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Spatial variation of nutritional content in enhalus acoroides (L.f.) royle seeds and seed pods

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Coastal and small islands communities generally have limited access to fresh vegetables. The tropical seagrass Enhalus acoroides fruits during the rainy season, when sea conditions often prevent fishing. Coastal communities in several countries, including Indonesia, traditionally collect seagrass fruit for food and traditional remedies. This study measured levels of 6 key nutrients in Enhalus acoroides fruit (seeds and seedpods). Samples were collected from two sites where E. acoroides fruits are harvested (Bulukumba, Selayar), and one unharvested site (Makassar). Interaction between collection site and fruit part was significant for 3 nutrients (P, K, ß-carotene). Nutrient content differed significantly between fruit parts, with higher P and Zn levels in seeds than seedpods. Levels of Ca and Fe were significantly higher in fruit from the unharvested site (Makassar), most likely due to environmental conditions. The Ca, K, P and Fe levels in E. acoroides fruit compared favourably to common vegetables.

1. Introduction

Coastal and small island communities tend to depend heavily on marine resources for their food. Their land is often limited and/or unsuitable for agriculture and the access to markets or shopping centres where agricultural produce could be purchased is often limited; thus, vegetables are often in short supply. Furthermore, small-scale fisheries are also affected by the seasons. During the rainy season, fishermen are often prevented from going to sea due to rough weather, causing them and their families to rely heavily on food collected by gleaning in sheltered shallow coastal waters. The fruit of some seagrasses have long been consumed as food by coastal and small island communities in several countries, including the Philippines, Hawaii, Australia, and the Pacific Islands (Montano et al., 1999; Nontji, 2007; Setyati et al., 2003; Wakano, 2013). Seagrass fruits are known to contain nutrients such as protein, carbohydrates, fats and fibre;, they can be used to increase immune system activity to combat degenerative diseases or infections and as remedies (Badui, 2010). The fruit of the seagrass E. acoroides can be consumed raw or boiled (Alino et al., 1990).

Several coastal communities in South Sulawesi consume E. acoroides fruit; however, each community is likely to have specific processing and cooking methods. For exam-

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ple, Pe-people in Bulukumba generally consume the fruit whole (seeds and seedpod), while people in Selayar only consume the seeds. This research evaluated the nutritional content of E. acoroides fruit, specifically, 6 micronutrients (Ca, P, K, Fe, Zn, and ß-carotene). The goals of this study were to determine the variation in micronutrient content between the seeds and the seedpods of E. acoroides from different locations, including Makassar where E. acoroides fruit is usually not considered as food and to evaluate the potential of E. acoroides fruit as a source of nutrition for coastal communities. The results will contribute to knowledge about coastal and marine resource-use for human nutrition, particularly, alternative sources of nutritious plant-based foods for people living in coastal and small-island communities.

2. Materials and Methods

Study sites and data collection

Fruits of the seagrass E. acoroides were harvested during August-October 2017 from three research sites: Kodingareng Lompo Island, Makassar City (5°8'57.2" S, 119°15'36.0" E); Tanaberu Village, Bulukumba Regency (5°32'39.7" S, 120°22'4.0" E), and Mekar Indah Village, Selayar Island (5°59'26.9" S, 120°26'51.5" E). The sites were determined based on the extent of seagrass fruit use: whole fruit (seeds and seedpod) in Bulukumba; seeds only in Selayar; and fruits rarely eaten in Makassar.

Samples of the young E. acoroides fruit (mostly selected for consumption) were collected and then cleaned with fresh water to remove any sand and salt attached to the fruit. The wet samples were then put in a plastic bag and stored in a cool-box. Samples were sorted, and the seeds were separated from the seedpods. The seeds and the seedpods from each sample were then weighed separately.

Mineral content (Ca, K, Fe, Zn, P)

In order to determine the content of four essential minerals (Ca, K, Fe, and Zn) in E. acoroides seeds or seedpods, a 1-gram aliquot of each part of the fruit from each sample was reduced to ash in a furnace. A 3-5 ml volume of concentrated HCl was added and then diluted to 100 ml. The solution was filtered through Whatman No.42 filter paper, then placed in the AAS (atomic absorption spectrophotometer) by AOAC, (2012) and the measurements recorded.

The phosphorus (P) content was determined by reducing a 1-gram aliquot of each part of the fruit from each sample to ash in a furnace. A 3-5 ml volume of concentrated HCl was added and then diluted to 100 ml. A volume of 1 ml was pipetted into a 50 ml volumetric flask to which 3 ml of ammonium molybdate solution and 2.5 ml of ascorbic acid solution were then added. The mixture stood for 30 minutes before being placed in a UV-VIS spectrophotometer at a wavelength of 570 nm (AOAC, 2012); the phosphorus content was recorded.

ß-Carotene content

The ß-Carotene content of each part of the fruit was determined by mixing 20 grams of the relevant fruit part with 70 ml of acetone and 15 ml of water and placing it in a 100ml volumetric flask with petroleum ether. The ß-carotene was filtered using Whatman No.1 filter paper. The sample was then placed into a test tube and centrifuged at as speed of 4000 rpm. The sample was then placed in a spectrophotometer at a wavelength of 460-480 nm (AOAC, 2012) and the ß-carotene pigment content was recorded.

Statistical analysis

Analysis of variance (ANOVA) was implemented to evaluate the differences of nutrient content between E. acoroides fruit parts and between sites and the interaction between site and fruit part. If the results of the ANOVA indicated significant differences at $\alpha = 0.05$, Duncan's post-hoc test was implemented. All statistical analyses were implemented in SPSS Statistics 21 software.

3. Results

The data on phosphorus (P), potassium (K), and ß-carotene content indicated significant interaction between site and fruit part, while for the other three nutrients (Ca, Fe, and Zn) the interactions were not significant (Table 1). Nutrient content differed significantly based on fruit part for phosphorus (P) and zinc (Zn), and by site for calcium (Ca) and iron (Fe).

The calcium (Ca) and iron (Fe) content of E. acoroides fruit were significantly different between the sites, for both seeds and seedpods (Figure 1). However, there was no significant difference between the fruit parts. The Ca content was higher in fruits from Makassar (6,613.84 mg kg-1) than in those from Bulukumba (1,594.88 mg kg-1) and Selayar (1,884.08 mg kg-1). Similarly, the Fe content of fruits from Makassar (116.17 mg kg-1) was higher than in fruits from Bulukumba (4.76 mg kg-1) and Selayar (11.49 mg kg-1).

The nutritional content of each part of the seagrass fruit varied, as shown in Figure 2. Overall (all three sites combined), the zinc content was significantly different between the seeds and seedpods (Figure 2). The average zinc (Zn) concentration was higher (1.5 mg kg-1) in the seeds than in the seedpods (0.4 mg kg-1).

