communities and ecosystems. Effective conservation requires a minimum of three criteria: (1) A comprehensive description of an area's biodiversity and its conservation goals; (2) an indication of the potential suitability of the conservation area for the sustainability of the target species and ecological communities and (3) an estimation of the ability of an area to support a requisite number of individuals and species in the long term (Jelbart *et al*., 2007). Another factor which is important to the conservation of fish resources is the extent of the area under protection. In order to protect fish stocks a minimum 20-30% of the total area is needed protected (Banks *et al*., 2005), for the protection of species between 30-50% and for the protection of fish larvae a minimum of 40% (Gladstone, 2007).

Conclusion

Seagrass ecology is central for the preservation of biodiversity in many coastal areas in Indonesia, but is becoming increasingly threatened by human activity. Although seagrass conservation efforts have been attempted by governments and non-governmental organizations, they are limited to the Marine National Park, the Natural Park of the Sea and the Regional Marine Conservation Area. Initiatives for protecting seagrass ecosystems more widely in the coastal waters of Indonesia, such as those in our study area, need urgently to be implemented. This research is intended to inform such initiatives and contribute to the development of models that are based on scientific data, such as that generated by this study. We would like to highlight, too, that involving fishermen and local communities is key to achieving conservation goals and the sustainability of seagrass biodiversity.

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Author's Contributions

Abdul Syukur: Conducted all experiments, data analysis and preparation of the draft manuscript.

Yusli Wardiatno, Ismudi Muchsin and Mohammad Mukhlis Kamal: Advised research design, organized the manuscript's structures and edited the manuscript.

Ethics

All authors have provided assurance that this peper is original research and has not been published elsewhere and all the author has read and approved the manuscript.

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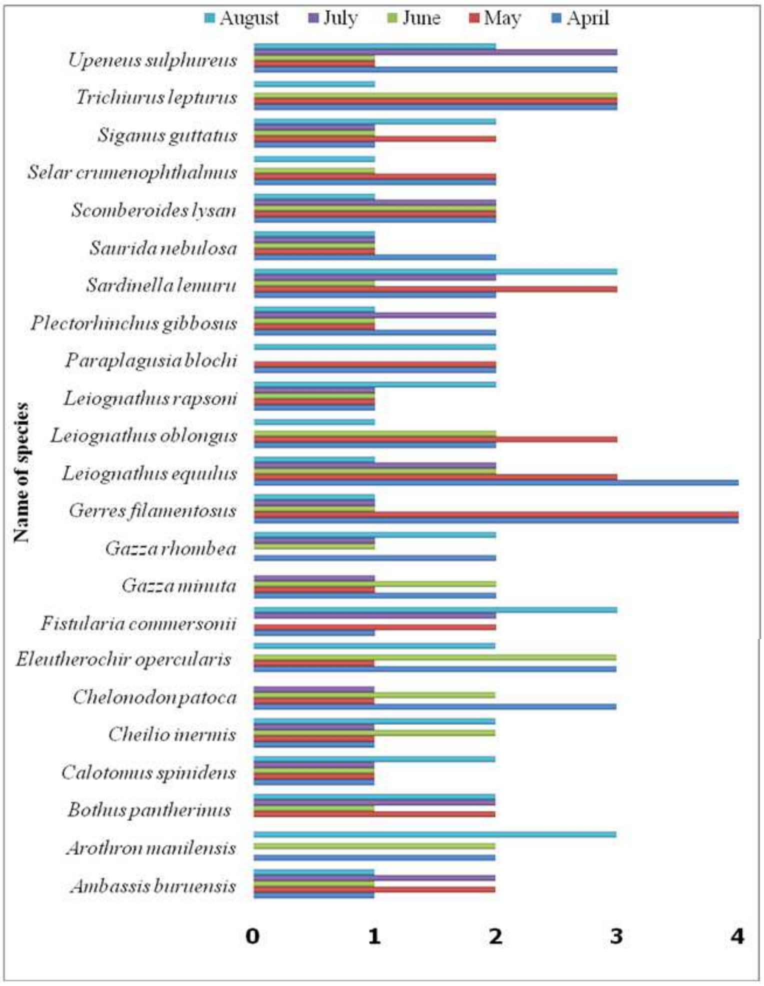
Appendices



Appendix. 1. Fish species with a frequency of between 6-12 of the total sampling

Appendix 2. Frequency of species 1-5 at the seagrass bed study sites during the study period

