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Morphometric characteristics of two seagrass species (*Enhalus acoroides* and *Cymodocea rotundata*) in four small islands in North Maluku, Indonesia

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Abstract. *Authors. 2018. Morphometric characteristics of two seagrass species (*Enhalus acoroides *and* Cymodocea rotundata*) in four small islands in North Maluku, Indonesia. Biodiversitas 19: 2035-2043.* Seagrass has an important ecological role as a protector of coastlines and small islands. It is known to be capable of forming phenotypic plasticity through morphometric variation as a response to its environmental conditions. This study aimed to determine the distribution and morphological differences between populations of two important seagrass species (*Enhalus acoroides* and *Cymodocea rotundata*) in the waters around four small islands in North Maluku. The study was conducted at two stations in each of Ternate Island and Maitara Islands, three stations at Tidore Island and one station at Hiri Island. A line transect method was used to collect seagrass samples. Morphometric characteristics included leaf sheath length, leaf length, leaf width, rhizome diameter, root length, root diameter, and internode length were measured. Discriminant analysis was performed to describe morphometric characteristics distinctive of the four islands. Leaf sheath length, leaf length, rhizome diameter, and root length of *E. Acoroides* differed significantly among the populations from the various islands except for leaf width. Meanwhile, leaf sheath length, leaf width, rhizome diameter, root length, and internode length differed significantly in *C. rotundata* among the populations from different islands except for leaf length.

Keywords: *Cymodocea rotundata*, discriminant analysis, *Enhalus acoroides,* morphometric variation, North Maluku

INTRODUCTION

The seagrass ecosystem occupies the coastal region as a meeting point between land and sea, creating a truly dynamic and heterogeneous ecosystem. The species living in this area need to adapt to large environmental variations. This variation leads to phenotypic plasticity and/or adaptation in many species, resulting in high levels of variation operating at different organizational levels (Arellano-Méndez et al. 2011). Seagrasses are well-known to be able to respond to environmental conditions by exhibiting morphological plasticity. Morphological plasticity in seagrasses can be seen in terms of variations in morphometric characteristics such as leaf length, leaf width, number of leaves per shoot, rhizome size, internode length, and root length (Hackney and Durako 2004). Variations in morphometric characteristics have been widely used to quantify plant diversity (Suwanvijitri et al. 2010), to distinguish seagrass populations, which occupy different habitats, either spatially or temporally, in the waters, and as an indicator of environmental health. Various studies have been conducted on many seagrass species such as *Thalassia testudinum* (Hackney and Durako 2004; Arellano-Méndez et al. 2011), *Halodule wrightii* (Creed 1997), *Halodule uninervis* and *Halodule pinifolia* (Sidik et al. 1999), *Enhalus acoroides* (Johnstone 1979; Verheij and Erftenmeijer 1993; Ambo-Rappe 2014, Putra et al. 2018), *Halophila ovalis* and *Halodule uninervis* (Hedge et al. 2009), *Halophila stipulacea* (Procaccini et al. 1999), and *Halophila hawaiiana* (McDermid et al. 2003).

Seagrasses can be found throughout the world except at the poles, and there are approximately 60 species of seagrass worldwide grouped into 13 genera and five families (Short et al. 2003). In Indonesia, there are currently 12 species of seagrasses belonging to seven genera, of which three genera are from the Hydrocharitaceae family (*Enhalus*, *Thalassia,* and *Halophila*), and four genera are from the Potamogetonaceae family (*Syringodium*, *Cymodocea, Halodule* and *Thalassodendron*) (Azkab 1999, Wahab et al. 2017). *Cymodocea rotundata and Cymodoce serrulata* are seagrass species found in Indonesian water. *Enhalus* is a genus of containing only one species, *Enhalus acoroides*, which is the most abundant seagrass species in Indonesia. *Cymodocea rotundata* Ascherson & Schweinfurth and *Enhalus acoroides* (L.f) Royle both play important roles in their respective ecosystems, with *E. acoroides* providing shelter for fish and shrimp juveniles, whereas *C. rotundata* is a major food plant for Dugong food in eastern Indonesia (Tomascik et al. 1997). Seagrass has also inhabited by macrozoobenthic (Wahab et al. 2018). In addition, both species of seagrass have bioprospecting value because they contain secondary metabolites. *E. acoroides* contains bioactive phenolic compounds that show potential antioxidants activities (Raja-Kannan et al. 2010) whereas extracts of *C. rotundata* seagrasses have antibacterial and antimicrobial activities (Mani et al. 2012).

North Maluku is one of the provinces located in eastern Indonesia consisting of large and small islands that make up the North Maluku islands with Halmahera Island being the largest island in the region. Ternate, Maitara, Tidore and Hiri Islands are the cluster of islands located opposite Halmahera Island on the west side. *C. rotundata* and *E. acoroides* can be found on all four islands. Good seagrass conditions have been recorded on Hiri and Maitara Islands, whereas seagrass conditions in Ternate and Tidore Islands are categorized as quite good with seagrass density lower than those on Hiri (Rahmawati and Rashidin 2012). To date, research on the morphometric characteristics of these two species of seagrass, *E.acoroides* and *C. rotundata* in Indonesia, especially in North Maluku has not been conducted to discriminate between the populations of the same species on different islands. Increased knowledge and information on morphometric characteristics would be able to explain the seagrass ability to adapt the environmental changes, which demonstrate its resilience. The present study aimed to determine the distribution of *E. acoroides* and *C. rotundata* over four islands and evaluate variation in morphometric characteristics of these two seagrasses in terms of adaptation to different conditions in North Maluku.

