Seagrass community structure in various zones in coastal waters of Haya village, Central Moluccas district, Indonesia

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Abstract. Seagrass ecosystem in Central Moluccas, Indonesia has a very important role in the aquatic environment, both for aquatic organisms and for coastal communities. The utilization of seagrass resource as medicine, food, and other necessities trigger decreased potential and contribution of ecology, which affects the ecological stress. This research aimed analyzing the structure of seagrass communities, including species composition, density, occurrence frequency and important value index of seagrass in coastal waters with the characteristics, namely natural zones, residential zones and touristic zones. The seagrass species found were *Cymodocea rotundata, Syringodium isoetifolium, Halophila ovalis* and *Thalassia hemprichii.* The water condition was in the range of 29.60-31.70°C, salinity 29.20-34.30‰, pH 6.83-8.59, current 0.04-0.24 cm/sec, and depth of 25-143 cm below sea level (bsl). The highest density and abundance of species were found in *T. hemprichii* (51.69 individuals/m^2) and the lowest was found in *S. isoetifolium* and *H. ovalis* species (0.00 individuals/m^2). *S. isoetifolium* and *H. ovalis* also have the lowest occurrence frequency (0.00 individuals/m^2), while *Thalassia hemprichii* (0.52 individuals/m^2) had the highest occurrence frequence. The highest important value index was at *T. hemprichii* (155.75%; residential zone) and *S. isoetifolium* and *H. ovalis* (0.00%; residential zone) was the lowest. The highest and the lowest diversity index were found in natural zone (1.384) and residential zone (0.694). The highest Dominance index was found in residential zones (0.495) and natural zone (0.251). The highest and the lowest evenness index were found in the residential zone (1.000) and touristic zone (0.885). All physico-chemical factors of water have a correlation with the abundance of seagrass species in all water zones.
Key Words: coastal area, diversity, ecological index, ecosystem, species composition.

Introduction. Seagrass beds have great potential and are very productive in ecological and socio-economic value, also support commercial fishing, ecotourism and enhance local economy (Orth et al 2006; Marba et al 2014). Seagrass is high level flowering plants (Anthophyta), seed covered (Angiospermae) and having one cotyledon (Monocotyledoneae) and fully adjust to life immersed in the sea (Barbier & Hacker 2013). The breeding system is unique because it is able to pollinate in the water, a) able to live in salt water media; (b) able to function normally in an immersed state; and (c) has a well-developed anchor root system. Short & Cole (2001) classifies seagrass into four families namely Zosteraceae, Posidonia, Potamogetonaceae, and Hydrocharitaceae that have many types and live forming seagrass communities.

Seagrass has several important functions, such as: as a place for spawning, seedling, a shelter for several species of fauna. In addition, seagrass can be used as indicators of aquatic environment damage because it is very sensitive (Marba et al 2013). Some seagrass species contain antibiotic compounds as *Enhalus acoroides* and some are suitable for consumption such as *Thalassia hemprichii*, *Cymodocea serrulata* and *Syringodium isoetifolium* (Yuvaraj et al 2012). Seagrass communities have high species diversity, if they are formed by many species, conversely the community has a low species diversity, if they are formed by few species of macroalgae (Burdick & Kendrick

2001). Odum (1996) states that species diversity has a number of components, namely, density, abundance, occurrence frequency, and important values. Seagrass communities live in aquatic zones which are always submerged in water, but they also require sunlight and some abiotic components in aquatic ecosystems to multiply. The abiotic components frequently give stress effect which suppresses the spread of some types of seagrass species known as “ecological stress” (Roca et al 2016). Ecological stress can be triggered by natural events affecting is abiotic factors such as tidal events (affecting the flow), the shallow due to coastal erosion (affecting depth), and fluctuations in water quality due to social activities of coastal communities (influence temperature, salinity, pH, DO, BOD, COD) and other events.