Data on the nutrient content of phosphorus (P), potassium (K), and ß-carotene showed significant interaction between fruit part and site (Figure 3). The highest phosphorus con-

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Table 1. Analysis of Variance on the nutrient content of E. acoroides fruit (seedpods and seeds) from sites in Makassar City, Bulukumba District, and Kepulauan Selayar District

Nutrient	Source	df	Mean square	F-ratio	Probability	Duncan test result
Calcium (Ca)	Site (L)	2	4.764	267.968	**0.004**	Significant
	Error	2	177798.457[a]			
	Fruit part (B)	1	412653.262	2.321	0.267	Not significant
	Error	2	177798.457[a]			
	L*B	2	177798.457	0.102	0.904	Not significant
	Error	12	1.742			
Phosphorus (P)	Site (L)	2	27779.792	2.351	0.298	Not significant
	Error	2	11817.030			
	Fruit part (B)	1	1053160.631	89.122	**0.011**	Significant
	Error	2	11817.030			
	L*B	2	11817.030	4.985	**0.027**	*Significant
	Error	12	2370.451			
Potassium (K)	Site (L)	2	1.458	2.858	0.259	Not significant
	Error	2	5100477.953			
	Fruit part (B)	1	8938455.542	1.360	0.364	Not significant
	Error	2	5100477.953			
	L*B	2	5100477.953	4.610	**0.033**	*Significant
	Error	12	1106398.472			
Iron (Fe)	Site (L)	2	23416.642	25.538	**0.038**	Significant
	Error	2	916.951			
	Fruit part (B)	1	6.457	0.007	0.941	Not significant
	Error	2	916.951			
	L*B	2	916.951	0.721	0.506	Not significant
	Error	12	1272.093			
Zinc (Zn)	Site (L)	2	1.259	7.025	0.125	Not significant
	Error	2	0.179			
	Fruit part (B)	1	5.481	30.573	**0.031**	Significant
	Error	2	0.179			
	L*B	2	0.179	1.291	0.311	Not significant
	Error	12	0.139			
ß-carotene	Site (L)	2	0.049	0.307	0.765	Not significant
	Error	2	0.158			
	Fruit part (B)	1	0.749	4.727	0.162	Not significant
	Error	2	0.158			
	L*B	2	0.158	6.317	**0.013**	*Significant
	Error	12	0.025			

*) significant interaction between study site and E. acoroides fruit part

centration was found in the seeds from Selayar (783.34 mg kg-1), while seedpods from Makassar had the lowest concentration (134.18 mg kg-1) (Figure 3A). The seeds from Makassar (MKS-S) had a significantly higher potassium (K) content (5,136.74 mg kg-1) than all the other site-fruit part combinations locations and parts of the fruit (Figure 3B). The ß-carotene concentration was highest in the seedpods of E. acoroides fruit from Bulukumba (1.36 mg kg-1) and lowest in the seeds from Selayar (0.59 mg kg-1).

4. Discussion

Every plant requires at least 16 elemental nutrients for normal growth. Three elements (carbon, hydrogen, and oxy-

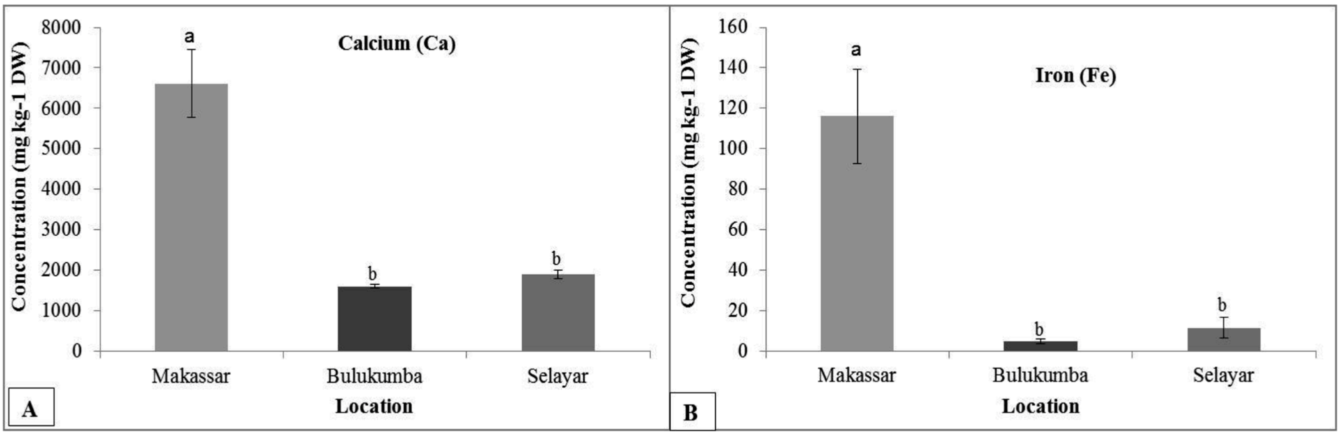

Figure 1. Mean nutrient content of E. acoroides fruit from sites in Makassar, Bulukumba, and Selayar: A) calcium; B) iron. Whiskers denote standard error (SE); lower-case letters (a, b) indicate significantly different values (p<0.05). DW=dry weight