MATERIALS AND METHODS

Study area

The sampling of the two seagrass *E. acoroides* and *C. rotundata* was conducted in the waters off Ternate Island, Maitara Island, Tidore Island, and Hiri Island, North Maluku (Figure 1). Administratively, the research locations were located in Ternate City and Tidore Kepulauan City. The study site in the Ternate City region includes the waters off Ternate Island and Hiri Island, whereas Tidore Kepulauan City consists of the island of Tidore and Maitara. Ternate is an archipelago city composed of eight islands. The area of Ternate is 5.709.58 km^2, which includes 162.03 km^2 land area and 5,547.55km^2 sea area. The Ternate Island area is of 101.5730 km^2 inhabited by 207,091 people. Hiri Island is approximately 14 km from Ternate Island, with an area 6.70 km^2, which is inhabited by 3,124 people (BPS-Statistics of Ternate Municipality, 2017). Sampling sites on Ternate island were located at Kelurahan Kastella (Tte1) and Gamalama (Tte2), whereas the site on Hiri Island was situated at Tafraka (Hr1). Tidore Kepulauan City has regional characteristics of an archipelago area, consisting of 10 islands. The area of Tidore Kepulauan City approximately 1,550.37 km^2 (BPS-Statistics of Tidore Kepulauan City, 2016), of which Tidore island has a land area of approximately 11,883.75 ha (hectare), whereas Maitara island is approximately 292.93 ha (Giyanto, 2012). Sampling sites in Tidore Island were located at three sites at Kelurahan Mafututu (Tdr1), Tosa (Tdr2), and Dowora (Tdr3). The sampling and measurement work was conducted between May and August 2017. The study stations were located on the windward and leeward waters (Figure 1). Each research station consisted of three observation substations. The distance between each observation substation is 50 m, whereas the distance between the observation points at each substation is 20 m, but it can be adjusted to the condition of the research location.

Data collection and morphometric measurements of seagrass

Data collection from each seagrass station was performed using a line transect method and observation plot, as described by English et al. (1997). At each sub-station, a transect line was drawn 100 m perpendicular to the shoreline with an observation distance in each sub-stations was 50 m. In each transect, the 1 m x 1 m observation plot (at each observation point) was placed along the transect, with a distance of 20 m between successive points at 20 m. The identification of each seagrass species was confirmed by Phillips and Menez (1988). At each observation point, specimen of *E. acoroides* and *C. rotundata* were collected and the morphometric characteristics were measured using the methods of Hackney and Durako (2004) with a modification in core sampler size. Seagrass samples were taken from the sediment, with a core sampler (made of PVC pipe, 10 cm in diameter, and 30 cm long) in order to obtain the rhizome and roots. Seagrass sampled in this manner were then washed to remove any sediment and then separated by species.

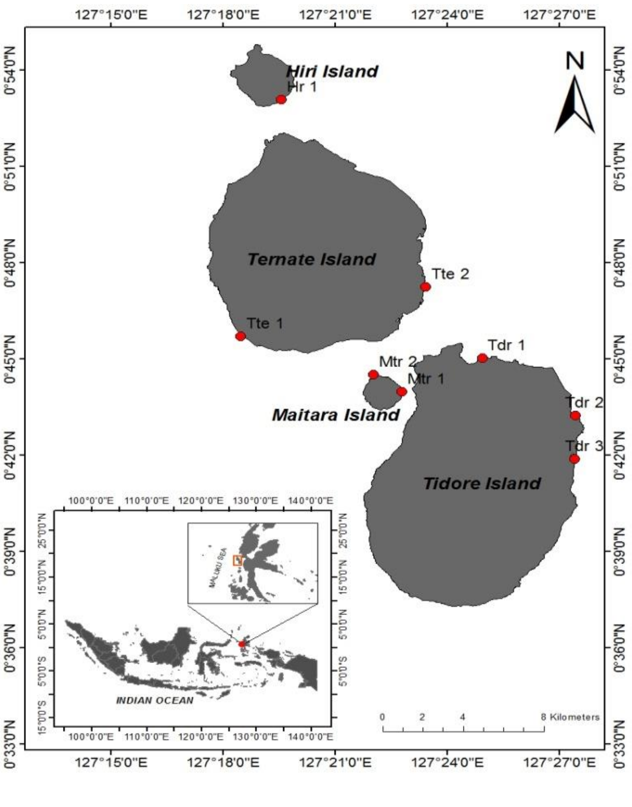

Figure 1. Sampling sites and their location on Hiri Island (Hr 1), Ternate Island (Tte1; Tte 2), Maitara Island (Mtr 1; Mtr 2) and Tidore Island (Tdr 1; Tdr 2; Tdr 3) (in red) in North Maluku, Indonesia

Morphometric measurements were performed on each specimen of each seagrass species, *E. acoroides* and *C. rotundata*. The above-ground measurements of morphometric characteristics were performed on all intact shoots (for green leaves) in a single seagrass stand and included leaf sheath length (cm), leaf length (cm) and leaf width (cm). The below-ground measurements of morphometric characteristics included rhizome diameter (cm), internode length (only *C. rotundata*), root length (cm) and root diameter (cm) (only for *E. acoroides*). Additionally, the number of leaves per stand was calculated and the presence of flowers and fruits was recorded. The environmental parameter data in the water such as temperature, salinity, pH, dissolved oxygen (DO), and turbidity were collected using a Water Quality Checker instrument (Horiba) and the sediment sample was collected using core sampler.