Based on the initial survey, one of the areas in Central Moluccas district, Indonesia which has a community of seagrass in coastal waters is Haya village. Haya village has a strategic location because it is surrounded by sea and overgrown with mangrove forests (mangroves), macroalgae and seagrass, and rich in various species of fish, gastropods, and echinodermata. The profile of water substrate is in the form of sand, mud, rocks and rubble, besides it does not have large rivers, so that the salinity of ocean waters is in a stable condition, and very suitable for the growth of seagrass. However, the development of human activities in coastal areas, especially in the coastal water of Haya village, such as tourism, residence, and other activity, has an effect on the seagrass, so that its community structure will undergo some changes. Kiswara (2004) and Marba et al (2013) stated that the loss of seagrass have widely occurred in various places in the world as a result of the direct impact of antrophic human activities including mechanical damage (dredging), and the effect of the development of coastal construction. It is feared that the loss of seagrass beds will continue to increase due to the development of human activities in coastal areas.

The purpose of this research was to determine the correlation between water quality and the structure of seagrass community consisting of the species composition, diversity of components, and ecological indexes based on zones influenced by human activities, including natural zones, residential zones, and touristic zones.

Material and Method. This research was conducted in the coastal water in Haya ing research area was divided into three stations (zones) with different characteristics, namely natural zone (station 1), residential zone (station 2) and touristic zone (station 3) (Figure 1). The data were collected by using sampling techniques to measure the environmental factors (temperature, salinity, pH, dissolved oxygen, and the strength of the currents of sea water) and the calculation of seagrass species on a transect quadrant, starting from the stands of the first seagrass toward the sea, with a length of transects 100 meter, and the distance between the transect is 20 m. On each transect was placed observation plot size of 1 x 1 m^2 of 10 quadrants, with the distance between quadrants is 10 meter.

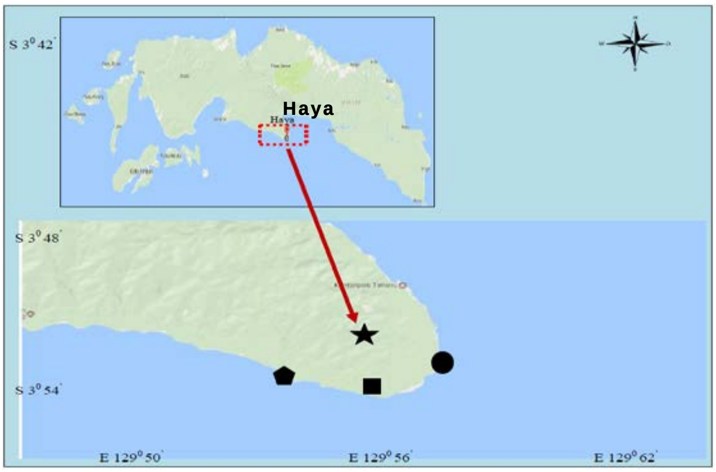

Figure 1. Map of research location (Note: ● - station 1, ■- station 2, ⬟ - station 3).

The structure of the seagrass community was determined based on the ecological aspects, that is, the diversity index of seagrass was determined using the Shannon - Wiener formula (Ludwig & Reynolds 1988), the dominance index and the evenness index of seagrass were determined by using Simpson index (Pielou in Ludwig & Reynolds 1988). Then, the density value and relative density, abundance and relative abundance, occurrence and the relative attendance frequency, and the important index value followed Krebs (1989). Regression analysis was used to examine the relationship between environmental chemical physical factors (temperature, strength of currents, salinity, pH) and Seagrass Diversity in various zones in the coastal water of Haya Village in Central Moluccas district.

Results and Discussion

Types of seagrass on several zones in the coastal water of Haya village in Central Moluccas district. The results of the observation in three research stations, namely in station 1 (natural zone), station 2 (residential zone), and station 3 (touristic zone) found the types of seagrass *Cymodocea rotundata*, *Halophila ovalis*, *S. isoetifolium*, and *T. hemprichii* with the distribution presented in Table 1.

