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Physical and chemical conditions of waters for seaweed cultivation in Morowali, Central Sulawesi, Indonesia

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Abstract
This study was aimed to examine the physical and chemical conditions of the seaweed growing areas in Morowali Regency. It was carried out in January–August 2019 in 13 sub-districts of Morowali Regency, however the sample was taken from 3 sub-districts, South Bungku District, Witaponda District, and Petasia District, because not all districts have seaweed cultivation locality. Data sampling was done in three observation stations, consisting of several research sub-stations. The result showed that only two of the fourteen criteria—carbon dioxide and nitrate—were found to be unfavorable for seaweed growth at three observation stations.

INTRODUCTION

In general, coastal communities in Morowali Regency are typically classified as low-income. These communities mostly employ as fishermen because of limited business land suitable for agriculture. Currently, the government's attention is focused on attempts to use coastal resources to produce numerous high economic commodities, such as seaweeds *Eucheuma cottoni*. This species has long been the main livelihood for coastal residents in the Menui Islands and South Bungku sub-districts.

Seaweed utilization in the two sub-districts is still categorized as traditional in which limits the production inputs to locally available seeds and even prohibits many of them from engaging in intensive growing (Ramenzoni, 2021). However, due to the fact that this kind of seaweed is resistant to disease, seaweed pruducer continue to harvest it using a simple method. (Ali *et al*. 2021). In addition, weak linkages between subsystems, such as cultivation, supply of production elements, seaweed production processes, processing/agro-industry, distribution, and marketing, have become constraints to develop the seaweed agro-industry (Sudarwati *et al*. 2020).

Seaweed culture in Morowali Regency has begun for 30 years ago, both in the sea and in ponds. However, the farming community's socioeconomic conditions are still highly troubling. This is because seaweed production is only sold dry, allowing collectors to manipulate the price anytime. Seaweed cultivators wait for consumers from various places, such as Kendari (Southeast Sulawesi), Banggai Regency (Central Sulawesi), and even Makassar (South Sulawesi) to sell their products.

In the coastal waters of Morowali Regency, seaweed is rather easy to cultivate. Seaweeds are one of the potential commodities to be developed for the agro-industrial development (Mira, 2012) because humans commonly eat seaweeds, either through simple processing or more complex processing to result in semi-finished commodities that can be further processed.

Cultivators and agro-industrialists must collaborate closely in order to accomplish this goal.

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To support growers in maintaining the continuity and sustainability of their culture, institutions that can help with seaweed farming, processing technologies, and marketing appear to be very important. Unfortunately, there hasn't been much work done to create seaweed products for agro-industrial use up until now. Due to this circumstance, both cultivators and the general public cannot profit from the seaweed products. It is feared that this circumstance will reduce the cultivators' motivation to grow seaweed.

The objective of this research is to examine the physical and chemical conditions of seaweed growing sites in Morowali Regency. The findings of this study will be used to inform the government, private sector, and public on the seaweed potential and production in Morowali Regency, give the ideas to the community, particularly cultivators, on how to produce superior seaweed in terms of quality and quantity with the correct management plan, and contribute to the provincial and district governments concerning the type of seaweed processing technology that might be created to benefit the inhabitants of Morowali Regency. The availability of seaweed marketing strategies can be used in Central Sulawesi Province, especially Morowali Regency. The application of seaweed agroindustry model can also be used to define the policies that would ultimately benefit the community's economy.

MATERIAL AND METHODS

This research employed a survey method in 3 sub-districts in Morowali Regency, i.e. South Bungku District, Witaponda District, and Petasia District. Three of the 13 sub-districts in Morowali Regency were chosen because they have coral reefs. The study was performed from January to August 2021. Three observation stations were used in the study for data sampling, and each consisted of research sub-stations. The results of the initial survey are used to determine the research location. Due to the fact that both MenuiKepulauan and South Bungku sub-districts farm the same (homogenous) variety of seaweed, *Eucheuma cottoni*, the research station is only conducted in one of the sub-districts listed above. The types of seaweed grown at each of the three data gathering stations are distinct. *Eucheumacottoni*is grown in the South Bungku district, *Eucheumacottoni* and *Gracilaria sp*. are grown in the Witaponda sub-district, and only *Gracilaria sp*. is grown in Petasiasub-district.

The physical, chemical, and predator data in *E. cottoni* cultivation were collected during the famine season in January and February, as well as the harvest season in June and February. Meanwhile, *Gracilaria* sp is only cultivated in January and February. However, because the production of *Gracilaria* sp is not impacted by the season, harvesting can be done at any time of the year. This data were collected throughout the course of one crop cycle.