Data analysis

The morphometric characteristics of each seagrass species (leaf sheath length, leaf length, leaf width, rhizome diameter, root length, root diameter, and internode length) were measured at each location and station and the morphometric characteristics distinguishing the two seagrass species on all four islands were analyzed by discriminant analysis and processed using XLstat 2014. The discriminant analysis aimed to classify an individual or observation into mutually exclusive/disjoint and exhaustive groups based on some independent variables (Bengen 2000). Each parameter value was present as mean±SE.

RESULTS AND DISCUSSION

Morphology and morphometric characteristics of *Enhalus acoroides* and *Cymodocea rotundata*

The study showed that both species of *E. acoroides* and *C. rotundata* were widespread in the survey area and were found in four islands, indicating that the local environment of the study areas was able to support the growth of both species of seagrass (Table 1). The water temperatures obtained were within the range of 27.3 -29.7ºC, salinity was within the range of 33.4 ⁰/₀₀-35.2 ⁰/₀₀, and pH value within the range of 4.8-9.5, whereas the dissolved oxygen (DO) within the range of 7.8-12.7 mg/l. The water current velocity at the study sites was within the range of 0.016-0.08 m/s. The organic matter concentration was within 7.29%-24.43%. The overall substrate conditions at the study sites were dominated by fine sand and very fine sand, except for those at Station Tte 2, the substrate dominated by gravel.

The result of the morphometric measurements of *E. acoroides* and *C. rotundata* presented in Table 2 and Table 3, respectively. There was at least one difference in the morphometric characteristics of *E. acoroides* found at each station (Figure 2; Table 2). The above-ground values of *E. acoroides* including the leaf sheath length, leaf length and leaf width found at each station, indicated high variation as suggested by the high SE values. The highest mean of leaf sheath length was found at Station Mtr 1 (13.63 cm), followed by Station Tte 1 (12.5 cm), whereas the lowest value was found at Station Tte 2 (9.44 cm). The shortest mean of leaf length was found at Station Mtr 2 (7.62cm) (Table 2), which was one-third of the length of the value from all other stations. The longest *E. acoroides* leaf measured (88 cm) at Station Mtr 1 followed by Station Tte 1 (74.7 cm). The broadest leaf width found in this study sample was 1.7cm at Station Tte 2, whereas the narrowest was 0.7 cm at Station Tdr 1. The number of leaves per shoot found at each station showed no marked variation ranging from 3.17 to 3.8 leaves per shoot (Table 2).

The below-ground morphometric characteristics *E. acoroides* included measurement of the rhizomes and roots. The greatest rhizome diameter was found at Station Tte 2 (2.0 cm), whereas the equal-smallest were found in Stations Tdr 1 and Tdr 3 (1.2 cm). Stations Tte 2 and Tte 1 had the highest mean of rhizome diameter (1.22 cm and 1.21 cm), whereas Station Mtr 2 has the smallest mean of rhizome diameter at 0.93 cm. The highest mean of root length was found at Station Tte 2 (15.0 cm), whereas the lowest mean of root length was found at Station Tdr 1 (5.16 cm). However, the longest root measured in this study was found at Station Mtr 1 (35.0 cm) followed by Station Tte 1 (26.6 cm). The mean greatest root diameter was found at Station Mtr 1 (0.39 cm), whereas the mean smallest root diameter was found at Station Tte 2 (0.21cm). The maximum root diameter root recorded in this study was found at Station Mtr (10.67 cm). The mean number of roots per seagrass stand ranged from 5.00 to 11.57. Specimen of *E. acoroides* at Station Hr 1 was not measured because it was found in an incomplete state (Table 2). However, fruits of *E. acoroides* were found at Stations Tte 1, Tdr 2 and Tdr3.

The morphology of *C. rotundata* (Table 3) also showed a considerable variation in morphometric characteristics. The minimum leaf sheath length of *C. rotundata* was found at Station Tdr 2 (1.8 cm), whereas the maximum leaf sheath length was found at Station Hr 1 (11.5 cm). The mean of leaf sheath length at Station Tdr 3 (6.5 cm) was higher than that all other stations. The maximum leaf length was found at Station Hr 1 (28.0 cm), which was twice that at Station Mtr 2 (12.2 cm). However, Station Tdr 3 had a mean of leaf length of 11.97 cm, considerably larger than those from all other stations. The minimum leaf width found ranged from 0.2 to 0.4 cm, whereas the maximum leaf width ranged from 0.5 to 0.8 cm. The mean leaf width obtained ranged from 0.35 to 0.5 cm, and Station Tdr 3 and Tte 1 had the largest mean of leaf width of 0.5 cm, whereas Station Tdr 2 had the smallest leaf width of 0.2 cm.

The minimum rhizome diameter of *C. rotundata* was found at nearly all stations (0.2 cm), whereas the maximum rhizome diameter was found at Station Tte 1 (0.5 cm). The mean value of rhizome diameter at Stations Tdr 1, Tdr 2, Tdr 3, and Hr 1 ranged from 0.23-0.24 cm, which was smaller than those of plants at Station Tte 1 and Hr 1. The maximum root length found at Station Hr 1, was 14 cm, twice longer as long as that at Stations Tdr 1, Tdr 2 and Mtr 2. The longest mean root length was found at Stations Hr 1 and Tte 1 (7.43 cm and 7.33 cm, respectively), whereas the shortest mean root length was found at Station Mtr 2. The maximum internode length was found at Stations Tdr 3, Mtr 2, and Hr 1 (4.5 cm) being 2.5 times that at Station Tdr 2. However, the longest mean internode length was recorded at Station Tte 1 (3.07 cm) which was higher than that at all other stations. Plant at Station Tdr 2 also had the lowest range for the following morphometric characteristics: leaf sheath length, leaf width, and internode length. The number of leaves per stalk ranged from 2.16 to 3 leaves per stand.