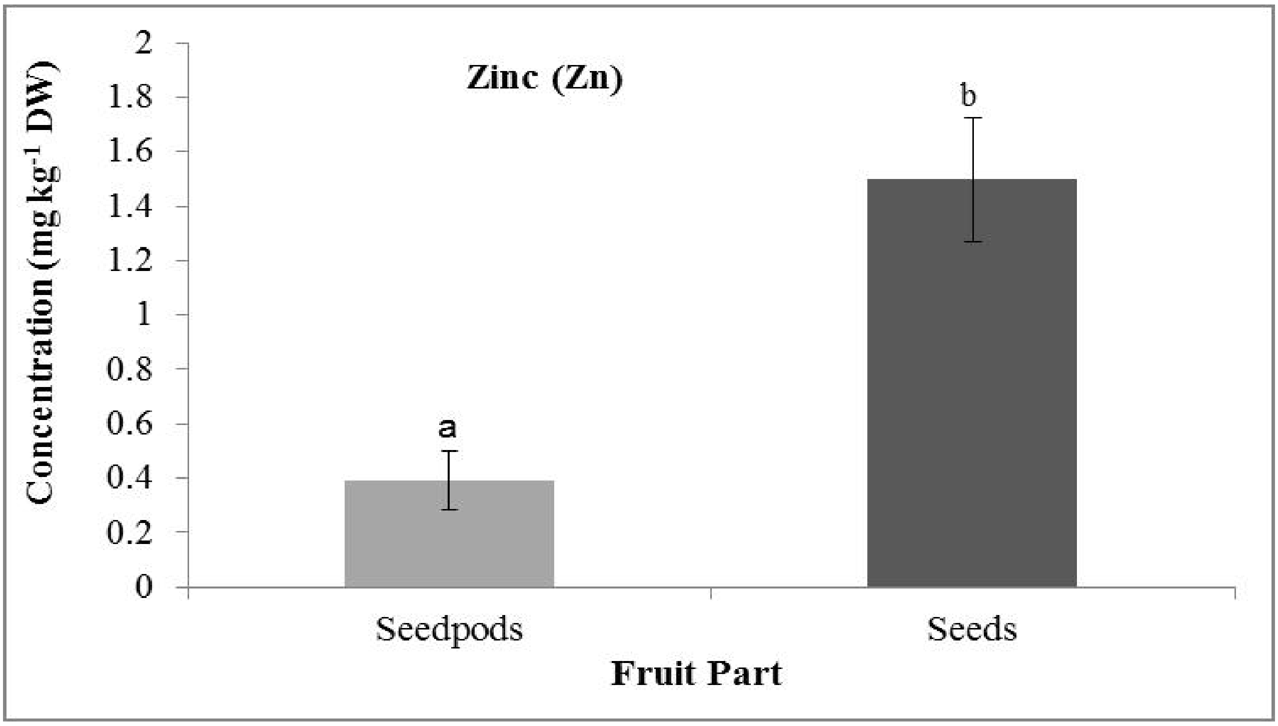

Figure 2. Mean Zinc (Zn) concentration in E. acoroides fruit from sites in Makassar, Bulukumba, and Selayar. Whiskers denote standard error (SE); different lower case numbers (a, b) indicate that the means

gen) are obtained from the air. The remaining 13 elements are provided by the soil and can be classified as either macro or micro elements. Macro elements are needed in large quantities (e.g. Ca, P, and K), while micro elements (e.g. Fe, Zn) and other micro-nutrients (e.g. ß-carotene) are needed in much smaller amounts. To enable normal growth, all nutrient requirements must be fulfilled, either in the form of metal salts or contained within organic compounds such as phosphoproteins or metal-containing enzymes (Lee, 1983).

The calcium (Ca) and iron (Fe) content of E. acoroides

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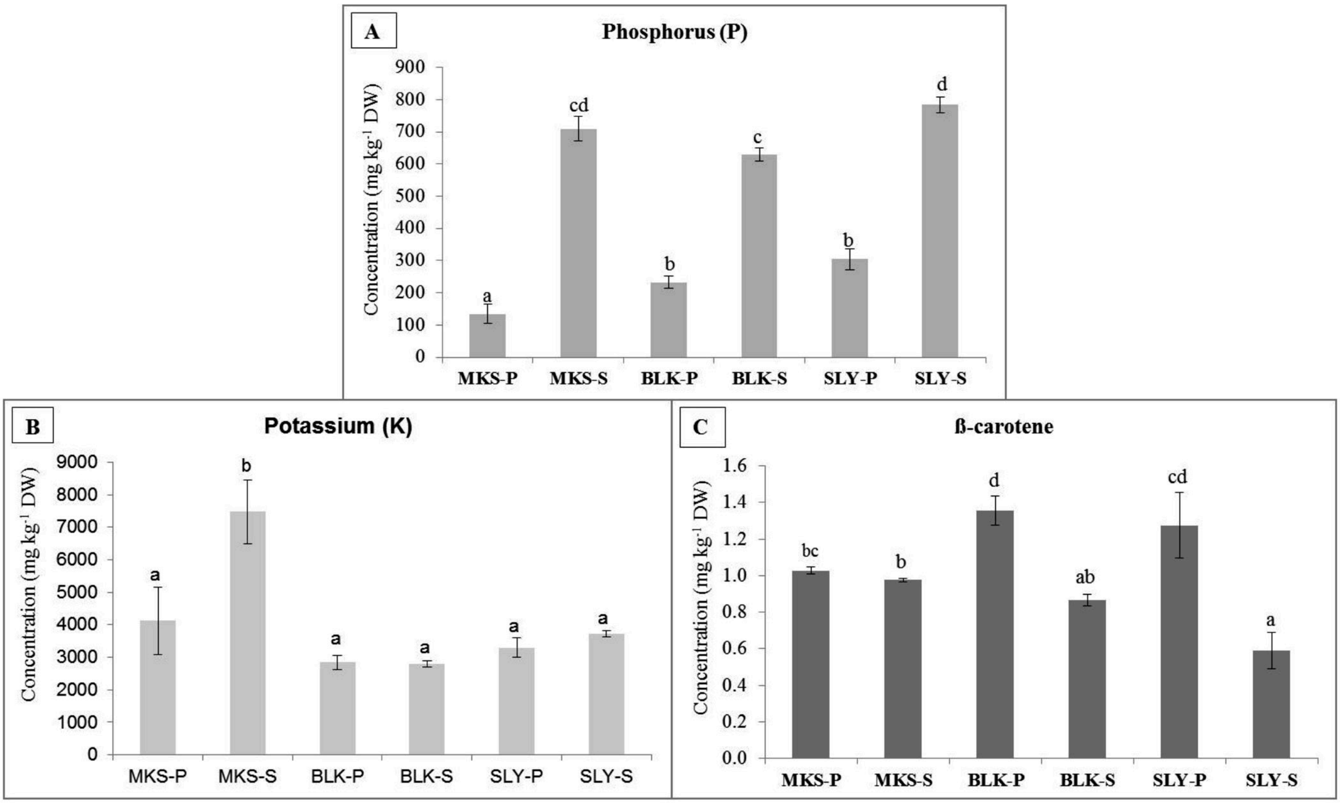

Figure 3. Mean nutrient content of E. acoroides fruit from sites in Makassar, Bulukumba, and Selayar: A) phosphorus; B) potassium; C) ß-carotene. Whiskers denote standard error (SE). Small case letters (a, b, c, d) denote significantly different ($p<0.05$) values. MKS=Makassar; BLK=Bulukumba; SLY=Selayar; P= seedpods, S= seeds, DW=dry weight

fruit was significantly different between the sampling sites, with higher content of both elements at the Makassar site compared to the sites in Bulukumba and Selayar (Figure 1). It is likely that this difference was due to differences in environmental conditions which can affect mineral transfer processes in E. acoroides (Montano et al., 1999; Wan-Hazma et al., 2015). The most influential environmental factor appears to be salinity. Although all three locations had salinity levels within the optimum range for seagrass growth (29-35 ‰), the salinity recorded at the Makassar site during the fruiting season (August - November) ranged from 33.00-34.56 ‰, which is higher than the salinity levels recorded at the Bulukumba (29.67-32.44 ‰) and Selayar (32.00-33.00 ‰) sites (Figure 4). In general, higher salinity tends to increase photosynthesis rates, and can thus contribute to seagrass productivity and density (Short and Coles, 2003). Seagrasses have a considerable tolerance to salinity (Hemminga and Duarte, 2000; Waycott et al., 2004). However, lowering or increasing salinity can influence the performance of seagrass photosynthesis in the adult phase (Kahn and Durako, 2006). Salinity can be influenced by various factors, such as water circulation, evaporation, rainfall, and river flow (Short and Coles, 2003; Nontji, 2007; Ambo-Rappe, 2010).