Table 1
Types of seagrass found in the coastal water of Haya village, Central Moluccas district, Indonesia

Family	*Species*	*Characteristics of observation zones*		
		Natural	*Residential*	*Touristic*
Potamogetonaceae	*Cymodocea rotundata*	+	+	+
	Syringodium isoetifolium	+	-	+
Hydrocharitaceae	*Halophila ovalis*	+	-	+
	Thalassia hemprichii	+	+	+

(+) - present; (-) - absent.

In station 1 (natural zone), there were 4 types of seagrass found, those were, two types from *Potamogetonaceae* family and 2 types from *Hydrocharitaceae* family. In station 2 (residential zone), two types of seagrass were found, whose were, one type of seagrass from *Potamogetonaceae* family and 1 type of seagrass from *Hydrocharitaceae* family. In station 3 (touristic zone), 4 types of seagrass were found, two types of seagrass from *Potamogetonaceae* family and 2 types of seagrass from *Hydrocharitaceae* families.

T. hemprichii and *C. rotundata* species were found almost in any zone or depth, or it is called as cosmopolite organisms. This is presumably because the tolerance level of these two species is higher than the other two species. The research results by Tupan & Azrianingsih (2016) found that *T. hemprichii* had the ability to absorb and to accumulate lead compound in the tissue of roots, rhizome and leaves. If the distribution of *T. hemprichii* increases, it is assumed that the water has been polluted with lead, so that it can be used as bio accumulator of residential zone. The distribution of *H. ovalis* and *S. isoetifolium* species was not observed in the residential zones. Wahab et al (2017) also found that an abundance of *S. isoetifolium* of <50 individuals/m^2 in the north coast of Panggang Island. The condition of Panggang Island almost represent the coast characteristics which has residential activities. The presence of *H. ovalis* with the lowest density is because it cannot adapt to a condition of the ebb and flood in a long time. This is in line with the statement by Campbell et al (2006) and Short et al (2010) stating that *H. ovalis* is a species which is susceptible to high temperature compared to other species. Thus, climate change is also a threat to this species of seagrass (Borum et al 2015; Wu et al 2016).

Physical, chemical, and environmental factors (temperature, salinity, pH, strength of sea water current) in various zones in the coastal water of Haya village in Central Moluccas district. An abundance of organisms in the water is influenced by the surrounding environment. Malang & Hamsiah (2016) found that the existence of seagrass organisms is heavily influenced by various factors of marine environment, such as temperature, salinity, pH, and current. The different zones in the coastal water in Haya village, Central Moluccas district significantly affect temperatures, strength of current, salinity, and pH ($p<0.05$) (Table 2).

Table 2

The distribution value of aquatic environmental parameters and density of seagrass in different zones of coastal water of Haya village, Central Moluccas, Indonesia

Environmental parameters	*Coastal water zone*		
	Natural	*Residential*	*Touristic*
Temperature (°C)	31.30 ± 0.79^{b}	29.60 ± 0.49^{a}	31.70 ± 0.46^{c}
Salinity (‰)	34.30 ± 0.46^{c}	28.58 ± 0.50^{a}	29.20 ± 0.40^{b}
pH	8.59 ± 0.08^{c}	6.83 ± 0.05^{a}	6.96 ± 0.05^{b}
Strength of current (cm.sec nd$^{-1)}$	0.04 ± 0.00^{a}	0.24 ± 0.00^{c}	0.06 ± 0.00^{b}
Seagrass density (individuals cm $^{-2)}$	1.00 ± 0.14^{b}	0.18 ± 0.02^{a}	0.29 ± 0.03^{a}