The inter-island difference in morphometric characteristics of seagrasses *Enhalus acoroides* and *Cymodocea rotundata*

Discriminant analysis showed that there were distinguishing morphometric characteristics for both seagrass species, *E. acoroides* and *C. rotundata*, which were found on the small islands of Ternate, Maitara, and Tidore. The Bartlett test was employed for testing the discriminant function used for the diversity of inter-island morphometric seagrass response of *E. acoroides* and *C. rotundata* (Table 4). Data diversity was explained by F2 (discriminant function) of 100% for *E.acorides* seagrass and 97.9383% for *C. rotundata*. Based on the Bartlett test, p-value <0.05, thus, the second discriminant function was sufficient to distinguish of both *E. acoroides* and *C. rotundata* from each island.

The morphometric characteristics of leaf sheath length, leaf length, rhizome diameter, root length and root diameter of *E. acoroides* from each island showed significant differences, indicating that each characteristics differed between the populations from the different islands, whereas the leaf width characteristic not significantly different between the island (Table 5). The morphometric characteristics of leaf sheath length, leaf width, rhizome diameter, root length, and internode length of *C. rotundata* for each island showed significant differences, whereas the leaf length characteristic of *C. rotundata* between the islands did not differ significantly (Table 5).

The variation in grouping of the population of *E. acoroides* and *C. rotundata* in each island was indicated by the strength of the discriminant component function through the canonical correlation coefficient values (r) for F1 and F2 functions are shown in Table 6. The value of the canonical correlation for *E. acoroides* was 0.615 in F1 and 0.548 in F2. The calculation of the coefficient of determination (r^2 x 100) meant that 37.8% (F1) and 29.9% (F2) or 67.7% (in total) of the variance of the dependent variable could be explained by the discriminant model for *E. acoroides*. The values of the canonical correlation coefficients for *C. rotundata* of 0.757 for F1 and 0.529 for F2 meant that 57.2% (F1) and 27.9% (F2) or a total 85.1% of the variance of the dependent variable can be explained by the discriminant model for the *C. rotundata*.

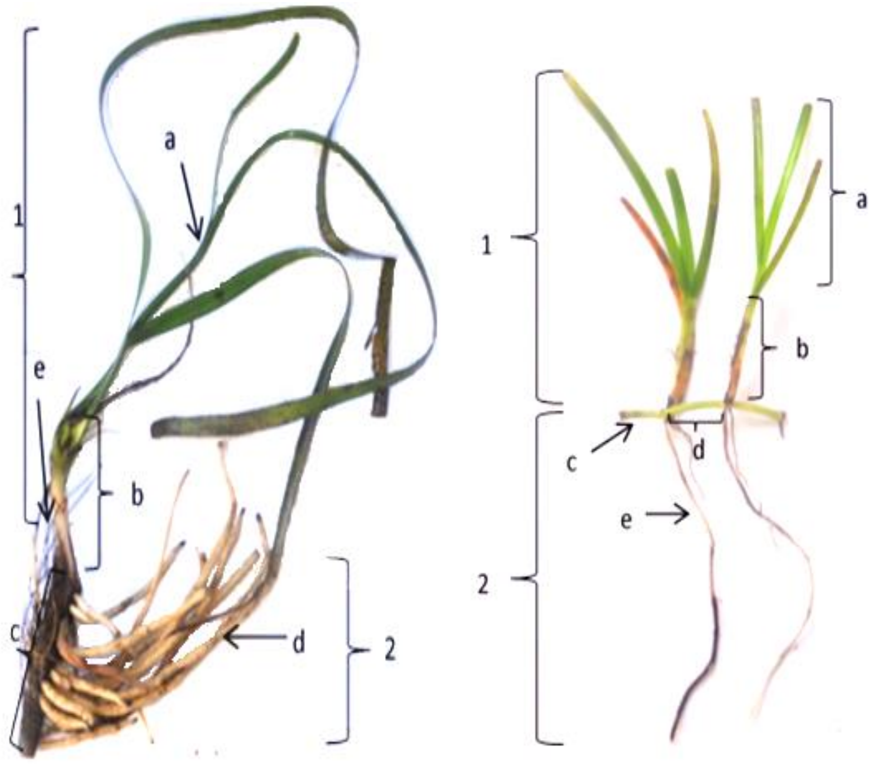

Figure 2. Morphology and morphometric characteristics of two seagrass species (left: *Enhalus acoroides* and right: *Cymodocea rotundata*) in four small islands in North Maluku, Indonesia: A. *Enhalus acoroides* (sample from Tidore Island): 1. Above-ground, plant parts consist of a. leaf and leaf sheath; 2. Below-ground, plant parts consist of c. rhizome, d. root and e. black fibers. B. *Cymodocea rotundata* (sample from Hiri Island: 1. Above-ground, plants parts consist of a. leaf and leaf sheath; 2. Below-ground, plant parts consist of c. rhizome, d. internode and e. root

Table 1. Environmental characteristics of the study site (station) in North Maluku, Indonesia

