Species diversity, density, phosphate concentration and the utilization of algae as a food material

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Abstract. The influence of nature and human activities greatly affects the distribution and diversity of algae. This study was conducted to determine the species diversity, density, phosphate concentration, and algae utilization as a food material found on the island of Ambon. The sampling location was on Ambon's island in three locations, i.e., Tantui, Hative Besar, and Allang. For 100 m, line transects were laid perpendicular to the shore at every station. For every of the transect line, four 50 cm×50 cm quadrat was placed randomly. There was 18 genus of seaweed. Of the 22 species, 11 species from Rhodophyta (50.0 %), 5 species from Phaeophyta (22.73%), and 6 were from the class of Chlorophyta (27.3%). The highest value density is village Hative Besar that is 1219.9 gr.m⁻² is from the Chlorophyta group (Enteromorpha prolifera), Tantui is 986 gr/m² from the Rhodophyta group (Gracilaria), and Allang that is 756.18 gr.m⁻² from the Rhodophyta group (Acantophora). The maximum concentration in Allang is 0.19 mg.L⁻¹, and concentration in Hative Besar is 0.18 mg.L⁻¹, while the minimum phosphate concentration is 0.15 mg.L⁻¹ at the Tantui location. The types of algae that can be used as food sources include Gracilaria sp., Caulerpa sp., Sargassum sp, Gelidium sp., and Ulva sp.

1. Introduction

As a maritime country, Indonesia has abundant biodiversity, including various types of seaweed or macroalgae, which are called algae. Algae are low-level plants that generally grow attached to specific substrates such as coral, mud, sand, rocks, and other hard objects. Apart from inanimate objects, macroalgae can also attach to other plant's epiphytic. The growth of algae that depends on the substrate is directly affected by sedimentation. Due to natural and anthropogenic influences such as sedimentation and solid waste disposal, water conditions can affect the growth and distribution of algae [1]. Rao and Vaibhav (2006) [2] explained that algae are the multicellular macroalgae with complex differentiated thallus and the macrobenthic (large and attached) forms of marine algae [3]. They are subdivided into four different groups: brown algae (Phaeophyta), red algae (Rhodophyta), green algae (Chlorophyta), and blue-green algae (Cyanophyta) [4]. They constituted one of the ocean's essential living resources and were found attached to the bottom on solid substrates such as rocks, dead corals, pebbles, shells, and plants [5].

Algae are generally found growing in shallow water areas (intertidal and sublittoral). Algae are primary producers and play a central role in coastal habitats [6]. They support the coastal and marine biodiversity [7] and base the food chain in the oceans [8]. According to Fernandes and Cortes (2005) [9], Caulerpa macroalgae is adaptable to various types of substrate, including being able to grow scattered and compete with live coral communities and stick to weathered live coral parts. Handayani et al. (2007) [10] argue that algae is an essential biota as one of the main components in the preparation of coastal ecosystems and plays a role in maintaining the ecosystem's balance. Algae are marine biological resources that are economically valuable and have an ecological role as producers in...
the food chain and spawning grounds for marine biota. Algae are of high ecological and great economic importance [11].

Biologically, algae are a group of chlorophyll plants consisting of one or many cells and colonies and contain various organic materials such as minerals, polysaccharides, vitamins, and agarose. The content of organic materials, namely minerals and vitamins, is used in the food and food sector, such as gelatin products, seaweed salads, and carrageenan. In Indonesia, algae’s potential as a food source (especially seaweed) has been used commercially, even cultivated intensively through a polyculture technique between fish and seaweed [12]. This study was conducted to determine the species diversity, density, phosphate concentration, and algae utilization as a food material found on the island of Ambon.

2. Materials and Method
Algae research was carried out in October 2019 at several research stations, namely Tantui, Hative Besar, and Allang (Figure 1). Algae samples were taken using the transect method. The transect line with a 100-meter interval is made perpendicular to the coastline towards the sea. At each 10 m interval from the transect line, biomass sampling was carried out by measuring the standing crop of seaweed on a 50 x 50 cm iron frame. Each transect is taken five plots with transect plots: 10 m, 20 m, and 30 m from the coastline. Thus, the total research plots were 15 transect plots with macroalgae sampling time carried out three times. Habitat observations were made visually along transect lines. Sampling results are collected in plastic, washed clean, sorted according to a clan, and weighed wet weight. A dry and wet herbarium was prepared to identify the type, then put in a sample bottle and preserved with 70% alcohol.

Figure 1. Map of sampling site

3. Result and Discussion
3.1. Species diversity
There were 22 species of seaweeds identified from 18 genera belonging to Rhodophyta, Phaeophyta Chlorophyta (Table 1). Of the 22 species, 11 species from Rhodophyta (50.0 %), five species from Phaeophyta (22.73%), and 6 were from the class of Chlorophyta (27.3%). Each research location has different diversity (Figure 2). Rhodophyta has the highest percentage of seaweed found in Hative Besar. Unlike the case with the diversity of algae on Nusalaut Island. Chlorophyta algae have a high
species diversity of 45.5% compared to Phaeophyta and Rhodophyta algae [13]; this may be due to a high number of species from Chlorophyceae are mainly found in shallow tropical waters [14].