Calcium plays a role in the process of cell division, controlling the distribution of photosynthesis products, hardening the stems and increasing the number of leaves and flower stalks, and promoting the formation of seeds, so that each fruit or spathe can contain more seeds (Olesen, 1999; Jacob and Pierson, 1981; Lavon et al., 1995). The higher levels of calcium may therefore help to explain the higher mean and median number of seeds in E. acoroides fruit from the Makassar site compared to Bulukumba and Selayar (Figure 5). The mean and median values of seedpod diameter (Figure 5) were also lower in Bulukumba. Although the differences in mean/median seed number were not statistically significant ($p > 0.05$), possibly due to the data spread and outliers (Figure 5), the seedpod diameter was significantly lower in Bulukumba compared to the other two sites ($p < 0.01$). Although the mean diameter was lower in Selayar than Makassar, the difference was not significant ($p > 0.05$). The mean seed weight (total seed weight divided by the total number of seeds collected at each site) followed the median seedpod diameter rather than the median number of seeds, being highest in Makassar (4.78g) followed by Selayar (4.34g) and lowest in Bulukumba (4.07g).

Iron is important for the formation of chlorophyll, carbohydrates, fats, proteins and enzymes. Iron is an essential element because it forms enzymes and proteins that function as electron carriers in both photosynthetic and respiration phases (Lakitan, 2007). Iron is absorbed by seagrass in the form of Fe2+ and Fe3+ ions. The absorption of iron through leaves is generally considered to be faster than absorption through the roots, especially in plants that are deficient in Fe, because green leaf pigments can mitigate iron deficiency. An excess of calcium will reduce iron availability (Poerwowidodo, 1992).

The zinc content (Zn) in E. acoroides fruit was significantly different between the seeds and the seedpods. One reason why zinc (Zn) content was higher in the seeds than in the seedpods might be because zinc content is related to the presence of proteins (Uribarri and Calvo, 2003). The high vegetable protein content of E. acoroides seed contributes to the sweet taste and crispy texture, as it does in other seeds containing high levels of vegetable proteins (Alino et al., 1990) which can promote wound healing as well as the production and effectiveness of insulin in the human body (Lee, 1983). However, Bouis et al., (2000) consider that the zinc content of plant tissues is genetically regulated, as indicated by plant genotypes with a high Zn efficiency. These plants can produce high dry biomass but have a low Zn content in their seeds. So far, a gene or genes which might control zinc concentration in correlation with Zn efficiecy has not yet been discovered.

Of the six mineral elements tested, only phosphorus (P), potassium (K), and ß-carotene showed significant interactions between study site and E. acoroides fruit part. This means that these three essential elements are influenced by factors associated with each site but are also determined by fruit part. Differences in the nutrient content of the different parts of the fruit are generally influenced by factors internal to the plant, while differences in nutrient content between sites is generally due to environmental factors. Montano et al., (1999) also found that the nutrient content of seagrasses tends to vary depending on species, geographical locations and the minerals present in the surrounding water

The phosphorus content of E. acoroides seeds was significantly higher than that of the seedpods. The seeds are sweet and have a crunchy texture, like that of beans, which also contain high levels of vegetable protein. Phosphorus is an important building block in the production of proteins (Uribarri and Calvo, 2003). Other key functions of phosphorus in seagrass include the storage and transfer of energy within and between the cells, and it serves as a vital component of the genetic system (Cole, 1983). The phosphorus content in E. acoroides fruit differs between locations, being higher in Selayar than in Bulukumba (Table 2). Likely reasons for this include the levels of Total Suspended Solids (TSS) and ammonia, both of which are lower in Selayar than in Bulukumba and Makassar. Lower TSS levels tend to support higher levels of photosynthesis and growth in seagrass. Seagrass requires sunlight for photosynthesis (Nybakken, 1992; Kikuchi and Peres, 1977). However,