Environmental parameter	Study site (station)							
	Tte 1	**Tte 2**	**Tdr 1**	**Tdr 2**	**Tdr 3**	**Mtr 1**	**Mtr 2**	**Hr 1**
Temperature (°C)	29.1±0.40	28.2±0.13	29.7±0.18	28.7±0.17	28.7±0.02	28.4±0.33	29.1±0.32	27.3±0.08
Salinity (ppt)	34.3±0.36	34.9±0.10	34.2±0.33	35.2±0.67	34.9±0.06	34.4±0.15	34.7±0.05	33.4±0.88
DO (mg/l)	10.9±2.84	7.8±0.24	12.7±2.42	10.4±0.65	10.4±0.63	8.6±0.34	10.14±0.55	9.0±0.84
pH	6.2±1.13	7.6±1.23	6.1±1.42	4.8±0.87	6.3±0.94	9.3±0.69	9.5±0.22	9.0±0.37
Turbidity (NTU)	46.3±46.33	0	0	3.4±1.83	102.2±51.07	32.5±27.77	10±3.059	15.9±15.37
Current (m/sec)	0.08±0.006	0.05±0.002	0.016±0.0006	0.04±0.005	0.017±0.0008	0.062±0.018	0.075±0.005	0.05±0.003
Gravel (%)	0.26	49.8	0.83	0.27	0.63	n.d	n.d	n.d
Granule (%)	0.26	32.2	3.89	0.99	5.16	n.d	n.d	n.d
Very coarse sand (%)	5.86	7.54	12.33	2.28	11.48	1.25	0.49	0.36
Coarse sand (%)	6.5	0.79	8.71	2.15	12.45	10.15	2.52	5.29
Medium sand (%)	31.72	7.41	15.04	14.16	23.98	20.94	15.12	9.41
Fine sand (%)	51.44	2.3	55.65	73.38	40.22	7	12.16	13.52
Very fine sand (%)	3.89	0.023	3.47	6.18	4.07	44.38	56.42	60.34
Dust (%)	0.05	0	0.067	0.52	1.99	2.75	0.85	1.21
Clay (%)	0	0	0	n.d	n.d	3.58	11.59	2.88
TOM (%)	7.29	22.6	9.3	13.2	8.12	24.43	18.42	17.43

Note: Tte 1 (Ternate 1); Tte 2 (Ternate 2); Tdr 1 (Tidore 1); Tdr 2 (Tidore 2); Tdr 3 (Tidore 3); Mtr 1 (Maitara 1); Mtr 2 (Maitara 2), Hr 1 (Hiri 1), n.d (not detected)

Table 2. The morphometric character of *Enhalus acoroides*

Stations	Morphometric character of *Enhalus acoroides*													
	Leaf sheath length (cm)				Leaf length (cm)				Leaf width (cm)				Leaves per shoots	
	Max	Min	Mean (±SE)	n	Max	Min	Mean (±SE)	n	Max	Min	Mean (±SE)	n		n
Above-ground														
Tte 1	17.5	7.5	12.5±0.759	14	74.7	4	34.37±4.364	19	1.3	0.8	1.06±0.028	19	3.43±0.20	14
Tte2	22	5.5	9.44±1.657	9	48	10.5	27.19±3.620	12	1.7	0.7	1.14±0.089	12	3.5±0.175	9
Tdr 1	15	6	9.93±0.934	12	51.5	7	26.47±2.898	19	1.2	0.7	0.98±0.028	19	3.17±0.11	12
Tdr 2	13	6.5	9.5±0.695	10	51.3	6	29.83±2.762	24	1.5	0.8	1.09±0.042	24	3.8±0.13	10
Tdr 3	17	7.5	12±0.681	15	69	5	32.59±2.795	28	1.4	1	1.12±0.022	28	3.4±0.16	15
Mtr 1	21	8	13.63±0.759	24	88	2.3	25.16±3.887	26	1.5	0.8	1.13±0.041	26	3.58±0.10	24
Mtr 2	15	8	11±1.483	5	13	2.5	7.62±1.748	5	1.2	0.8	0.94±0.074	5	3.2±0.37	5
Below-ground														
Tte 1	1.5	0.8	1.21±0.053	14	26.6	5.5	12.27±1.681	14	0.6	0.12	0.27±0.038	14	11.57±2.471	14
Tte 2	2	1	1.22±0.111	9	24	8	15±1.685	9	0.3	0.2	0.21±0.011	9	11±1.699	9
Tdr 1	1.2	0.6	0.96±0.051	12	10.1	1	5.16±0.638	14	0.5	0.15	0.32±0.029	14	6.67±1.437	12
Tdr 2	1.4	0.8	1.06±0.059	10	15.1	2.6	7.68±0.666	24	0.6	0.2	0.37±0.019	24	5±1.414	10
Tdr 3	1.2	0.8	0.99±0.030	15	21.7	2.7	7.72±0.911	29	0.6	0.2	0.35±0.024	29	10.07±1.637	15
Mtr 1	1.75	1.028	1.19±0.029	24	35	1.2	7.45±0.682	57	0.67	0.14	0.39±0.049	57	9.62±1.17	24
Mtr 2	1.35	0.57	0.93±0.128	5	18.1	2.2	8.74±1.711	11	0.4	0.2	0.29±0.022	11	8.2±3.05	5

Note: Tte 1 (Ternate 1); Tte 2 (Ternate 2); Tdr 1 (Tidore 1); Tdr 2 (Tidore 2); Tdr 3 (Tidore 3); Mtr 1 (Maitara 1); Mtr 2 (Maitara 2), Hr 1 (Hiri 1)