No	Species	Month April	May	June	July	August	Total of Frequency
1	*Abudefduf septemfasciatus*		1				1
2	*Amphiprion frenathus*				1		1
3	*Acreichthys sp*	1		1			2
4	*Aeoliscus strigatus*				1		1
5	*Alticus saliens*			1	1		2
6	*Ambassis urotaenia*		2				2
7	*Amphiprion frenathus*				1		1
8	*Andamia tetradactylus*				1		1
9	*Antherinomorus duodeccimalis*				1		1
10	*Antherinomorus lacunosus*					1	1
11	*Apogonichthys ocellatus*		2		1		3
12	*Archamia compressus*				1		1
13	*Archamia zosterophora*					1	1
14	*Arothron immaculatus*		1	1			2
15	*Atherinomorus duodecimalis*		1				1
16	*Atherinomirus lacunosus*				1		1
17	*Atule mate*		1	1		1	3
18	*Balistapus undulates*				1		1
19	*Canthigaster compressa*				1	2	
20	*Chaetodon sp.*		1				1
21	*Chanos chanos*		1				1
22	*Chinocentrus dorab*			1		1	2
23	*Cheilodipterus macrodon*		1	2			3
24	*Diodon holocanthus*		1		1		2
25	*Diodon litorosus*			1			1
26	*Drepane punctata*			2			2
27	*Foa brachygramma*	1					1
28	*Filimanus xanthonema*	1	1	1			3
29	*Gazza achlamys*		1				1
30	*Gerres erythourus*		1				1
31	*Gerres oyena*	1	1	1	2		5
32	*Gerres macracanthus*		1				1
33	*Gymnocranius elongates*		1	1		2	4
34	*Hemiramphus far*		1	1		1	3
35	*Helichoeres papilionaceus*			1	1		2
36	*Hyporamphus quoyi*	1					1
37	*Johnius amblycephalus*	1		1		2	4
38	*Johnius borneensis*	1				1	2
39	*Johnius macropterus*		1	1	1	1	4
40	*Lagocephalus ivheeleri*	1					1
41	*Lagocephalus gloveri*	1					1
42	*Lagocephalus lunaris*				1		1
43	*Leiognathus daura*	2		2			4
44	*Leiognathus splendens*	2	1				3
45	*Leiognathus smithursi*	1	1		1	1	4
46	*Leptosccarus vaigiensis*	2		1	1	1	5
47	*Lethrinus harak*	1	1		1		3
48	*Lethrinus variegates*	1	1	1		1	4
49	*Lutjanus argentimaculatus*		3		1		4
50	*Lutjanus erythropterus*					1	1
51	*Lutjanus lutjanus*		1		1		2
52	*Neopomacentrus azysron*	1	1	1	1	1	5
53	*Petroscirtes variabilis*	1		1	1	1	4
54	*Pisodonophis cancrivorus*				1		1
55	*Platax boersi*	3					3
56	*Plectorhinchus celebicus*		2	1	1		4
57	*Polynemus pelbeius*		1			1	2
58	*Pomacentrus lepidogenys*				1		1
59	*Pomadasys argenteus*		1	1			2

Appendix 2. Continue

60	*Pomadasys maculatum*	1	1	1			3
61	*Saurida gracilis*	2			1	1	4
62	*Scomberoides tala*	1	3		1		5
63	*Sheilodipterus quinquelinatus*	1					1
64	*Siganus argentheus*			1	1	1	3
65	*Sillago chondropus*	2		1			3
66	*Sillago macrolepis*	1		1			2
67	*Sillago sihama*		2				2
68	*Sphyraena flavicauda*	1				1	2
69	*Syngnathoides biaculeatus*			1		1	2
70	*Synodus dermatogenys*					2	2
71	*Sphyraena flavicauda*	1				1	2
72	*Synodus dermatogenys*					2	2
73	*Takifugu radiates*		1				1
74	*Thalossoma hardwickii*	1	1				2
75	*Thryssa mystax*		1				1
76	*Thryssa setirostrus*		1			1	2
77	*Trachinotus blochii*	1		2	1	1	5
78	*Trachinotus botola*				1		1
79	*Upeneus indicus*			1			1
80	*Upeneus tragula*	1				1	2

Appendix 3. Family and species of fish at the seagrass bed research sites

No	Family	Species
1	Apogonidae	*Archamia goni*
2	Bothidae	*Bothus pantherinus*
3	Carangidae	*Caranx ignobilis*
		Caranx melampygus
		Caranx sexfasciatus
4	Clupeidae	*Sardinella gibbosa*
5	Cynoglossidae	*Paraplagusia bilineata*
6	Enggraulidae	*Stolephorus indicus*
7	Fistulariidae	*Fistularia commersonii*
8	Haemulidae	*Plectorhinchus falvomaculatus*
9	Leiognathidae	*Leiognahus bindus*
		Leiognathus equulus
		Secutor interpuptus
10	Lutjanidae	*Lutjanus boutton*
11	Mullidae	*Upeneus vittatus*
12	Monacanthidae	*Acreichthys tomentosus*
13	Siganidae	*Siganus canaliculatus*

Appendix 4. Family and species of fish distributed at four seagrass bed sites in the study area.