The spatial analysis approach was used to identify the land suitability of a water location in the establishment of optimal and sustainable seaweed agriculture that supports coastal sustainability. There are various processes to conducting geographic analysis, including the compilation of the spatial database and the overlaying approach. The ranking or order of land suitability classes for seaweed farming is the result of the GIS study using the overlay model index approach. The following are the land suitability classes, which are defined at the class level:

Sl Class: Not suitable, i.e. land or an area that is not suited for seaweed production due to a severe, persistent restricting factor.

S2 Class: Less suitable, i.e. if the land or location has a significant limiting factor that influences seaweed agriculture productivity. It is vital to incorporate technology from the therapy level into its management.

S3 Class: Suitable, i.e. if the land or location is well suited to seaweed production and has no substantial limiting factors, or has a minor limiting factor that will not considerably affect productivity.

The range of suitability index values distinguishes the land suitability classifications listed above. The index interval value for each appropriateness class is calculated by dividing the interval into three equal parts and subtracting the difference between the highest and lowest overlay index values.

Land suitability will be established utilizing a Geographic Information System (GIS), which is one of the systems developed for an information management system that can support and process data from multiple variables involved in policy determination.

RESULTS AND DISCUSSION

Current velocity at station 1 varied between 0.05-0.26 m/sec during the lean season of January to February and between 0.11-0.17 m/sec during the harvest season of June to July during the research. While the current velocity at station 2 varied from 0.03 to 0.09 m/sec at each sampling point during the lean season, it varied from 0.24 to 0.40 m/sec during the harvest season. The current velocity around the South Bungku Islands is relatively very weak, especially during the lean season and only a few stations have a current velocity of 0.1 – 0.26 m/sec. The current velocity at station 1 in the lean season and harvest season and at station 2 in the lean season is not optimal for cultivation development, but in the peak harvest season it is quite optimal for seaweed cultivation. According to Atmanisa (2020), the optimal current velocity for *E. cottoni* growth ranges from 20 – 40 cm/sec. Waves and currents move water masses horizontally and vertically, causing homogenous mixing that may help carry nutrients and other suspended items through the water. (Sumampouw, 2019). In addition, this homogeneous mass of water can prevent the extreme fluctuations in temperature, salinity, pH and dissolved oxygen.

The very small current velocity causes the movement of the water mass to be relatively slower or stagnant so that nutrients and other suspended materials are not normally distributed (Kurniawan, 2018). This situation causes the cultured seaweeds not move much, so that sedimentation materials in the form of sand and mud as well as other organic and inorganic materials are easily attached. To prevent the seaweed from disease infection, these materials need to be removed. This occurred during the measurement of water quality in January-February, where around 50–70% of the seaweed was infected with moss and diseases. This condition causes stunted growth so that the cultivators had to immediately harvest it. Figures 1 and 2 display the flow velocity map graphically.

In general, the current conditions at the research site suggested that the current velocity is insufficient for good production of *Eucheuma cottoni*. When the east season begins in December-February, the wind blows from west to east across the mainland of Sulawesi Island, causing the current to weaken when it reaches the Salabangka Islands, whereas when the west season begins in June-October, the current blows from east to west across Tolo Bay, causing the current velocity to increase. The change in current velocity between the east and west seasons has a significant impact on *Eucheuma cottoni* growth. The seaweed growth becomes very slow and infected by disease in several sampling places, and the farmers have to immediately harvest it. This condition lasts until April. The growth of seaweed began to improve when the western season began, especially from June to October, and the water currents rose.