Figure 2. Species diversity algae

The results showed that each location has a different diversity. This difference is caused by differences in habitat, season, and sedimentation rate. In general, habitats have a close relationship with algae, where the habitat is very influential on the picocolloid content of macroalgae. Season affects the growth of macroalgae. Macroalgae are found in small amounts due to the presence of seasonal factors. Most of the macroalgae are seasonal plants, so it is possible that when sampling the macroalgae is not in season, it is only found in small quantities. The high rate of sedimentation occurs due to anthropogenic factors so that it has a significant impact on the growth of macroalgae, which causes the macroalgae ecosystem to be disturbed due to the accumulation of mud and sand.

According to Soegiarto et al. (2011) [15], algae live as phytobenthos by sticking or attaching themselves to the substrate of mud, sand, coral, dead coral fragments, rocks, or wood. Habitat differences much determine the growth of seaweed. Season also affects the type of seaweed that grows; besides sunlight is the main factor needed by marine plants, at depths where sunlight is not available, seaweed cannot live.

Hative Besar has the highest macroalgae diversity, followed by Allang; this is due to the two beaches' location in the Outer Ambon Bay and near the high seas, so the possibility of spreading macroalgae from the open seas is enormous, and this is following the opinion of Handayani et al. (2007) [10] where the research location which is located near the high seas has an extensive spread of macroalgae. Tantui is in the Inner Ambon Bay, so it has the least diversity of macroalgae. Observations show that the sedimentation rate in Tantui is relatively high and has spread almost along the coast where algae live, and the substrate affects the growth of macroalgae.

3.2. Density
Total density is village Tantui that is 986 gr/m² is from the Rhodophyceae group (Gracilaria), Hative Besar is 1219,9 gr/m² is from the Chlorophyta group (Enteromorpha prolifera), and Allang that is 756,18 gr/m² from the Rhodophyta group (Acantophora) (Figure 3). The highest value density is village Hative Besar. The highest density in Hative Besar is related to conditions habitat that is still good where there is almost no sedimentation. Good water movement causes clean waters apart from invisible waste disposal. Thus, the abundant growth of algae is due to the type of habitat and good water quality. According to Litaay (2014) [1], the difference in the value density of macroalgae shows habitat and environmental influences due to season, sedimentation, and solid waste disposal to algae diversity.

The difference in the substrate at each research location is due to the damaged aquatic ecosystem. This damage will affect the low density of algae in these waters. The coastal waters of Hative Besar and Allang Bay have tidal seawater habitats with almost the same substrate, namely sand substrate + massive rock or coral towards the edge of the rock substrate with exposure to sandy reefs. The substrate conditions and algae growth in these coastal waters are better than those in Tantui waters.
Tantui has shallow water habitats along the coast and in the tidal zone with a sand-mud substrate. Besides, much damage to uneven distribution and low algae growth. This condition results in a low density. The difference in seaweed density at each study location is due to differences in substrate and seasonal factors [16]. Seasonal factors also cause algae density. Several types of algae growth are influenced by seasons, such as Sargassum, Turbinaria, Homorphysa, Caulerpa, Codium, Ulva, Chaetomorpha, Hypnea, Gelidiettelle, Gracilaria, Halimenia, Tricleucarpia, Liagora, and Ampyroa. Algae will begin to appear and grow on the substrate in January (transitional season I), with the peak growth occurring in May-July (East Season), then disappear in November (West Season).

![Figure 3. Total macro algae density (gr/m²)](image)

### 3.3 Phosphate concentration

Phosphate is an essential element for all living things, especially as a transformation of metabolic energy, where other elements cannot replace its role. This element is a constituent of total phosphate pyototal bonds from energy-rich adenosine triphosphate (ATP) and is a constituent fuel for all activities in cells, and is another vital constituent of cells. This organic phosphate bond is used to control various chemical reactions.

The phosphate analysis results showed that the minimum phosphate concentration was found at Tantui with a concentration of 0.15 mg.L⁻¹, compared Hative Besar 0.18 mg.L⁻¹ and Allang 0.19 mg.L⁻¹. Based on the Quality Standard, the phosphate concentration in Ambon Bay's waters exceeds the permitted quality standard threshold of 0.015 mg.L⁻¹. The phosphate concentration required for algae growth ranges from 0.018-0.090 mg.L⁻¹, and the highest limit is 8.90-17.8 mg.L⁻¹ (P-PO₄) if nitrogen is in the form of nitrate. Whereas nitrogen is in the form of ammonium, the highest limit is 1.78 mg.L⁻¹ (P-PO₄) (Figure 4).