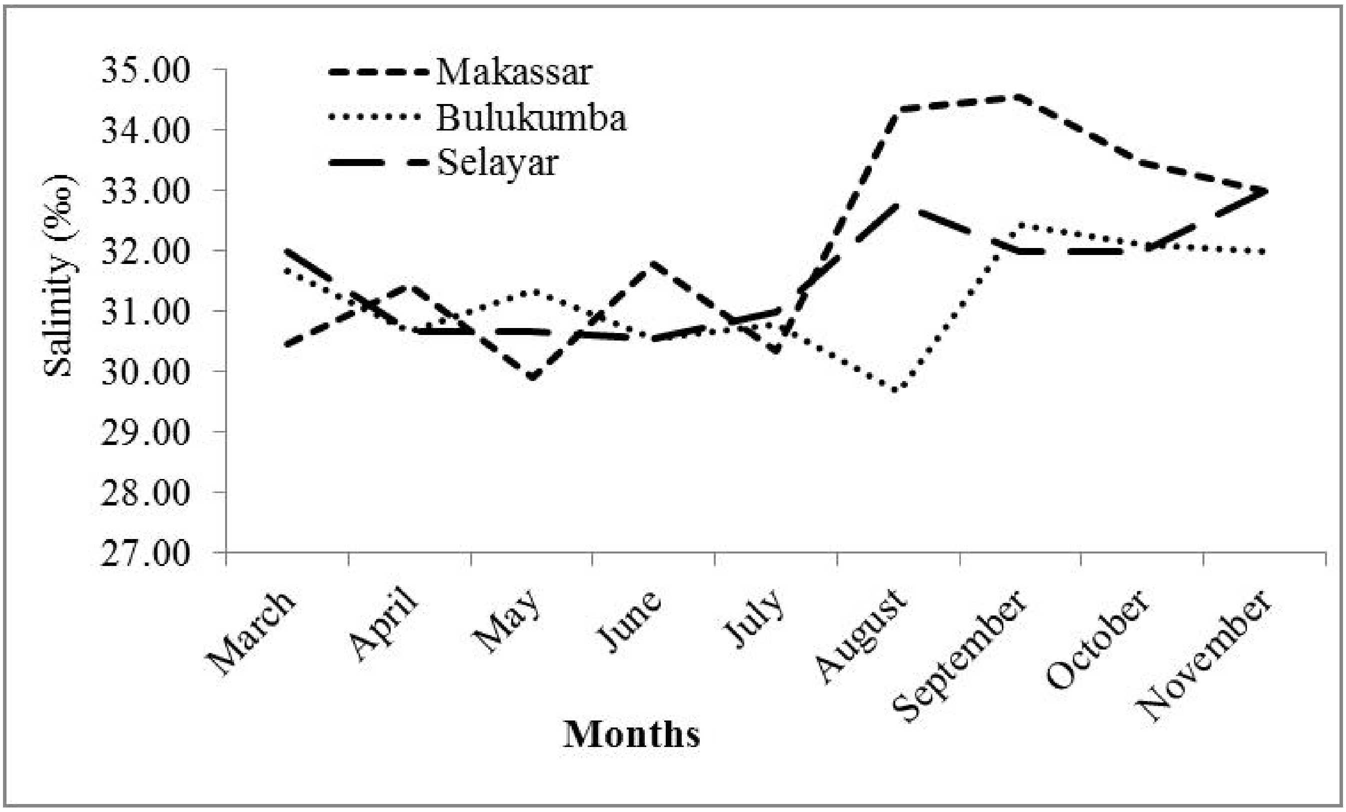

Figure 4. Salinity data at the sampling sites from March to November 2017

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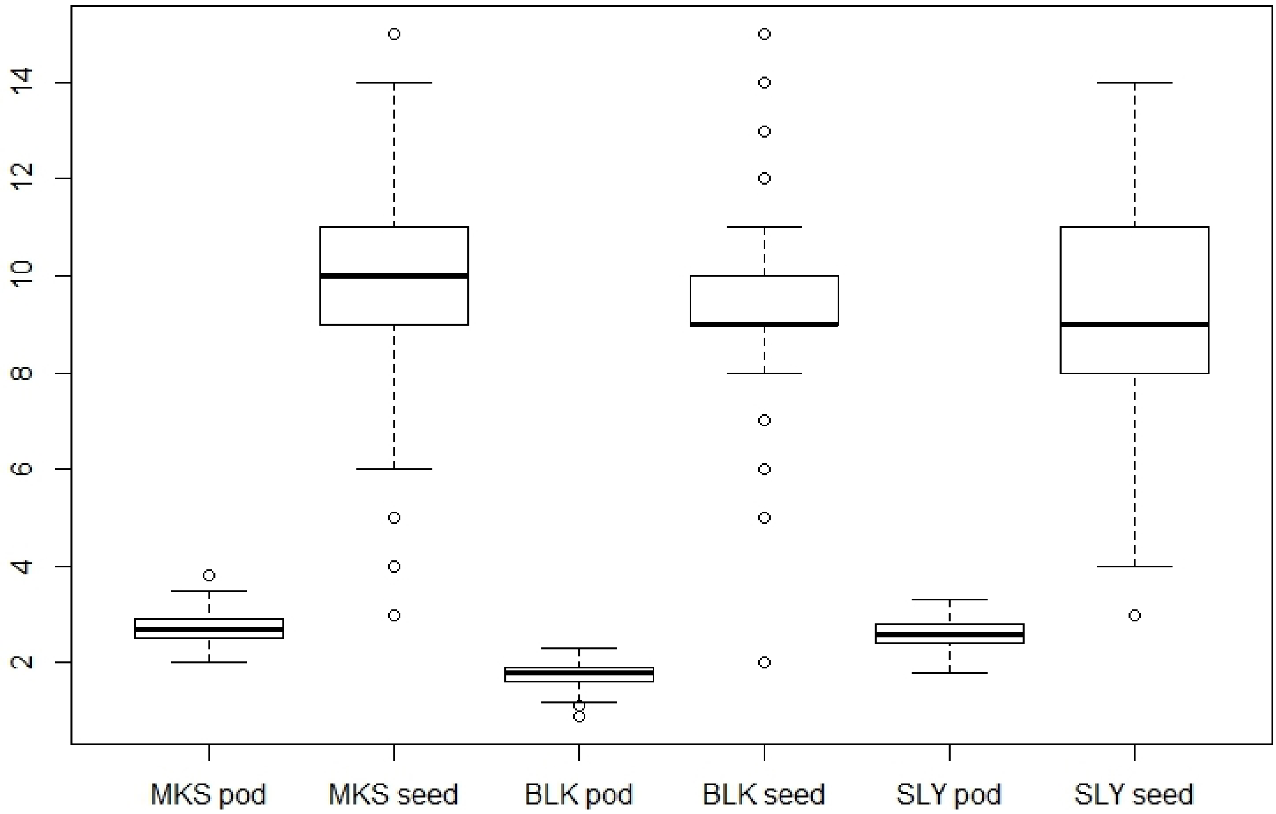

Figure 5. Boxplot of the pod diameter (cm) and seed number per pod of E. acoroides fruit collected from the coastal waters of Makassar City (MKS), Bulukumba District (BLK), and Kepulauan Selayar District (SLY). The bold band indicates the median value (Q2), the boxes indicate the interquartile range (IQR). The upper whisker shows (Q3+ 1.5 IQR) or the maximum data value, whichever is lower; the lower whisker shows (Q1- 1.5 IQR) or the minimum data value, whichever is higher. Outliers are shown as unfilled circles.

turbidity associated with an increase in suspended solids can interfere with light penetration, and thus limit photosynthesis. Sediments suspended in the water column can have a negative impact on water quality, both directly and indirectly, and can lead to a decline in production and an increase in mortality (Ritchie et al., 1976). Ammonia is an organic pollutant which can be present in widely varying concentrations; furthermore, ammonia levels can change very rapidly. Ammonia tends to be toxic to aquatic biota if the concentration exceeds certain levels (Bonnin et al., 2008). The Indonesian Ministry for the Environment has set an upper limit of 0.3 mg/l on the ammonia concentrations in seawater considered suitable for most marine biota (KLH, 2004). The main sources of ammonia in seawater are the breakdown of organic nitrogen (protein and urea) and inorganic nitrogen in the water column, as well as the decomposition of organic matter (dead plants and aquatic biota) mediated by microbes and fungi. High levels of ammonia often result from contamination of organic matter from the discharge of domestic waste, industrial waste, and fertilizer-rich agricultural runoff. The oxidation of ammonia to produce nitrites and nitrates is an important process in the nitrogen cycle and takes place in aerobic conditions. High nitrate concentrations in the water column can stimulate the growth and development of seagrass if supported by the availability of other nutrients (Effendi, 2003).