During the harvest season, *Eucheuma cottoni* cultivation ranged from 2 m to 4.6 m, whereas it ranged from 1.7 m to 4.4 m during the lean season. In Station 2, the height varies from 1.5 m to 4.20 m in the lean season and from 2.70 m to 4.20 m in the harvest season. The height required to cultivate *Gracilaria* sp. varies from 45 cm to 60 cm. At station 3, the height required to cultivate *Gracilaria* sp. varies from 40 cm to 60 cm. The brightness of the waters at the study site in almost every sampling point can be seen all the way to the bottom. This shows that the suspended material in the water does not absorb the penetration of sunlight that enters the water column. The general depth through which the sun penetrates is up to 5 meters above sea level according to Putra (2017) , but in South Bungku district with a depth of 6 to 8 meters is still overgrown with seaweed, indicating that the brightness can reach the bottom of the waters. This is due to the relatively slow current velocity so that the particles of mud and sand are not mixed, as well as the lack of waste, both household and high fuel oil, which can block the sun's rays from penetrating the waters. The general depth of the sunlight penetration is up to 5 meters above sea level Putra (2017), but in South Bungku district, it ranged from 6 to 8 m and still overgrown with seaweeds, indicating that the brightness can reach the sea bottom. This is due to the relatively slow current velocity so that the particles of mud and sand are not mixed, the lack of waste, both household and high fuel oil, which can block the sunlight into the water. In stations 2 and 3, the water brightness was almost the same, not fluctuating much, ranging from 40-60 cm. This indicates that the waters are very saturated so that they are suitable for *Gracilaria* sp cultivation because seaweed can grow properly in waters with a brightness level of 80-100%. The brightness of 100% can support the life of seaweed because the photosynthesis occurs properly. The same finding was also reported by Ya'la & Nasmia (2012) that good seaweed cultivation area should be able to have good water brightness. According to Atmanisa (2020), the brightness level for algae cultivation is greater than 5 meters. Turbid waters have many fine particles floating in the water and attached to the thallus can inhibit the absorption of food and the photosynthesis.

This finding showed that all sampling points of station 1 were located on one island, namely Salabangka island, where each village is located within protected area), while the sampling point of station 2 was located in the open sea but around the cultivation site there are many coral reefs so that they are protected from strong currents. This is in accordance with Poncomulyo *et al*. (2006) that waters in the form of canals and located between 2 islands or a group of coral islands usually have strong currents and waters with barrier reefs are very suitable for cultivation of *E. cottoni.*

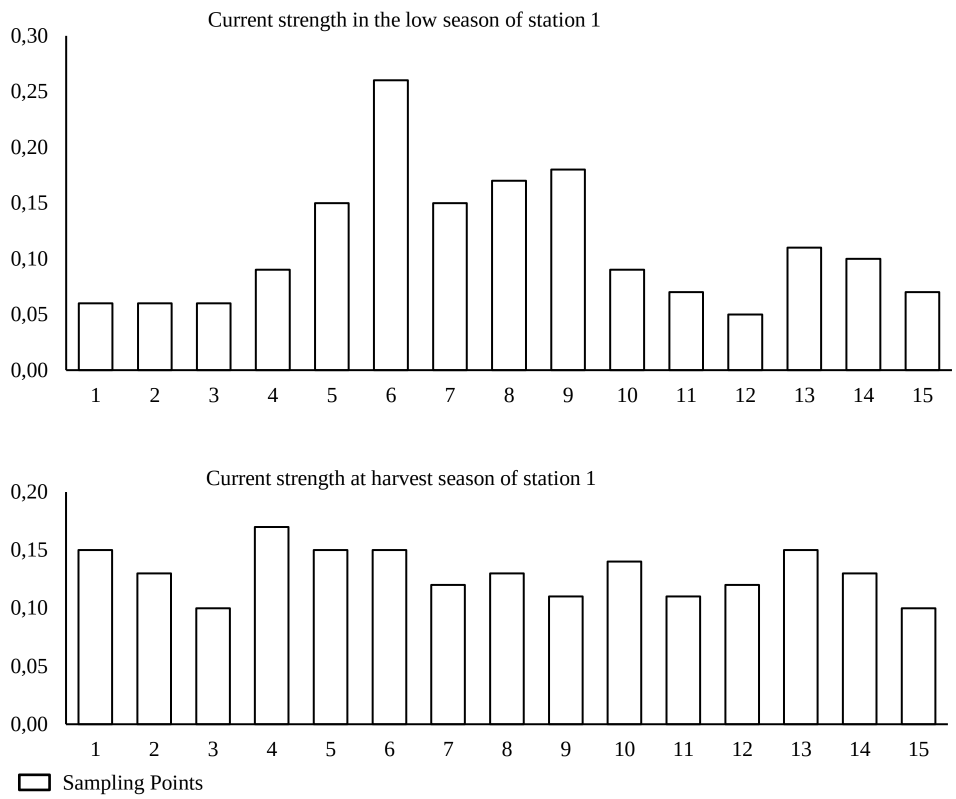

Figure 1. Map of flow speed in famine season (January-February) and harvest season (June-July) at station 1

The location of seaweed cultivation in the Salabangka Islands shows that December–February is the eastern season in which water condition is relatively calm. Therefore, grass production is generally less than that in May–September, which is the west season. For the transition season from the west to the east, October - November, the physical and chemical conditions of the waters are almost the same as the transition season from the east to the west in March–April. This is quite reasonable because the climatic conditions in tropical countries such as Indonesia only recognize 2 seasons so that the conditions of the oceanographic parameters of the waters are relatively the same.