The phosphorus content in algal cells can affect the rate of phosphate uptake, and conversely, the phosphate content in the cells will increase along with the reduction in phosphorus content. For example, algae can absorb phosphate over its needs (luxury consumption), and besides that, it can also absorb phosphate at low concentrations; this is because it (algae) has an alkaline phosphatase enzyme which can convert phosphate into orthophosphate, which is ready for use, and this is one of the causes of the orthophosphate content in the waters to run out quickly. Phosphate deficiency will be more critical for aquatic plants, including algae. In this case, phosphorus availability in the waters is relatively abundant, but not in orthophosphate (PO₄³⁻); this is what distinguishes between phosphate and nitrogen. Phosphate requirements for algae growth will be lower if nitrogen is in the form of an ammonium salt and vice versa if nitrogen is in the form of nitrate, the required phosphate concentration is higher.
Figure 4. Phosphate concentration algae

According to Freeman (2002) [17], unhealthy pond with an enormous proliferation of algae, there is not enough oxygen for the decomposers to survive; thus, the dead biomass is not decomposed, and nitrate and phosphates are not released into the water system, and this results in nitrate and phosphate depletion which results in a decrease in algal growth. Phosphate has a positive effect on algae growth. An increase in nitrate and phosphate levels increases algal growth [18]. Martins et al. (2011) [19] explain that algae Hypnea musciformis, there was a positive correlation between the increase of phosphate in the medium and photosynthetic pigments’ content.

3.4 Utilization of algae as a food material
Algae has been used as a food ingredient in various parts of the world. In Indonesia, algae’s potential as a food source (especially seaweed) has been exploited commercially and intensively through cultivation. Several types of algae have been used as food ingredients because they contain several proteins, minerals, carbohydrates, and vitamins. Types of algae in the research location that has the potential to be used as a source of food include Gracilaria sp., Sargassum sp., Gelidium sp., and Ulva sp. (Figure 5).

Figure 5. The types of algae algae as a food material a) Gracilaria, b) Sargassum, c) Gelidium, and d) Ulva

Gracilaria sp. is Rhodophyta alga has enormous potential in the food industry. Gracilaria sp. is included in the category of marine resources, which have high economic value because they produce hydrocolloids for agar, alginates, and carrageenan. Many food industries use Gracilaria sp. as a thickener (thickener), gelling (gelling agent), stabilizer (stabilizer), and emulsifier (emulsifying agent). Gracilaria sp. is also widely used by people as food such as salads and soups. According to Ate et al.
(2017) [20], Gracilaria sp. is a food source that is low in fat and rich in fiber, safe for consumption in large quantities. Low-fat content is used as a major constituent of low-fat diet foods. Gracilaria sp. is the raw material for making jelly and the raw material for making nori. Gracilaria sp is an alternative raw material for making nori because of its large supply in Indonesia [21].

Sargassum sp is a Phaeophyta alga that is used by the community as food. Sargassum sp used as a vegetable eaten with yellow spiced fish. Sargassum is a source of folic acid, iodine, protein, and vitamin C. Sargassum is often used as a food ingredient in Japan and Korea [22]. Local food made from this alga is seasonal and depends on the growing season. During the growing season, this type of algae is used as a vegetable because it is relatively easy to find or sell in several traditional markets [23].

Gelidium sp. is an alga of Rhodophyta species, which is very potential as an agar source because it has agarose and agarpectin. Gelidium contains bioactive compounds such as polysaccharide sulfates, phenolics, flavonoids, and chlorophyll, 6-7, which can be used as raw material to produce healthy and/or functional food [24,25]. Apart from that, Gelidium sp. is also used to diversify algae in the jelly candy manufacturing process. Ulva is a Chlorophyta alga, widely consumed as a food ingredient in China, the Philippines, Chile, and the West Indies [26]. Ulva is used as a food ingredient by drying and salting and then traded under the name "cachiyugo". Ulva is also used as an ingredient in salads and soups. According to Trono et al. (1998) [22], Ulva is a source of vitamin C, folic acid, protein, very high iron content, and several types of minerals (Ca, Na, K, Fe, Mg, Cu, and Zn).

4. Conclusion
The diversity of macroalgae in the observation location contained a total of 18 genera of seaweed. Of the 22 species, 11 species from Rhodophyta (50.0 %), five species from Phaeophyta (22.73%), and 6 were from the class of Chlorophyta (27.3%). The highest value density is village Hative Besar that is 1219.9 g/m² is from the Chlorophyta group (Enteromorpha prolifera), Tantui is 986 gr/m² from the Rhodophyta group (Gracilaria), and Allang that is 756.18 g.m⁻² from the Rhodophyta group (Acanthophora). The maximum concentration in Allang is 0.19 mg.L⁻¹, while the minimum phosphate concentration is 0.15 mg.L⁻¹ at the Tantui location. The types of algae that potential be used as food sources include Gracilaria sp., Sargassum sp, Gelidium sp., and Ulva sp. Variations in sedimentation, season, and habitat type significantly affect the diversity of algae.

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