The potassium content varied significantly, with an interaction between site and fruit part. Potassium (K) levels in the seeds were highest in Makassar, and lowest in Bulukumba. Potassium levels in seagrasses appear to be influenced by PO4 concentration in the surrounding water (Table 2). The PO4 concentration was higher in Makassar than at the other sites; such an increase in potential sources of energy in the seagrass habitat can accelerate the process of seagrass growth (McClintock and Baker, 2001). The K content of the substrate is another factor which can increase the concentration of K+ in seagrass leaves and thus increase its effect on the processes of opening the stomata, absorbing CO2, and photosynthesis. Potassium plays an important role in seagrass growth; it serves as an activator in the energy transport of several enzymes involved in the growth and division of meristematic cells, leading to increased weight, size and volume of various organs (Sjofjan and Idwar, 2009). This is apparent in the higher number of seeds and heavier weight of fruit from Makassar compared to those from Bulukumba and Selayar (Figure 5).

The variation in ß-carotene content also showed a significant interaction between site and fruit part. The ß-carotene content was higher in the seedpods than in the seeds. Compared to other plant tissues, the role of carotenoids in seeds is not as well understood. It seems that carotenoid production in seeds is important for the production of abscisic acid (ABA) and plays a role in seed dormancy (Maluf et al., 1997). During photosynthesis, carotenoids have important photo-protective functions, enabling the absorption of light energy while preventing photo-oxidative damage; they also function as precursors for the biosynthesis of phytohormones (Van den berg et al., 2000; Pogson et al., 2006). The ß-carotene content is influenced by the spongy texture of the seedpod, which enables it to absorb and retain more water; thus, chlorophyll and nutrients generated through photosynthesis which are transported through aerenchyma and lacuna tissues that function like blood vessels in the body, will tend to accumulate in the pod (Shariati and Hadi, 2011).

The ß-carotene levels were higher in Bulukumba than in Makassar (Figure 3). Likely contributing factors include sediment texture, ammonia levels (lower in Bulukumba), and phosphate levels in the sediment (higher in Bulukumba). The sediment texture in Bulukumba is sandy loam with a composition of 78.5% sand, 9% silt, and 12.25% clay, whereas in Makassar and Selayar the sand content in the sediment exceeds 80% (loamy sand) (Table 2). A higher proportion of clay in the substrate tends to enable the retention of much higher nutrient levels compared to sand. Putri et al., (2016) found the highest proportion (50%) of organic material in mud and clay fractions. A smaller grain size also means that these fractions can store water and nutrients more readily than sand. The organic matter content within the sediments tends to increase when the mud (silt) and clay fractions are enhanced. Sediment is a major source of nutrition for seagrasses, because sediments tend to contain higher levels of nutrients compared to the water column where nutrient levels are generally low (Erftemeijer and Middelburg, 1993).

Table 2. Physical and chemical parameters recorded at the three study sites

Compound	Sample source	Site		
		Makassar	Bulukumba	Selayar
NH_3 (ppm)	Water column	0.036±0.007^a	0.585±0.005^b	0.031±0.01^a
NO_3 (ppm)	Water column	0.026±0.005	0.010±0.003	0.005±0.001
PO_4 (ppm)	Water column	0.513±0.041^c	0.007±0.001^a	0.497±0.021^b
TSS (ppm)	Water column	83.73±1.186^c	53.12±1.009^b	45.15±1.000^a
NO_3 (ppm)	Sediment	15.17±0.856	11.52±1.527	19.26±1.658
PO_4 (ppm)	Sediment	24.87±0.676^b	24.87±0.453^b	21.49±0.338^a
Depth (cm)	Water column	58.04±5.305	72.60±5.386	65.85±7.581
Substrate type	Sediment	Loamy sand	Sandy loam	Loamy sand
Sand content (%)	Sediment	84.19	78.5	88.58
Silt content (%)	Sediment	6.72	9	3.08
Clay content (%)	Sediment	9.06	12.25	8.33

Data are mean values ± S.E in row with different superscript alphabet (a<b<c) are significantly different ($p<0.05$) DMRT, N=8

Phosphates in sediment are the main source of phosphorus for seagrass growth. Phosphate is taken in by the seagrass roots and then delivered to the leaves; very few seagrasses take in nutrients through their leaves (McRoy et al., 1982). According to Lizumi et al., (1982), nitrogen for seagrass growth is mostly derived from sediments in the form of ammonia, whereas nitrates are taken up from the ambient water. Decomposition processes are the main natural source of ammonia and phosphate in seawater, including the decomposition of aquatic plants, in particular the rhizomes and roots of seagrass itself, as well as the remnants of other dead organisms; furthermore, waste discharged from the land will also be decomposed by bacteria and release nutrients into the water (Wattayakorn, 1988; Philips and Menez, 1988; Chester, 1990).

Nutritional value of Enhalus acoroides fruit for human

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Enhalus acoroides fruit are an alternative food source for coastal communities; they can be consumed both as a vegetable and as an ingredient in a variety of dishes (Alino et al., 1990). One factor that affects food quality is the macro-micro nutrient content (Willet, 1994). E. acoroides contains high levels of calcium, potassium, phosphorus, and iron, meeting daily human nutritional needs, but it is low in zinc and ß-carotene. Yet, the content of Ca, P, and Fe in E. acoroides fruit is higher than in rice flour (Montano et al., 1999).

Calcium in E. acoroides fruit was between 1,493 – 6,957 mg kg-1. This range makes a significant contribution to fulfilling the daily calcium requirement of people of reproductive age, which is 1,000 mg - 1,200 mg. The calcium content of E. acoroides fruit is higher than that of many other plant-based foods, for example salad vegetables only contain around 490 mg kg-1 (Pennington and Fisher, 2010).

Enhalus acoroides seeds can also make a substantial contribution to the daily dietary requirement for phosphorus, especially in adult humans (19-70 years) who need to consume around 700 mg of phosphorus per day (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). The phosphorus content of E. acoroides seeds is around 783 mg kg-1, which is higher than that of root vegetables such as carrots, which contain about 258 mg kg-1 (Bajaj et al., 1980).

The daily requirement for potassium in adult humans is around 4,700 mg day-1 (Pennington and Fisher, 2010; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). The potassium content of E. acoroides fruit ranged from 2,851 mg kg-1 to 7,477 mg kg-1 (mean 5,137 mg kg-1). This potassium level can be considered high, as it compares to those found in bananas, which are considered a major source of potassium with levels around 3,580 mg kg-1 (Mahapatra et al., 2012).
The human dietary requirement for iron, an essential element particularly important for haemoglobin formation, is between 8 and 18 mg day-1 (Pennington and Fisher, 2010; NIH, 2016). The iron content of E. acoroides fruit ranged between 0.057 mg kg-1 and 129 mg kg-1, with an average of 65 mg kg-1. The iron content of E. acoroides fruit was variable, but in general was relatively high compared to other fruits and vegetables; for example, cabbage typically provides around 4.9 mg kg-1 (Pennington and Fisher, 2010).