The protection factor needs to be considered in choosing a location for seaweed cultivation to avoid damage to cultivation facilities and seaweed from the influence of large winds and waves (Burdames & Ngangi, 2014) . The waters of the Salabangka Island group have open and protected waters. In the west season, the Banda Sea current from the north-northeast enters the waters of the Salabangka Island group. Almost the entire water area of the Salabangka Island cluster in this season is protected from the influence of currents and supports seaweed cultivation. In the east monsoon, the current from the Banda Sea increases and only the northern part of the Salabangka Island group is protected from the influence of the current, on the contrary in the southern part it is not protected. The eastern waters in the eastern monsoon are quite suitable for seaweed cultivation compared to that of the southern waters. This is in accordance with Atmanisa (2020) that to avoid physical damage to cultivation facilities and seaweed, a location needs to be protected from the influence of wind and large waves.

TSS levels varied from 1.26 to 14.31 ppm during the famine season of E. cottoni cultivation at station 1, but only from 1.16 to 7.35 ppm during the harvest season. The TSS concentration in station 2 during the lean season varied from 1 to 3.88 ppm, whereas during the high harvest season it was only about 1-2.1 ppm. TSS levels for the cultivation of Gracilaria sp. were from 2.02 to 5 ppm at station 2 and from 1.98 to 20 ppm at station 3 respectively.The highest concentration of TSS in *Gracilaria* sp. cultivation is at station 3, due to its proximity to the oil palm plantations, where liquid waste from the plantation enters the watershed (DAS) so that mass of river water can enter the ponds where *Gracilaria* sp cultivation is located through the inlet. The suspended solids at each station were still in the appropriate category for the cultivation of *E. cottoni* and *Gracilaria* sp. because according to Atmanisa(2020), the TSS content was <25 ppm suitable for seaweed cultivation activities. Suspended solids generally consist of phytoplankton, zooplankton, human waste, animal waste, sludge, plant and animal residues as well as industrial waste in both solid and liquid form. The high content of suspended substances can reduce the sunlight, so that the heat received by the sea surface is not effective enough for the photosynthesis process (Effendi *et al*. 2020; Susiati and Yurianto, 2016) .

In the cultivation of *E.cottoni*, the TDS content in the lean season at station 1 was in the range of 27.26 – 54.08 ppm, while in the harvest season it ranges from 50.27 to 51.16 ppm. The TDS of Station 2 in the famine season was in the range of 36.37 – 54.76 ppm, while during the peak harvest season it ranges from 49.71 to 52.11 ppm. For *Gracilaria* sp cultivation at station 2, the TDS concentration ranged from 10.11 to 45.12 ppm, while at station 3, it ranged from 9.43 to 52.60 ppm. The content of TDS in the lean season at the two stations is caused by differences in the parameters of marine and brackish waters, which are extreme from a bioecological perspective.

Dissolved materials usually come from solid waste materials, both industrial waste materials and waste materials from settlements (Intania *et al*. 2020). These waste products come in both soluble and insoluble forms. The latter will float and eventually settle to the bottom of the waters. Dissolved solids can block the penetration of sunlight, which can inhibit the process of photosynthesis. The TDS content at the three stations was still in the appropriate category for the cultivation of *E. cottoni* and *Gracilaria* sp, based on the threshold value (NAV) set by the Ministry of Environment (2004), that the TDS content for fisheries and marine parks was <80 ppm.

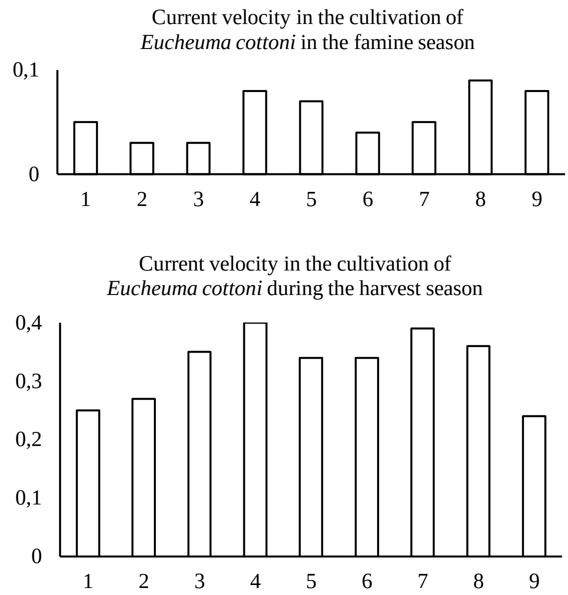

Figure 2. Map of Flow Velocity in famine season (January-February) and Harvest Season (June-July) at Station 2