Temperature affects all biological processes, especially by increasing the rate of biological reaction. Climate change can affect the lives of seagrass, such as, the morphology, metabolism, nutrient absorption and survival of seagrass (McDonald et al 2016). Photosynthesis is an important process in seagrass, which runs slowly at very low temperatures, but gradually increases with increasing temperature (Roca et al 2016). Based on environmental parameters, the range of 29.60 to 31.70°C temperature approaching the upper limit of the temperature range of 25-30°C which is the optimum temperature of the growth of seagrass organisms (Nybakken 1992). Salinity of coastal water zone station 1, 2, and 3 ranged between 29.20-34.30‰ and the natural zone had the highest salinity. This range was still included in the range of salinity tolerance of seagrass, which are 5‰ and 45‰ (Garrote-Moreno et al 2014). In general, the degree of acidity of coastal water is in the range between 6.83 and 8.59 pH, and the highest pH was observed in the natural zone. The changes of pH are generally caused by the calcium diffusion (Ca) organic and organic carbon (in the form of CO_2, HCO^{3-} or CO_3^{2-}) thus alkalinity increases, so that the water becomes base (McDonald et al 2016). The range of PH in station residential zone and touristic zone lower is allegedly because the plants photosyntesize in large quantities, so that it alters the pH to be slightly more acidic. Sea water has strength of current between 0.04 and 0.24 cm/sec and does not experience large fluctuations as long as 100 m offshore. The strength of ocean currents contributes to the jolts or pounding for seagrass structure and is strongly associated with the type of substrate as a habitat for many organisms, particularly seagrass.

Diversity, dominance, and evenness of seagrass species in coastal water of Haya village in Central Moluccas district. The high value of density, abundance, occurrence frequency and the importance value of seagrass species *H. ovalis, T. hemprichii,* and *C. rotundata* (Table 3) on each of the research stations is due to: (a) number of individuals, (b) total transect the individuals found, and (c) number of individuals found more than other species. The research conducted by Tuahatu et al (2016) found that *H. ovalis* and *C. rotundata* species are commonly found in the water of Moluccas, particularly in the water of Waai and Lateri.

C. rotundata and *T. hemprichii* seagrass species can be said to be cosmopolitan organisms in the three coastal water zones because they have a wide range of tolerance toward temperature, salinity, pH and current strength. *C. rotundata* is a cosmopolitan seagrass which is widely spread in the Indo-Pacific waters which is thermohaline and resistant to high salinity (Arriesgado et al 2014).

Table 3
Species composition, density (K; in ind./m^2), and the relative density of seagrass (%) based on zoning in the coastal water of Haya village, Central Moluccas, Indonesia

Species	*Natural*			*Residential*			*Touristic*		
	K (ind./cm^2)	*Σ ind*	*K (%)*	*K (ind./cm^2)*	*Σ ind*	*K (%)*	*K (ind./cm^2)*	*Σ ind*	*K (%)*
Cymodocea rotundata	1.31	131	26.10	0.43	43	48.31	0.60	60	38.46
Syringodium isoetifolium	1.11	111	22.11	0	0	0.00	0.05	5	3.21
Halophila ovalis	1.39	139	27.69	0	0	0.00	0.51	51	32.69
Thalassia hemprichii	1.21	121	24.10	0,46	46	51.69	0.40	40	25.64
	–	502	100.00	–	89	100.00	–	156	100.00

The close relative of *C. rotundata*, *C. nodosa* is known to grow in hotter environments, about 10°C to 35°C (Garrote-Moreno et al 2014). Some species of seagrass genus adapt to geographical and hydrological temperature changes repeatedly, so that the tolerance range is expanding (McDonald et al 2016). *Thalassia* genus is found live from salinitym of 3.5 to 60 ‰, but with a short period of tolerance (Tupan et al 2016; Wuthirak et al 2016). The optimum range for the growth of *T. hemprichii* is reported from to be at the salinity of 24-35 ‰ (Noviarini & Ermavitalini 2016). *T. hemprichii* is also included in the magnozosterid group. One of the characteristics of the magnozosterid group is the ability to live in a wide variety of substrates, particularly in sublittoral areas that are still submerged in low tide.