5. Conclusion

These results demonstrate that seagrass ecosystems serve as an important habitat for various marine organisms and can also provide direct benefits for humans in terms of nutrition. The fruit of E. acoroides (both the seedpods and seeds) contain relatively high levels of essential nutrients such as calcium, potassium, phosphorus, and iron. This fruit can thus be used as a substitute or additional source of nutritious plant-based foods (vegetables). In fact, in terms of certain essential elements, seagrass fruit can rival or exceed the nutritional value of some vegetables and fruit such as lettuce, carrots, bananas and cabbage.

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Conflict of Interest

The authors declare that there is no conflict of interest.

References

Association of Official Analytical Chemist (AOAC). (2012). Official Methods of Analysis. 19th ed. The Association of Official Analytical Chemist. Gaithersburg, MD, USA.

Ambo-Rappe, R. (2010). “Fish community structure in different seagrass beds around Barranglompo Island.” [Struktur komunitas ikan pada padang lamun yang berbeda di Pulau Barranglompo]. J Ilmu Tek Kel Trop 2(2): 62-73. Retrieved from https://repository.ipb.ac.id/handle/123456789/53374

Badui, D. (2010). “Analisis Kadar Gizi Buah Lamun (Enhalus Acoroides) Dan Hubungan Antara Pengetahuan, Persepsi Dengan Pemanfaatan Buah Lamun Sebagai Sumber Makanan Alternatif Masyarakat Desa Waai Kec. Salahutu Kab. Maluku Tengah.” [Analysis of the Nutritional Content of Seagrass (Enhalus Acoroides) Fruits and the Relationship Between Knowledge and Perception and the Utilization of Seagrass Fruit as an Alternative Food Source in Waai Village, Kec. Salahutu Kab. Central Maluku]. Thesis. Malang University. Retrieved from http://karya-ilmiah.um.ac.id/index.php/disertasi/%20article/view/8025

Bajaj, K. L., Kaur, G., and Sukhija, B. S. (1980). Chemical Composition and Some Plant Characteristics in Relation to Quantity of Some Promising Cultivars of Carrot (Daucus carota L.). Qualitas Plantarum - Plant Foods for Human Nutrition, 30(2): 97-107. https://doi.org/10.1007/BF01099047

Bonnin, E. P., Biddinger, E. J., and Botte, G. G. (2008). Effect of Catalyst on Electrolysis of Ammonia Effluents. Journal of Power Sources 182(1): 284-290. https://doi.org/10.1016/j.jpowsour.2008.03.046

Bouis, H. E., Graham, R. D., and Welch, R. M. (2000). The Consultative Group on International Agricultural Research (CGIAR) Micronutrients Project: justification and objectives. Food and Nutrition Bulletin. 21(4): 374-381. https://journals.sagepub.com/doi/pdf/10.1177/156482650002100406

Chester, R. (1990). Marine Geochemistry. Unwin Hyman, Ltd. London.

Cole, G. A. (1983). Text Book of Limnology. 3r ed. Missouri: C.V. Mosby Company.

Effendi, H. (2003). "Review on water quality for aquatic living resources management." [Telaah Kualitas Air bagi Pengolahan Sumberdaya Hayati Lingkungan Perairan]. Kanisius. Yogyakarta. Retrieved from https://repository.ipb.ac.id/handle/123456789/79927

Erftemeijer, P. I. A. and Middelburg, J. J. (1993). Sediment Nutrient Interactions in Tropical Seagrass Bed; a Comparison Between a Terrigenous and Carbonate Sedimentary Environment in South Sulawesi (Indonesia). Marine Ecology Progress Series 95(1): 187-198. doi: 10.3354/meps095187

Hemminga, M. A. and Duarte, C. M. (2000). Seagrass Ecology. Cambridge: Cambridge University Press.

Jacobs, W. M. and Pierson, E. S. (1981). Phenology of Reproductive Shoots of Eelgrass, Zostera marina L., at Roscoff, France. Aquatic Botany 10: 45-60. https://doi.org/10.1016/0304-3770(81)90004-8

Kahn, A. E. and Durako, M. J. (2006). Thalassia testudinum Seedling Responses to Change in Salinity and Nitrogen Level. J Exp Mar Biol Ecol 335: 1-12. https://doi.org/10.1016/j.jembe.2006.02.011

Kementerian Lingkungan Hidup (KLH). (2004). "Keputusan Menteri Negara Lingkungan Hidup Nomor 51 Tahun 2004 tentang Baku Mutu Air Laut." [Decree of the Environment Minister Number 51/2004 on sea water environmental quality standards].

Kikuchi, T. and Peres, J. M. (1977). Consumer Ecology of Seagrass Beds. In: C. P. McRoy and C. Hellferich (ed.), Seagrass Ecosystems. Scientific Perspective Marcel Dekker, Inc. New York: 147-194.

Lakitan, B. (2007). "Basics of Plant Physiology" [Dasar-Dasar Fisiologi Tumbuhan]. PT. Raja Grafindo Persada. Jakarta.

Lavon, R., Goldschmidth, E. E., Salomon, R., and Frank, A. (1995). Effect of Potassium, Magnesium, and Calcium Deficiencies on Carbohydrate Pools and Metabolism in Citrus Leaves. J. Amer. Soc. Hort. Sci. 120(1): 54-58. doi: 10.21273/JASHS.120.1.54

Lee, F. A. (1983). Basic food chemistry. Second edition. Food science and technology textbook series. The AVI Publishing Company, Inc. Westport, Connecticut: 225-234

Lizumi, H., Hattori, A., and McRoy, C. P. (1982). Ammonium regeneration and assimilation in eelgrass (Zostera marina) beds. Marine Biological 66(1): 59-65. https://doi.org/10.1007/BF00397255

Mahapatra, A. K., Satarupa, M., Basak, U. C., and Panda, P. C. (2012). Nutrient Analysis of Some Selected Wild Edible Fruits of Deciduous Forests of India : an Explorative Study Towards Non Conventional Bio-Nutrition. Advance Journal of Food Science and Technology 4(1): 15-21. Retrieved from https://studylib.net/doc/13311267/advance-journal-of-food-science-and-technology-4-1---15-2...

Maluf, M. P., Saab, I. N., Wurtzel, E. T., and Sachs, M. M (1997). The Viviparous12 Maize Mutant is Deficient in Abscisic Acid, Carotenoids, and Chlorophyll Synthesis. Journal of Experimental Botany 48: 1259–1268. https://doi.org/10.1093/jxb/48.6.1259

McClintock, J. B. and Baker. B. J. (2001). Marine Chemical Ecology. CRC Press, Florida, USA.