The color of the surface waters is not fixed at all times. The aftermath looks brownish because the rain has brought in so many dissolved and suspended particles. The water column turns greenish during the dry season as a result of the abundance of algae. This shift is brought on by dissolved and suspended components. These components are not visible in regular situations due to the low concentration of these compounds. At station 1, the water was between 1.7 and 6.5 meters asl (below sea level), while at station 2, it was between 2.75 and 4.5 meters asl. For *Gracilaria* sp cultivation at station 2 the depth ranges from 60 cm - 90 cm, while at station 3 the depth level ranges from 50 cm - 70 cm. The difference in depth is determined by the difference in the topographic conditions between the two stations, thus affecting the process of entering the water mass from the watershed (DAS) to the in-lead pond.

The sea depth that supports the growth of seaweed is up to 10 m (Hasnawi *et al*. 2016) . Seaweeds in Indonesian waters grow well at these depths, because the sunlight is still relatively good at that depth. The depth ranges at station 1, 2, and 3 are still in the appropriate category for the cultivation of *E. cotttoni* and *Gracilaria* sp. This in line with Halomoan(2020) that seagrasses are abundant in the intertidal zone. The depths of pond waters ranging from 50 to 80 cm at the stations 2 and 3 are categorized as suitable for *Gracilaria* sp cultivation and Atmanisa(2020) that *Gracilaria* sp requires a minimum depth of 50 cm. This condition is sufficient to support the effectiveness of *Gracilaria* sp cultivation to yield maximum production.

The wave height in the lean season ranged from 0.01 to 0.05 cm and in the harvest season from 1.05 to18.6 cm. In station 2 of the lean season, the wave height ranged from 0.19 to 0.31 cm and in the harvest season from 20 to 30 cm. The waves in the waters of South Bungku (station 1) are influenced by the east season and the west season. The former occurs in December - February and the latter in June - October. In the east season, the wind blows from the west across the mainland of Sulawesi Island and then turns east to Tolo Bay, because it crosses the mainland, the wave conditions are relatively weak. In the west monsoon, a strong wind blows from the east (Banda Sea) to the west across the Tolo Bay at a certain speed, which can cause currents and waves.. It causes a faster circulation of water masses, and thereby, accelerates the distribution of nutrients and other dissolved materials evenly in the water's column. This condition is needed by seaweed, including other cultured organisms.