			Location of seagrass beds				
No	Family	Species	Gili Kere	Gili Maringkik	Kampung Baru	Lungkak	Poton bakau
1	Callionymidae	*Eleutherochir opercularis*	1	1		1	1
2	Carangidae	*Scomberiodes lysan*	1	1	1		1
3	Chandidae	*Ambassis buruensis*	1		1	1	1
4	Gerreidae	*Gerres filamentosus*	1	1	1		1
5	Haemulidae	*Plectorhinchus gibbosus*		1	1	1	1
6	Leiognathidae	*Leiognathus oblongus*	1	1	1	1	
7	Mugilidae	*Moolgarda delicates*	1		1	1	1
8	Tetraodontidae	*Arothron manilensis*	1	1	1	1	
9	Sphyraenidae	*Sphyraena barracuda*	1		1	1	1
10	Synodontidae	*Saurida nebulosa*	1		1	1	1
11	Trichiuridae	*Trichiurus lepturus*	1	1		1	1
12	Tetraodontidae	*Chelonodon patoca*	1		1	1	1
Total	11	7	10	10	10		

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Appendix 5. Families and species of fish observed to assess the diversity of types of fish food at the seagrass bed sites in the study area

No	Family	Species	Biota obtained from the stomach contents
1	Siganidae	*Siganus canaliculatus*	seagrass dan algae
		Siganus guttatus	seagrass and algae
2	Scaridae	*Calotomus spinidens*	seagrass and algae
3	Atherinidae	*Atherinomirus lacunosus*	seagrass and algae
4	Apogonidae	*Archamia goni*	shrimp, crab and squid
5	Tetraodontidae	*Canthigaster compressa*	fish and shrimp
		Arothron immaculatus	fish and shrimp
6	Gerridae	*Gerres oyena*	fish
7	Mugilidae	*Moolgarda delicates*	fish and shrimp
8	Pomacentridae	*Abudefduf notatus*	fish and shrimp
9	Haemulidae	*Plectorhinchus celebicus*	fish and crabs
10	Lutjanidae	*Lutjanus boutton*	fish, larvae of fish and shrim
		Lutjanus argentimaculatus	fish, larvae of fish and shrim
11	Lethrinidae	*Lethrinus lentjan*	crabs
		Lethrinus variegates	crabs
12	Mullidae	*Upeneus vittatus*	shrimp
13	Balistidae	*Balistapus undulates*	Larvae of see-urchin and shell
14	Monacantidae	*Acreichthys tomentosus*	crustaceans, fish, larvae of sea-urchin and seagrass
15	Carangidae,	*Caranx sexfasciatus*	Phytoplankton and zooplankton
16	Leiognathidae	*Leiognahus bindus*	Phytoplankton and zooplankton
17	Clupeidae	*Sardinella gibbosa*	Phytoplankton and zooplankton

Appendix 6. Attraction of seagrass beds for fish

No	The location of seagrass beds	Famili	Species	The main habitat for several species of fish	The type of fish food in seagrass beds	Ecological function of seagrass for fish
1	Gili Kere	Apogonidae	*Archamia goni*[1]	Seagrass beds	Shrimp, crabs and cephalopods	Habitat
		Lutjanidae	*Lutjanus boutton*[2]	Coral reefs and areas nearmangroves	Fish, larvae of fish and shrimp	Feeding ground
2	Kampung Baru	Clupeidae	*Sardinella gibbosa*	Marine waters	Plankton	Feeding ground
		Haemulidae	*Plectorhinchu falvomaculatus*[2]	Coral reefs	Fish and crab	Feeding ground
3	Gili Maringkik	Leiognathidae	*Leiognathus equulus*[1]	Coastal waters	Phytoplankton and zooplankton	Feeding ground
		Monacanthidae	*Acreichthys tomentosus*[2]	Seagrass beds and areas with sandy bottom	Crustaceans, fish, larvae of sea-urchin and seagrass	Habiat and feeding ground
		Siganidae	*Siganus guttatus*[2]	Coral reefs and seagrass beds	Seagrass and algae	Nursery and feeding ground
4	Lungkak	Mullidae	*Upeneus vittatus*[1]	Coral reefs	Shirmp	Feeding ground
		Leiognathidae	*Leiognathus oblongus*[2]	Marine waters	Phytoplankton and zooplankton	Feeding ground
		Mugilidae	*Moolgarda delicates*[2]	Mangroves and estuaries	Fish and shrimp	Feeding ground
		Mullidae	*Upeneus vittatus*[2]	Coral reefs	Shrimp	Feeding ground
5	Poton Bakau	Apogonidae	*Archamia goni*[1]	Seagrass beds	Shrimp, crabs and cephalopods	Habiat
		Apogonidae	*Archamia goni*[2]	Seagrass beds	Shrimp, crabs and cephalopods	Habiat
		Haemulidae	*Plectorhinchus falvomaculatus*[2]	Coral reefs	Fish and crab	Feeding ground
		Mugilidae	*Moolgarda delicates*[2]	Mangroves and estuaries	Fish and shrimp	Feeding ground
		Mullidae	*Upeneus vittatus*[2]	Coral reefs	Shrimp	Feeding ground

[1)]Fish species with the highest number of individuals
[2)]Fish species with the highest abundance