Occurrence frequency of species describes the opportunities of seagrass in observation plots. *C. rotundata* and *T. hemprichii* were found in 3 locations of the four seagrass species found. This means that both of the seagrass species are able to adapt to a variety of substrates which are evenly distributed (Figure 2).

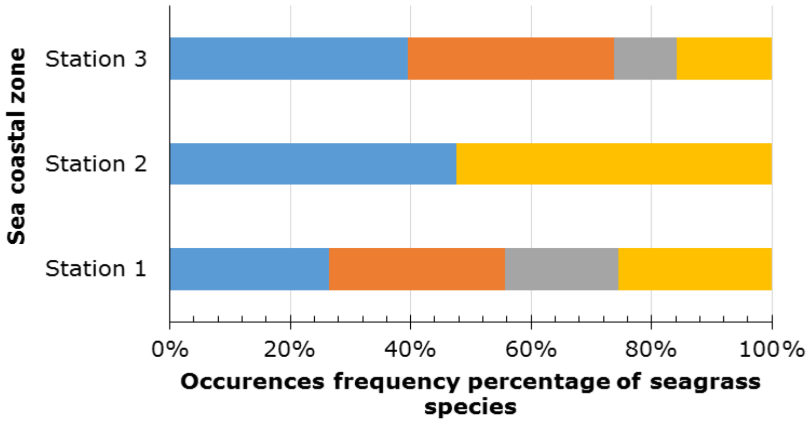

Figure 2. Relative occurrences frequency percentage of seagrass ■ *Cymodocea rotundata*, ■ *Halophila ovalis*, ■ *Syringodium isoetifolium*, and ■ *Thalassia hemprichii* in natural zones, residential zones, and touristic zones.

Burdick & Kendrick (2001) explain that the density and the abundance (Figure 3 and Figure 4) are determined by the number of the individuals. The bigger the number of the individuals, the higher the density and the abundance value is. Conversely, the smaller the number of individuals, the lower the density and the abundance value is. The individuals with high density and abundance value indicate that the individual has occurrences in large numbers. Conversely, the individuals with low density and abundance value indicate that the individual has low occurrence. Therefore, it can be concluded that the individual which has high density, abundance, and occurrence frequency value will also have high important index value (IVI). This is because the important value is obtained from the sum of the relative density, relative abundance, and relative occurrence frequency.

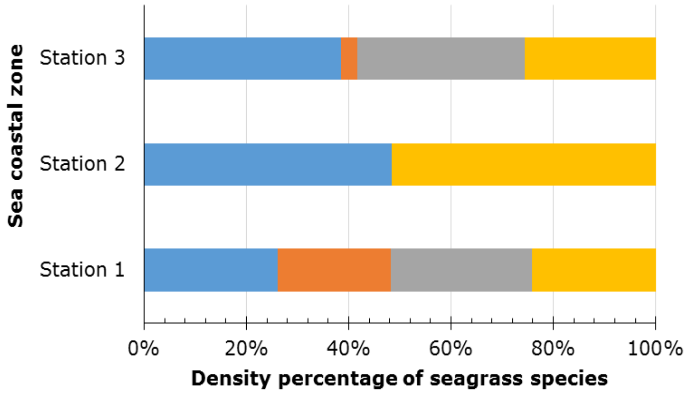

Figure 3. Relative Density percentage of seagrass ■ *Cymodocea rotundata,* ■ *Halophila ovalis,* ■ *Syringodium isoetifolium,* and ■ *Thalassia hemprichii* in natural zones, residential zones, and touristic zones.