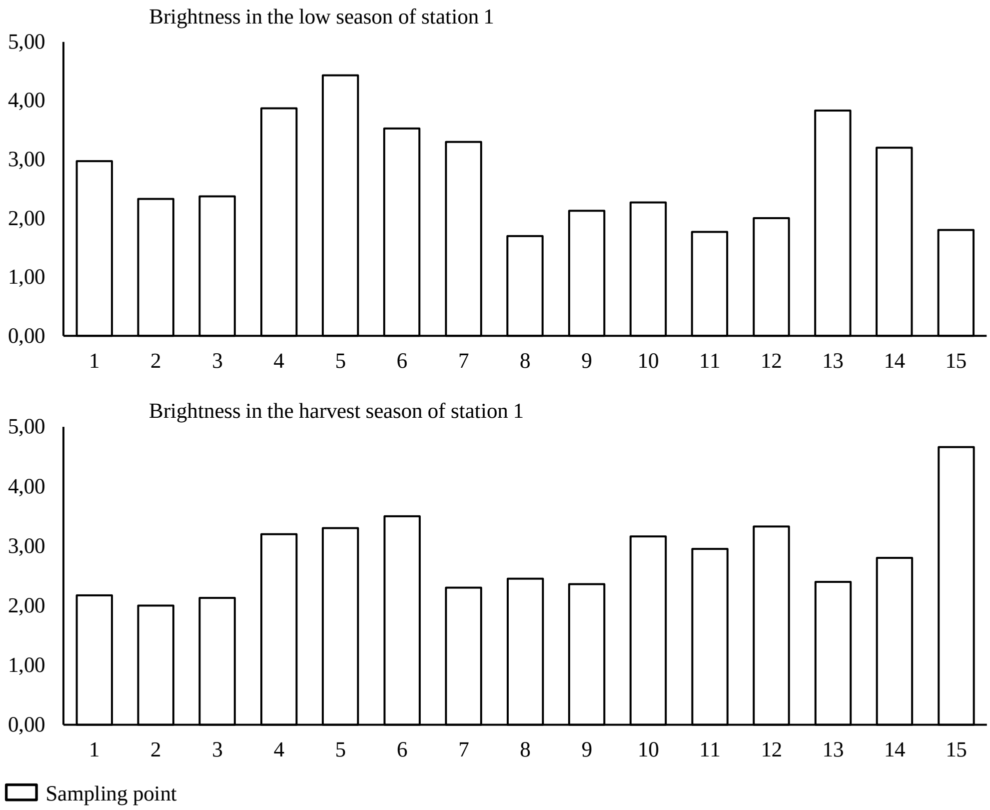

Figure 3. Map Brightness in the Low Season (January-February) and Harvest Season (June-July) at Station 1

In bioecology, waves have a decisive role in the supply of dissolved oxygen in a sustainable manner, where oxygen is needed in the life processes of the aquatic organisms. Waves also play a significant role in the occurrence of upwelling and turbulence, which are an indicator of water fertility.

In the lean season, the low production of *E. cottoni* is due to the lack of nutrient supply and other dissolved materials from small waves and low current speed in supporting the circulation of the water mass at the station. Geologically, small wave and current movements and high rainfall enhance the disease infections, especially ice-ice disease and the attachment of moss and barnacle parasites to occur. This situation causes almost all of the thallus branches of *E. cottoni* be covered by mosses and barnacles which can inhibit nutrient uptake through stomata. Meanwhile, during the harvest season, the waves and currents are relatively larger so that they are sufficient to support the circulation of the mass of water, which in the end the supply of nutrients and other dissolved materials to the needs of *E. cottoni* is are fulfilled biologically. This is in line the Research and Development Research and Development Center P3 LIPI (1995) that seaweeds are generally able to tolerate large wave action and is exposed to rocky intertidal areas and dense substrates. The desired wave height for the cultivation of *E. cottoni* is < 0.5 m.

Waves that move towards the coast will change shape due to the process of refraction, diffraction, and breaking waves. In areas that are quite dominantly influenced by tides (intertidal), waves have a considerable influence on the local organisms and communities. It directly affects the life on the coastal area by destroying and washing away the objects, and stir or mix the atmospheric gases into the water, so that waves can increase the oxygen content in the waters. The wave conditions in the South Bungku waters describe the characteristics of the waters that are protected from the large waves that disturb the aquaculture activities. If the wave is too high, the thallus and the absorption of nutrients will be hampered and the surrounding waters will become cloudy so that it inhibits the photosynthesis. According to Atmanisa (2020), sea waves have a negative and positive influence on seaweed cultivation activities. The selection of *Eucheuma cottoni* cultivation sites must be protected from large waves, usually the protected locations such as bays, small islands, sea hills, or coral reefs. Sea waves also have an important role in marine aquaculture activities, because the process of water turbulence plays a role in mixing the water mass to maintain the homogeneity of temperature, salinity, and dissolved oxygen content in the waters.

Tide data in the lean season (January-February) shows a range of 0.1 -1.6 m, while in the harvest season (June-July) it is 0.2 – 1.7 m. The high tidal range during the lean season is not only influenced by the full moon and the dead moon, but also by the height of the waves. Meanwhile, during the harvest season, the full moon and the dead moon and higher waves when compared to the lean season also influence the high tidal range.

Tides affect the water depth and circulation so that the distribution of nutrients and other dissolved materials can occur evenly which causes the nutrient absorption easier and the thallus not covered by mosses, barnacles and other particles. The effective absorption of nutrients by *E. cottoni* will accelerate its growth and increase the seaweed production. *E. cottoni* lives in tidal areas by attaching to the substrate so that it can survive and not be carried away by currents and waves (Poncomulyo *et al*. 2006).