Table 3. The morphometric characteristics of *Cymodocea rotundata*

Stations	Morphometric characteristics of *Cymodocea rotundata*													
	Leaf sheath length (cm)				Leaf length (cm)				Leaf width (cm)				Leaves per shoots	
	Max	Min	Mean (±SE)	n	Max	Min	Mean (±SE)	n	Max	Min	Mean (±SE)	n		n
Above-ground														
Tte 1	5.4	3.5	4.13±0.16	16	16.2	2	9.06±0.770	26	0.6	0.4	0.51±0.016	26	2.81±0.10	16
Tdr 1	7	2	4.7 ± 0.31	18	18	2.6	8.36±0.91	23	0.6	0.3	0.44±0.015	23	2.16±0.12	18
Tdr 2	6	1.8	4.45±0.289	14	15.5	3.4	8.5±0.785	21	0.5	0.2	0.43±0.016	21	2.2±0.11	4
Tdr 3	10	3	6.5±0.85	11	20	3.8	11.97±1.173	19	0.8	0.3	0.5±0.033	19	2.7±0.14	11
Mtr 2	7.5	4	5.83±0.557	6	12.2	2.2	7±1.249	8	0.5	0.3	0.35±0.032	8	2.5±0.20	7
Hr 1	11.5	3	6.21±0.635	17	28	2.2	9.86±1.180	28	0.5	0.3	0.43±0.010	28	3±0.148	17
Below-ground														
Tte 1	0.5	0.2	0.31±0.027	16	13.8	3.7	7.33±0.778	16	3.5	1.9	3.07±0.153	16	1.3±0.218	16
Tdr 1	0.3	0.2	0.24±0.012	18	6.8	1.2	3.67±0.397	18	1.7	0.5	1.1±0.06	18	1.61±0.183	18
Tdr 2	0.3	0.2	0.23±0.017	14	6.8	1.2	3.36±0.429	14	2.5	0.2	1.3±0.13	14	1.42±0.137	14
Tdr 3	0.3	0.2	0.24±0.015	11	9.5	2	5.21±0.673	11	4.5	0.7	2.21±0.456	11	1.2±0.14	11
Mtr 2	0.4	0.2	0.24±0.029	7	6.4	1	2.64±0.649	8	4.5	0.7	1.64±0.446	8	1.57±0.297	7
Hr 1	0.35	0.25	0.30±0.006	17	14	1.3	7.43±0.979	18	4.5	0.7	2.27±0.305	18	1.94±0.20	17

Note: Tte 1 (Ternate 1); Tte 2 (Ternate 2); Tdr 1 (Tidore 1); Tdr 2 (Tidore 2); Tdr 3 (Tidore 3); Mtr 1 (Maitara 1); Mtr 2 (Maitara 2), Hr 1 (Hiri 1)

Table 4. Bartlett test for *Enhalus acoroides* and *Cymodocea rotundata*

Function	Eigen-value	Discrimina-tion (%)	Cumulative %	Bartlett's statistic	p-value
E.acoroides					
F1	0.6081	58.6700	58.6700	146.7706	≤0.0001
F2	0.4284	41.3300	100.0000	62.9266	≤0.0001
C. rotundata					
F1	1.3389	75.9095	75.9095	148.0700	≤0.0001
F2	0.3886	22.0288	97.9383	44.4066	≤0.0001

Table 5. Test of equality means for individual variables of *Enhalus acoroides* and *Cymodocea rotundata*

Variable	Lambda	F	DF1	DF2	p-value
E. acoroides					
Leaf sheath length	0.8744	12.8616	2	179	< 0.0001
Leaf length	0.9311	6.6203	2	179	0.0017
Leaf width	0.9952	0.4305	2	179	0.6509
Rhizome diameter	0.8777	12.4664	2	179	< 0.0001
Root length	0.8083	21.2316	2	179	< 0.0001
Root diameter	0.8911	10.9429	2	179	< 0.0001
C. rotundata					
Leaf sheath length	0.8915	5.0321	3	124	0.0025
Leaf length	0.9810	0.7994	3	124	0.4965
Leaf width	0.8569	6.9047	3	124	0.0002
Rhizome diameter	0.7788	11.7383	3	124	< 0.0001
Root length	0.7467	14.0206	3	124	< 0.0001
Internode length	0.7094	16.9292	3	124	< 0.0001

Table 6. Canonical correlation within *Enhalus acoroides* and within *Cymodocea rotundata*

Function	Eigen-value	% of discriminant	Cumulative %	Canonical correlation
E. acoroides				
F1	0.608	58.670	58.670	0.615
F2	0.428	41.330	100.000	0.548
C. rotundata				
F1	1.339	75.909	75.909	0,757
F2	0.389	22.029	97.938	0,529

Table 7. Function at the centroid of *Enhalus acoroides* and *Cymodocea rotundata* based on islands of North Maluku, Indonesia

Islands	F1	F2
E. acoroides		
Ternate	1.613	-0.468
Tidore	-0.586	-0.522
Maitara	-0.029	0.830
C. rotundata		
Ternate	1.815	0.544
Tidore	-0.768	0.318
Maitara	-1.799	-0.618
Hiri	0.677	-1.044

The centroid group was the average discriminant value of each variable within each group. The centroid group was the intra-island differentiator of the canonical model formed on related component functions for both *E. acoroides* and *C. rotundata* as shown in Table 7. For *E. acoroides*, the centroid group of Ternate Island was represented by F1 and F2 component functions of 1.613 and-0.468 respectively, whereas they are-0.586 (F1) and-0.522 (F2) on Tidore Island and-0.029 (F1) and 0.830 (F2) on Maitara Island. This implies that the average discriminant value between the three islands was sufficient to distinguish the groups present for *E. acoroides*. For *C. rotundata*, the centroid group for Ternate Island was represented by components F1 and F2 of 1.815 and 0.544 respectively, whereas they were -0.768 (F1) and 0.318 (F2) for Tidore Island, -1.799 (F1) and-0.618 (F2) for Maitara Island, and 0.677 (F1) and-1.044 (F2) for Hiri Island. These values indicated that the mean discriminant values for the four islands were sufficient to differentiate among the groups.