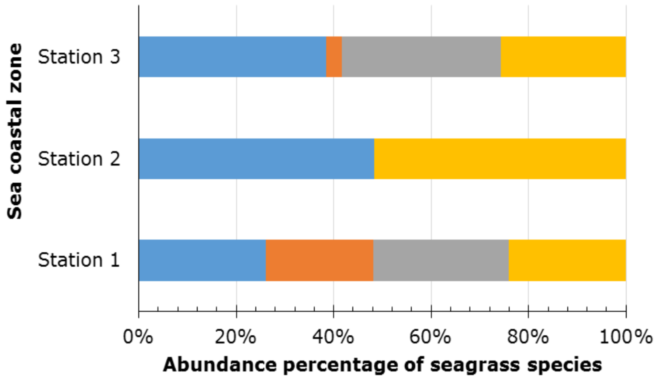

Figure 4. Relative abundance percentage of seagrass ■ *Cymodocea rotundata,* ■ *Halophila ovalis,* ■ *Syringodium isoetifolium,* and ■ *Thalassia hemprichii* in natural zones, residential zones, and touristic zones.

Seagrass organisms with a high occurrence frequency indirectly give clues about the condition of the water (Marba et al 2013). Furthermore, seagrass organisms with high abundance, diversity and occurrence frequency value will also have high important index value because it is the sum of all the three factors. Figure 5 shows that there are individuals which become an indicator of the characteristic of the water assessed from the important value index. Station 2 or the residential zone in the coastal water of Haya village is characterized by the occurrence of *T. hemprichii.* Touristic zone is characterized by the occurrence of *C. rotunata*, and natural zone is characterized by the occurrence of *S. isoetifolatum.*

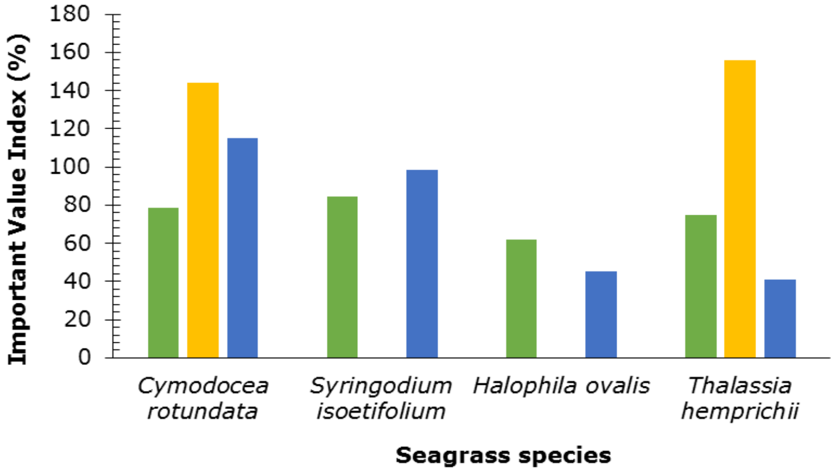

Figure 5. Important Value Index (IVI) of seagrass species in natural zones ■, residential zones ■, touristic zones ■.

Ecological index covering the diversity index, dominance index and evenness index in the various zones of coastal water in Haya village, Central Moluccas district is shown in Figure 6. According to Akaahan et al (2014), diversity index 1.81-2.91 is categorized as moderate conditions, >3 stable and equilibrial condition, and <1 habitat as polluted and damage in the habitat structure. Diversity Index (H') was found 1.384; 0.459; and 1.227 in station 1, 2, and 3 (Figure 6).

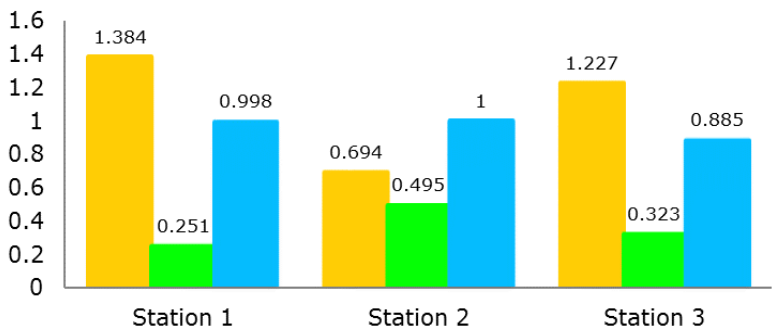

Figure 6. Ecological index, covering the diversity index (■) dominance index (■) and evenness index (■) in various zones of coastal water in Haya village, Central Moluccas.