The salinity level of seawater at station 1 during the lean season is 30.3 -33.7, during the harvest season it is around 28-33. At station 2 it is 30 – 31, both during the lean season and during the harvest season. The distribution of salinity at station 1 is quite fluctuating; this is due to differences in depth at several sampling points. This value is still in the appropriate class for the cultivation of *Eucheuma cottoni*.In general, it also meets the criteria for determining the appropriate and optimal level of water quality for the survival of aquatic organisms as described by Atmanisa(2020), that the salinity of waters suitable for the cultivation of *Eucheuma cottoni* generally ranges from between 28-35‰. Salinity below 28‰ causes seaweed to be susceptible to disease. For *Gracilaria* sp cultivation activities at station 2 the salinity level ranges from 23–24 and at station 3 it ranges from 11–20. In line with what Atmanisa(2020) stated, that *Gracilariasp*has a maximum growth during cultivation ranging from 15-28‰, with an optimal level of 25‰.

The different levels of salinity at each station indicate that the water conditions are not the same. The salinity in stations 2 and 3 is affected by several rivers, while in station 1, there is no big river. Dissolved oxygen in water generally comes from oxygen diffusion, currents, water flow from rain and photosynthesis. Its concentration varies depending upon temperature, salinity, water turbulence and atmospheric pressure. The measurements showed that dissolved oxygen content at station 1 in the lean season ranged from 6.8 to 9.84 ppm and during the harvest season it ranged from 7.1 to 9.83 ppm. In the lean season, the dissolved oxygen content ranged from 6.1 to 9 ppm and during the harvest season from 7 to 9.20 ppm. For *Gracilaria* sp cultivation activities, the dissolved oxygen concentration in station 2 ranged from 5.98 ppm - 8.01 ppm, and in station 3, it ranged from 5.31 ppm - 8.43 ppm. The dissolved oxygen content in Bungku Selatan District was in proper and natural conditions for *E. cottoni* cultivation with the lowest content of 6.8 ppm. According to Sastrawijaya (2000), the aquatic life in the water column survives at the lowest of 4 ppm, and the rest depends on the resistance of organisms, the presence of pollutants and water temperature.

Dissolved oxygen at station 1, station 2, and 3 indicated that the waters of the culture location had dissolved oxygen content suitable for the cultivation of *E. cottoni* and *Gracilaria sp*. Dissolved oxygen in the waters is influenced by various factors including temperature, salinity, and the process of decomposition and respiration of organisms. The presence of dissolved oxygen is also influenced by the movement of water masses (Effendi 2003), in which its concentration can fluctuate daily and seasonally depending on mixing and movement (turbulence) of water masses, photosynthetic activity, respiration, and waste entering water bodies. Low oxygen content will inhibit the growth of *E. cottoni* and reduce its productivity. According to the Ministry of Agriculture (1998), dissolved oxygen could also act as a directive factor in several biochemical processes. In station 3, the dissolved oxygen concentration was lower than stations 1 and 2, although it was still suitable for cultivation of *Gracilaria* sp. This is presumably due to the influx of organic matter from rivers and being near the oil palm plantation area.

Water acidity (pH) in station 1 of *Eucheuma* sp cultivation area ranged from 7.9 to 8.7 in the lean season 7.7 to 8 in the high harvest season. In station 2, it ranged from 7.3 to 8.2 in lean season and 7.5 to 8 during the peak harvest season 7.5 – 8. In the cultivation area of *Gracilaria* sp, station 2 had the pH range of 6.1 to 8.2 and station 3 had pH ranged of 6.3 to 8.7. Good pH for *Eucheuma* sp growth ranged from 7.3 to 8.2 (Poncomulyo *et al*. 2006). The optimal pH is 6.5 for the growth of both *Eucheuma* sp and *Gracillaria* sp. Water pH has a great influence on the cultured seaweed and the water conditions with a neutral or slightly alkaline pH are ideal for the growth of marine organisms (Atmanisa 2020). This acidity condition is still in the appropriate range for the cultivation of *Eucheuma cottoni.* Generally, low pH is found in aquaculture ponds because at the time of planting *Gracilaria* sp, liming is rarely done. After the stocking of *Gracilaria* sp, the cultivators just left the ponds without further maintenance until harvesting.

Carbon dioxide (CO2) is a gas needed by small and high-level aquatic plants to carry out photosynthesis. This gas comes from the dismantling of organic substances by microorganisms on the bottom of the water. Carbon dioxide from air is always exchanged when water and air come into contact. In calm water, this exchange is little. If the water is bumpy then the exchange changes faster. During the study, carbon dioxide (CO2) in station 1 in the cultivation area of *E. cottoni* ranged from 0.35 to 0.99 ppm in the famine season and from 0 to 41.13 ppm during the harvest season. In station 2, it ranged from 0.34 to 3.12 ppm in the famine season and 0 to 1.91 ppm during the peak harvest season. In the cultivation of *Gracilaria* sp, station 2 had CO2 range of 0.67 to 4.21 ppm, and station 3 from 0.22 to 4.05. Low CO2 content in stations 1, station 2 and 3 was not suitable for the growth of *E. cottoni* and *Gracilaria* sp. The carbon dioxide in a certain amount is a limiting factor for the life and growth of organisms. Therefore, CO2 plays an important role as a food element for all living plants.