Discussion

E. acoroides and *C. rotundata* were observed to be present at all stations indicating that the local water environment conditions were able to support the growth of both species of seagrass. The range of environmental parameter values obtained in the water at each observation point location was still within the range of optimum condition for each seagrass species. According to Phillips and Menez (1988), seagrasses are eurybionts in that they can tolerate some variation in environmental factors such as temperature, salinity, light, substrate, and water movement, but most seagrasses in the tropics are more stenobiont, requiring relatively constant environmental conditions. *E. acoroides* and *C. rotundata* were known to have widespread distribution in Indonesian waters (Tomascik et al. 1997; Kawaroe et al. 2016). One of the physical factors affecting seagrass distribution is the availability of suitable substrate to grow. Most seagrass species distribution was limited by sand to a muddy substrate, whereas some species can grow on rocks, by rooting into the organic matter contained therein (Kawaroe et al. 2016; Hemminga and Duarte 2000).

The basic types of substrates occupied by seagrasses fall into categories ranging from sludge, sand, gravel to coral beds and other which are more dominated by fine sand and very fine sand and almost all of these substrate types can be colonized by both species of seagrass. *C. rotundata* is able to colonize substrate types ranging from fine to coarse sand in intertidal areas. Similarly, *E.acoroides* can be found in a wide range of habitats, with different variations in substrate ranging from mild terrigenous sludge to rough carbonate sediments in reef flats in intertidal waters (Tomascik et al. 1997).

Seagrass distribution is also influenced by seagrass dispersal capability (Hogarth 2007). In the current research, we found the existence of fruit of *E. acoroides* at Stations Tte 1, Tdr 2 and Tdr 3. Of the two seagrass species studied, only *E. acoroides* releases pollen onto the surface of the water through sexual reproduction, a phenomenon which limits its distribution in the shallow intertidal and subtidal areas (Short et al. 2007). The distribution of *C. rotundata* more limited because of the characteristics of the pollen and seeds that have negative buoyancy. However, *C. rotundata* has large seed reserves in deep sediments and the seed bank indicates the significance of this species as an active colonizer (McMillan et al. 1982). According to Coles et al. (2011), many environmental biophysical parameters, the availability of seeds and vegetative fragments, and anthropogenic inputs can determine the presence of seagrasses along coastal areas and regulate the growth and morphology of seagrasses.

Variation in morphometric characteristics of the seagrass *E. acoroides* and *C. rotundata* found among the four islands indicated the ability of these two species to develop their own strategies to adapt to the different habitat conditions. Previously, it had been reported that seagrass species exhibit variation in morphometric between different stand in different location, such as *Thalassia testudinum* in different habitats in Florida Bay (Hackney and Durako 2004) and Bahia de la Ascension (Arellano-Mendez et al. 2011), *Halodule* seagrasses in Malaysia occupying habitats with different ecological conditions (Sidik et al. 1999), *Halodule wrightii* seagrass on the Brazilian coast (Creed 1999), as well as *Halophila hawaiiana* in the Hawaiian Islands (McDermid et al. 2003).

The lack of information on the variation of morphometric characteristics of *E. acoroides* and *C.rotundata* from previous report in the study area makes it difficult to make comparisons with the current study. *E. acoroides* found in Gusung Talang in Indonesia had the longest leaves of more than 2 m and maximum leaf widths of 1.8 cm (Verheij and Erftemeijer 1993), whereas in the current study, the longest leaf length was 88 cm and the maximum leaf width was 1.7 cm. *C. rotundata* is a small pioneer species. The maximum leaf length of *C. rotundata* found in the current study was 28 cm and maximum leaf width of 0.8 cm, whereas in Sulawesi waters the longest leaf reported was 31 cm, whereas the greatest width was 0.4 cm (Verheij and Erftemeijer 1993). Vermaat (2009) revealed great variation in the morphological characteristics of the two of seagrass species, *E. acoroides* leaf width ranging from 1.2 to 1.8 cm with a maximum leaf length of 150 cm, whereas the *Cymodocea* sp. had a leaf width between 0.2 cm and 0.9 cm with a canopy height (maximum leaf length) of 60 cm. *E. acoroides,* which is a climax species is known to show high phenotypic plasticity in response to environmental conditions and nutrient availability (Verheij and Erftenmeijer 1993). Ambo-Rappe (2014), showed that *E. acoroides* plants which grew on Kapopposang Island had a larger leaf length and width than those of plants which grew on the surrounding islands, this finding relating to relatively deep and turbid waters around Kapopposang Island.