In general, the diversity index of seagrass in station I or residential zone, is categorized as polluted, one of which is allegedly due to ecological stress because of the community activities at the station I. However, in general, the other environmental parameters can still be tolerated by seagrass for their survival. Arbi (2011) states that the high or low diversity index is the result of many factors, such as the number of species or individuals, substrate homogeneity condition, the condition of three important coastal ecosystems (seagrass beds, coral reefs and mangrove forests) as the habitat of aquatic fauna. On the other hand, according to Akhrianti et al (2014), diversity index is influenced by the number of genera, in which uniformed population has higher diversity index than the non-uniformed population.

Dominance index of genus reaches 0.251 (natural), 0.495 (residential), 0.232 (touristic). In general, this value reflects the relative condition of species and even there is none which is dominant (not significantly different). Kharisma et al (2012) states that low dominance index illustrates the balance of ecological communities, in that the lower the dominance is, the between the environmental quality for the seagrass is, although there are some seagrass species which have higher number than the others. Evenness index of seagrass in all zones is in the range of 0.88-1.00, which represents a low evenness. This is presumably because at any depth there is not any regular pattern of seagrass vegetation. An irregular distribution indicates that the distribution of the four seagrass species in the coastal water of Haya village is still low. Jorgensen et al (2005) suggest that the index value less than 2 is included in the low category.

The correlation between environmental, chemical, physical, factors (temperature, strength of currents, salinity, pH) and seagrass diversity in various zones in the coastal water of Haya village in Central Moluccas district. Seagrass live in aquatic environments by utilizing abiotic factors, thus indirectly, the fluctuations in water environment have an effect on seagrass and its abundance. The results of the regression analysis in Table 4 indicate that the value of R2 *(*adjusted R square*)* is 0.114. It means that the contribution of independent variables (temperature, strong currents, depth, salinity, and pH) is 11.4% toward the dependent variables (diversity of seagrass), while the remaining 88.6% was the contribution of the other factors which were not examined. This shows that there are other factors that can affect the diversity level of seagrass in the natural zone in coastal water of Haya village, central Moluccas District, which cannot be described in this research.

Table 4

The results of multiple regression test on the correlation between temperatures, strength of currents, depth, salinity, and pH, with seagrass diversity in the natural zone

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*	*Sig. F change*
1	.000[a]	.000	.114	.00000	.000

The variables that allegedly influenced the diversity of seagrass are turbidity, nitrates, phosphates, dissolved oxygen, biological oxygen demand (BOD) and chemical oxygen demand (COD).

The results of the regression analysis also showed that the regression coefficient of each independent variable toward the dependent variable is significant and can be used to predict the changes in the diversity level of seagrass. The result of regression coefficient significance can be seen in Table 5.

Table 5

The results of multiple linier regression analysis

No.	*Independent variables*	*B*	*B standardized coefficients*	*t*	*Sig.*	*Note*
1	Temperature	.000	.000	.000	1,000	significant
2	Current strength	.000	.000	.000	1,000	significant
3	Depth	.000	.000	.000	1,000	significant
4	Salinity	.000	.000	.000	1,000	significant
5	pH	.000	.000	.000	1,000	significant

The temperature of sea water has an effect of the seagrass diversity presumably because temperatures lead to optimal growth of seagrass. Feryatun et al (2012) explains that the seagrass found in tropical climates can grow well at temperatures ranging between 24 and 35°C. Such temperature range triggers the metabolic activity of seagrass, such as photosynthesis and respiration. Nontji (2005) states that the temperature on the surface water is affected by meteorological conditions. The meteorological factors that play a role here are precipitation, evaporation, wind speed, humidity and solar radiation intensity.