Nitrate is described as a micronutrient compound controlling primary productivity in the surface layer of the euphotic area(Schnetger & Lehners, 2014). Nitrate levels are strongly influenced by nitrate transport in the area, ammonia oxidation, and the uptake for primary productivity processes(Smith *et al*. 2016). The nitrate content at station 1 ranged from 0.88-2.2 ppm in the lean season and from 0.48 to 16.97 ppm at the peak harvest season. In station 2, it ranged from 0.36 to 0.75 ppm in the famine season and from 1.51 to 5.43 ppm at the peak harvest season. For the cultivation of *Gracilaria* sp. the nitrate concentration ranged from 0.10 to 0.53 ppm in station 2, and 0.2 to 6.65 ppm in station 3. Romimohtarto and Juwana (2007) stated that the average nitrate content in marine waters is 0.5 ppm and should not exceed 3 ppm.

Nitrate measurements at the three stations showed variations. Stations 1 and 2 had very high nitrate concentration during the harvest season. It is caused by the east monsoon where the wind blows, generates waves, and stirs the water. The entry of organic materials from the settlements and rainfalls can increase nitrate levels. *Eucheuma cottoni* requires fertile and rich water conditions for nutrients to support its growth. A very important nutrient in waters is nitrate and is a bioindicator of the fertility of waters. However, it is not needed in large quantities because it could cause eutrophication. Naturally, nitrate enters the waters usually comes from river on the mainland and oxygen fixation, rain (precipitation), and upwelling.

The concentration of orthophosphate in the surface waters is due to high absorption due to high organic production. Phosphate is an essential nutrient for the growth of an aquatic organism. As the depth increases, the phosphate concentration also increases. Phosphate content at station 1 in the lean season ranged from 0.07 to 0.30 and at the peak harvest season from 0.03 to 0.35 ppm. Station 2 had phosphate content of 0.02 - 0.41 ppm in the famine season and 0.01 - 0.41 ppm in the harvest season. For *Gracilaria* sp cultivation activities, the phosphate concentration ranged from 0.1 to 0.54 ppm in station 2 and 0.11 to 0.86 ppm in station 3. These ranges are still optimal. Yala & Sulistiawati (2017) also found that the appropriate phosphate content for the cultivation of *E. cottoni* and *Gracilaria sp* ranges from 0.02 – 1 ppm. Nitrates, phosphates and silicates in certain amounts or ranges are limiting factors for the formation of protoplasm of aquatic biota. The ratio of phosphorus to other elements in aquatic ecosystems is smaller than in the bodies of living organisms. Phosphorus enters the waters through animal waste, sewage, agricultural residues, plant residues and dead animals. Phosphate dissolved in seawater is the main nutrient needed for the growth of *E. cottoni* and *Gracilaria* sp. Phosphate plays a role in the formation of proteins and cell metabolism.

CONCLUSION

The results of the analysis of the 14 limiting factors considered include current speed, brightness, protection, temperature, suspended solids, dissolved solids, depth, waves, salinity, DO, pH, CO2, nitrate, and phosphate. Based on the research location, both station 1 and station 2, indicates that the current state of the research location did not permit the growing of *E. cottoni*. Water brightness reached the bottom, making it suitable for the cultivation of *E. cottoni* and *Gracilaria* sp. Stations 1 and 2 were very suitable for cultivation of *E. cottoni*. The suspended solid, TDS, and depth were also in appropriate category for the cultivation of E. cottoni and *Gracilaria sp*. During the harvest season, the waves and currents were relatively sufficient to support the water circulation for the supply of nutrients and other dissolved materials to the seaweeds. Water salinity for the cultivation of *E.cottoni* at stations 1 & 2 and the cultivation of *Gracilaria* sp at stations 2 & 3 is quite appropriate. Dissolved oxygen and pH at stations 1, 2, and 3 were acceptable for the cultivation of *Eucheuma cottoni* and *Gracilaria* sp as well. While the phosphate content at stations 1, 2, and 3 was still ideal, the nitrate content at the three observation stations surpassed the acceptable limit for seaweeds.

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