In the current study, the *E. acoroides* plants found at Station Mtr 1 had the highest leaf length, and greatest root length and highest density, indicating favorable environmental conditions for the growth of this species. This corresponded to the location of the station which was close to the mangrove forest that contributes nutrients and the subtle sedimentary inputs connected with the seagrass growing underneath. In addition, large seagrass canopies, such as those of *E.acoroides*, support sedimentation and increased nutrient supply (Hemminga and Duarte 2000). This finding was supported by another study, which showed that *Thalassia testudinum* had the highest number of leaves per shoot, high shoot density and the greatest biomass due to nutrient and sediment input from the nearby mangrove community (Arrelano-Mendez et al. 2011). However, *C. rotundata* had the lowest density at Station Mtr 1 where it was found in small quantities. Station Mtr 1 was a semi-sheltered water environment, and there was a mangrove forest area in front of it. According to Tomascik et al. (1997), in sheltered aquatic environments with basal types of waters dominated by muddy substrates, *E. acoroides* tends to form climax communities in which the environmental conditions become unsuitable for the growth of other species.

In the present study, discriminant analysis revealed that the *E. acoroides* characteristics of leaf sheath length, leaf length, rhizome diameter, root length, and root diameter all differed significantly between populations from the different islands, whereas leaf width did not differ significantly between the four islands. Leaf length of *C. rotundata* did not differ significantly, whereas the other characteristics, i.e., leaf sheath length, leaf width, rhizome diameter, internode length, and root length, were significantly different among populations from the four islands. According to Tomascik et al. (1997), variation in the length of *E. acoroides* leaves is related to the depth of the waters, whereas variation in the width of *E. acoroides* leaves in Papua New Guinea is a function of plant development (Johnstone 1979). Furthermore, Creed (1997), stated that the effect of grazing or movement of water affected the length but not the width of the leaves. This was also evident in the conditions of the top of *E. acoroides* seagrasses, where damage was caused by the movement of water, due to wave energy and exposure during low tide (Verheij and Erftemeijer 1993), whereas the top of damaged *C. rotundata* seagrasses was predominantly caused by grazing. Other studies on morphometric variations in seagrasses indicated that the characteristic of *Thalassia hemprichii* leaf length did not differ significantly at different sites in the Negros Oriental Philippines (Wagey 2013).

Seagrasses have leaves comprise a leaf sheath and a leaf (blade). The unchlorophyllized leaf sheath, or leaf base, encloses the growth of the rhizome edges and protects the young leaves (Tomascik et al. 1997). One important key adaptation of seagrass that enables it to colonize marine habitats is a leaf shape equipped with a leaf sheath that can adapt to high-energy environments (Hemminga and Duarte 2000). The longest leaf sheath of *E. acoroides* was found at Stations Mtr 1 and Tte 2. This may be related to the sediment load where the Station Mtr 1 which had a semi-sheltered water environment and was located in front of the mangrove forest, had a substrate type that dominantly comprised sludge sand, whereas the substrate of Station Tte 2 was dominated more by gravel and was becoming a reclamation area. Creed (1997) stated that if the sediment was deep or if the sediment input is constant, then the length of the sheath will be high. The number of leaves of seagrass enforcement is a conservative characteristic existing in each seagrass individual (Hemminga and Duarte 2000). The number of leaf enforcement for *E. acoroides* averaged 3 leaflets whereas for *C. rotundata.* It ranged from 2.16 to 3 leaves. This was similar to the situation reported for *C. rotundata* in Kenya where the number of leaves per shoot ranged from 2.5 to 2.8 leaves (Uku and Bjork 2005).

The ability of seagrass to occupy an area is also inseparable from the rhizome ability to develop its root system on different types of substrates and indicates morphological plasticity (Balestri et al. 2015). The rhizome is the main organ of carbohydrate storage (in the form of sucrose) in seagrasses (Vermaat and Verhagen 1996), and the rhizome diameter is a conservative nature of seagrass (Hemminga and Duarte 2000). Small-sized seagrasses have a short lifespan with rapid rhizome extensions while large-sized seagrasses have a longer lifespan with shorter rhizome extensions (Vermaat 2009). Root growth capabilities in different types of substrates exhibit morphological plasticity, and thus, root system on a sandy substrate grows vertically, whereas, on a hard substrate, it will extend horizontally and generate superficial formations (Balestri et al. 2015).

In the current study, the ability of *E. acoroides* and *C. rotundata* roots to penetrate to the bottom of the waters at each study site was shown in Tables 3 and 4. The strong *E. acoroides* root enabled it to penetrate the bottom of the seafloor to strengthen seagrass beds in various types of substrates (Tomascik et al. 1997), whereas *C. rotundata,* although having small roots, is still able to stabilize and consolidate various types of the substrate from fine sand to coarse sand (Tomascik et al. 1997). The expansion of the rooting system and its penetration into the substrate are essential for the growth of new seagrasses to overcome physical disturbance and the low availability of nutrients (Balestri 2015). However, research conducted by Kiswara et al. (2009) on the root morphology of six species of tropical seagrasses in different habitats indicated that the different types of sediments and nutrient availability that exist between sites had a little effect on the root shape.

These two seagrass species, *E. acoroides* and *C. rotundata,* were distributed in the waters off the small islands of Hiri, Ternate, Maitara, and Tidore, indicating that the prevailing environmental conditions at these sites were capable of supporting the growth of seagrasses. Examination of the two species on these four islands revealed a wide variation in morphometric characteristics that showed significant differences among populations of the same species among four island, except for leaf width in *E. acoroides* and leaf length in *C. rotundata,* which did not differ significantly between populations. The variations in the morphometric characteristics shown by the seagrasses species indicated a relationship with the marine environmental conditions on each of these islands. Our finding is expected to contribute to a baseline for seagrass ecosystem management, and this ecosystem is an important coastal ecosystem for small islands in North Maluku because it is physically to protect the coastline and small mainland islands in the region.

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