The results of the analysis of the correlation between the strength of sea water currents and the diversity of seagrass in the touristic zone in the coastal waters of Central Moluccas district show that there is a positive correlation (1.000). Dahuri et al (2004) explains that the range of the current strength which is good for the growth of seagrass is

0.040-0.240 cm/sec. In addition, the strength of currents has an effect on the growth of seagrass associated with the supply of nutrients and dissolved gases needed by seagrass. The current strength of sea water gives contribution towards jolts or pounding for seagrass structure and is strongly associated with the type of substrate as a habitat for many organisms, particularly seagrass.

The results of the analysis of the correlation between the current strength of sea water and the diversity of seagrass in touristic zones in coastal water in Haya Village in Central Moluccas district show that there is a positive correlation (0.907). Dahuri (2003) explains that the depth range which is good for the growth of seagrass is 0-12 m. The shallow water condition can affect the lives of seagrass because the changes in depth of water can affect several other aquatic environmental factors, such as temperature, light intensity and the hydrodynamic water (Barbier & Hacker 2013). The intensity of sun light which can reach a particular depth of water is the limiting factors of growth and production of seagrass.

The results of the analysis of the correlation between the salinity of sea water and the diversity of seagrass in touristic zones in coastal water in Haya Village in Central Moluccas district show that there a positive correlation (0.999). Wuthirak et al (2016) explains that the range of salinity that is good for the growth of seagrass is 24-35 ‰ . This is supported by the statement of Barbier & Hacker (2013) that a change in salinity of the ocean is affected by seasonal factors, estuaries, and the salinity of the ocean water. Salinity affects the osmotic pressure within the cell, but a lot of seagrass are also adapting to sudden changes in salinity.

The results of the analysis of correlation between the pH of sea water and the diversity of seagrass in the tourism zone in the coastal waters of Central Moluccas district show that there is a positive correlation (1.000). Nybakken (1992) explains that the pH range which is good for the seagrass growth is 7.3-9.0. The changes of sea water to become acidic are due to the increase of organic materials in the water which liberates CO_2 when the process of decomposition occurs. The lower pH range in the stations of residential zone and the touristic zone is allegedly due to the plant photosynthesis in large quantities so that it alters the pH to be slightly more acidic (Garrote-Moreno et al 2014).

Conclusions. Seagrass species found are *C. rotundata* and *S. isoetifolium* from the *Potamogetonaceae* family and *H. ovalis* and *T. hemprichii* from *Hydrocharitaceae* family. Conditions of temperature, current strength, depth, salinity, and pH of seawater, on average, in the entire zoning are quite good and can become the habitat of seagrass. Seagrass species with high density, abundance, occurrence frequency are *C. rotundata* and *T. hemprichii* for all zoning. Seagrass species *S. isoetifolium* and *H. ovalis* have the lowest value of density, abundance, occurrence frequency for all zoning. The index of diversity, dominance, and richness of seagrass structure each zone is the medium category, the low category, and the low category. Zoning using natural characteristics, residential characteristics, and tourism characteristics has an effect on the spread of seagrass in water area. The structure of seagrass in the coastal water of Haya Village, Central Moluccas district has a close correlation with the temperature, pH, salinity, depth and flow of water.

Acknowledgements. The authors thank the Director of the College of Teacher Training and Education Science, Gotong Royong, Masohi (STKIP-Gotong Royong), which has provided scholarship assistance for the completion of this research in Biology Education Study Program, Postgraduate, Pattimura University, year 2014/2015.

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Received: 28 April 2017. Accepted: 18 October 2017. Published online: 25 October 2017.
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How to cite this article:
Namakule U., Rehena J. F., Rumahlatu D., 2017 Seagrass community structure in various zones in coastal waters of Haya Village, Central Moluccas District, Indonesia. AACL Bioflux 10(5):1226-1237.