McRoy, C. P., Barsdate, R. J., and Nebert, M. (1972). Phosphorous Cycling in an Eelgrass (Zostera marina L.) ecosystem. Limnol. Oceanogr. 17: 58-67. doi: 10.4319/lo.1972.17.1.0058

Montaño, M. N. E., Bonifacio, R. S., and Rumbaoa, R. G. O. (1999). Proximate Analysis of the Flour and Starch from Enhalus acoroides (L. f.) Royle Seeds. Aquatic Botany 65: 321–325. https://doi.org/10.1016/S0304-3770(99)00049-2

Montano, N. E., Ganton-Fortes, E.T., Alino, P. M., Tupas, L.

ISSN-Internet 2197-411x OLCL 862804632

M., Licuanan, W. R. Y., and Cajipe, G. J. B. (1990). The Use of Marine Organisms in Folk Medicine and Horticulture: a preliminary study, SICEN Leaflet I: 1-8.

National Institutes of Health (NIH). (2016). Iron. Available at https://ods.od.nih.gov/factsheets/Iron-Consumer. Accessed on 6 April 2018

Nontji, A. (2007). Laut Nusantara [Indonesian Archipelagic Seas]. Djambatan. Jakarta.

Nybakken, J. W. (1992). Marine Biology. An Ecological Approach. Gramedia. Jakarta.

Olesen, B. (1999). Reproduction in Danish eelgrass (Zostera marina L.) stands: size-dependence and biomass partitioning. Aquatic Botany 65(1-4): 209–219. https://doi.org/10.1016/S0304-3770(99)00041-8

Pennington, J. A. T. and Fischer, R. A. (2010). Food component profiles for fruit and vegetable subgroups. Journal of Food Composition and Analysis 23(5): 411-418. https://doi.org/10.1016/j.jfca.2010.01.008

Philips, R. C. and Menez, E. G. (1988). Seagrasses. Smithsonian Contribution to the Marine Science number 34. Smithsonian Institution Press. Washington: 21-27.

Poerwowidodo. (1992). Telaah Kesuburan Tanah [Review of Soil Fertility]. Bandung: Angkasa.

Pogson B. J., Rissler, H. M., and Frank, H. A. (2006). The Roles of Carotenoids in Energy Quenching. In Photosystem II. Advances in Photosynthesis and Respiration. Wydrzynski T.J., K. Satoh, and J. A. Freeman (ed). Springer, Dordrecht, The Netherlands: 515–537. Retrieved from https://link.springer.com/chapter/10.1007/1-4020-4254-X_24

Putri, A. M. S., Suryanti, and Widyorini, N. (2016). "Relationship of organic matter and makrozoobenthos abundance with sediment texture in the Banji Kanal Timur river estuary, Semarang." [Hubungan Tekstur Sedimen dengan Kandungan Bahan Organik dan Kelimpahan Makrozoobenthos di Muara Sungai Banjir Kanal Timur Semarang]. Jurnal Saintek Perikanan. 12(1): 75-80. Retrieved from https://ejournal.undip.ac.id/index.php/saintek/article/view/13196

Ritchie, J. C., Schiebe, F. R., and McHenry, J. R. (1976). Remote Sensing of Suspended Sediments in surface waters. Photogrammetric Engineering and Remote Sensing. 42(12): 1539-1545. Retrieved from https://www.asprs.org/wp-content/uploads/pers/1976journal/dec/1976_dec_1539-1545.pdf

Setyati, W. A., Subagyo, and Ridlo, A. (2003). "Study on the Potential of Various Types of Seagrass Beds as Sources of Health Food: Proximat Analysis." [Studi Potensi Berbagai Jenis Lamun Sebagai Sumber Makanan Kesehatan: Analisis Proksimat.] Ilmu Kelautan: Indonesian Journal of Marine Science 10(2): 115-118. doi: https://doi.org/10.14710/ik.ijms.10.2.115-118

Shariati, M. and Hadi, M. R. (2011). Microalgal Biotechnology and Bioenergy in Dunaliella. In Progress in Molecular and Environmental Bioengineering-From Analysis and Modeling to Technology Applications. Carpi, A. (Ed). Intech. Europa: 483-506. doi: https://doi.org/10.5772/19046

Short F. T. and Coles, R. G., ed. (2003). Global Seagrass Research Methods. Amsterdam: Elsevier Science BV.

Sjofjan, J. and Idwar. (2009). "Effects of potassium enrichment on sweet corn growth and production at different soil moisture levels." [Pemberian Kalium Pada Beberapa Kelembaban Tanah Terhadap Pertumbuhan dan Produksi Jagung Manis (Zea mays saccharata sturt)]. Universitas Riau. 8(1): 17-22.

U.S. Department of Agriculture and U.S. Department of Health and Human Services, (2010). Dietary Guidelines for Americans. 7th Edition, Washington, DC: U.S. Government Printing Office.

U.S. Department of Health and Human Services and U.S. Department of Agriculture, (2015). Dietary Guidelines for Americans 2015–2020. 8th Edition. Available at http://health.gov/dietaryguidelines/2015/guidelines/

Uribarri, J. and Calvo, M. S. (2003). Hidden Source of Phosphorous in the Typical American Diet: Does it Matter in Nephrology? Seminar in Dialysis, May-June 2003, 16(3): 186-188.

Van den Berg, H., Faulks, R., Granado, H. F., Hirschberg, J., Olmedilla, B., Sandmann, G., Southon, S., and Stahl, W. (2000). The Potential for The Improvement of Carotenoid Levels in Foods and The Likely Systemic Effects. J Sci Food Agric 80: 880-912. doi: https://10.1002/(SICI)1097-0010(20000515)80:7<880::AID-JSFA646>3.0.CO;2-1

Wakano, Deli. (2013). Seagrass Enhalus acoroides Fruit Utilization as Alternative Food Sources Lomin Village Community East of Seram. In Prosiding FMIPA Universitas Pattimura 9–12. Retrieved from https://ejournal.unpatti.ac.id/ppr_paperinfo_lnk.php?id=497

WanHazma, W. N., Harah Z. M., Sidik B. J., and Natrah, F. M. I. (2015). Macro and Micro Nutrient of Tropical

Seagrasses, Halophila ovalis, H. spinulosa and Halodule uninervis in Johore, Malaysia. Iranian Journal of Fisheries Sciences, 14(1): 246-261. Retrieved from: http://jifro.ir/article-1-1860-fa.html

Wattayakorn, G. (1988). Nutrient Cycling in Estuarine. Paper presented in the Project on Research and Its Application to Management of the Mangrove of Asia and Pacific, Ranong, Thailand: 17.

Waycott, M., McMahon, K., Mellors, J., Calladine, A., and Kleine, D. (2004). A Guide to tropical seagrasses of the Indo West Pacific. Townsville: James Cook University. Retrieved from: https://ro.ecu.edu.au/ecuworks/5179/

Willet, W. C. (1994). Diet and health: what should we eat? Science 264 (5158): 532-537. doi: 10.1126/science.8160011

ISSN-Internet 2197-411x OLCL 862804632