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Seaweed (*Kappaphycus alvarezii*) condition exposed to temperature change in Sulamu waters, Kupang Regency, East Nusa Tenggara, Indonesia

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Abstract

Climate change is related to global warming, which indicates the rising temperature on the earth's surface, which in turn increases sea level. Rising seawater temperatures have a very complex effect on various aspects of the ocean, including fisheries. These impacts can occur directly or indirectly, which appear in different time variations. The impact of increased seawater temperature gives very complex effect on various marine aspects including seaweed. Temperature change greatly affect life in the sea. This study aims to know the effect of temperature on the seaweed *Kappaphycus alvarezii* production and growth in Sulamu waters. The study used survey method and direct field observations. Results showed that the seaweed production was 81.07 kg m^{-2} 6 weeks^{-1} at 27^{0}C, 73.07 kg m^{-2} 6 weeks^{-1} at 28^{0}C, 64 kg m^{-2} 6 weeks^{-2} at 29^{0}C, 60.8 kg m^{-2} 6 week^{-1} at 31^{0}C, and 30.47 kg m^{-2} 6 week^{-1} at 32 – 33 ^{0}C. The specific growth rate was 6.25% at 27^{0}C, 5.19% at 28^{0}C, 4.6% at 29^{0}C, 3.6% at 30^{0}C, 2.08% at 32^{0}C, and 1.9% at 33^{0}C, respectively. The seaweed production and growth at 27 – 30^{0}C were not infected by ice-ice disease, but those were infected by ice-ice disease at 32 – 33 ^{0}C.Key words: climate change, temperature, growth, production, *Kappaphycus alvarezii*

Introduction

Seaweed is one of the development programs in East Nusa Tenggara province to support the food security (Sunadji et al., 2014). For this, seaweed culture needs to be done in order to prepare seeds and produce good quality seeds that are resistant to water temperature change and disease. (MMAF, 2020). Nevertheless, seaweed culture is highly affected by climate change that can eventually influence food availability. Seaweed is also one of the fisheries commodities that have been utilized in food industries, pharmacy, medical, cosmetics, and others (Oedjoe et al., 2019). This commodity has even been established as major commodity in fisheries rehabilitation program since 2005, so that fast and appropriate culture is needed to keep pace with demand in quantity, quality, and continuity using appropriate technology in climate change condition (Joppy et al., 2015). Seaweed culture technology needs to be thoroughly mastered to obtain maximum profitability. This culture technique includes locality-related culture system, seaweed species, seed selection, planting technique or seasonal change-related planting pattern (Radiarta et al., 2013). Seaweed culture development can be influenced by biophysically aquatic environmental condition and climate condition (Harley,et al., 2012). Temperature is a factor regulating the seaweed growth (Aris,et al.,2021), and thus, it is important for marine ecosystem (Charan et al., 2017), because seaweed can grow well at the suitable water temperature (Kumar, et al., 2015). It results from highly dynamic water condition and unpredictable climate impact. Harvest failures often experienced by the seaweed farmers are caused by big waves, wind direction, and unstable water temperature. This condition indicates that climate is one of the highly important factors needed to be considered in the sustainability of seaweed culture activity, and one of which is temperature. Previous studies found that seaweed growth response differs with time and season (Radiarta et al., 2013; Daud, 2013). Water temperature is an important factor for the seaweed life (Serdiati & Widiatuti, 2010), and water mixing can prevent high temperature fluctuation (Ramdhan et al., 2018). High water temperature can cause protein denaturation and damage enzyme and cell membrane (Rao et al., 2008), so that temperature highly influences the seaweed life, such as growth, production, reproduction, photosynthesis, and respiration (Sarojini and Sujata., 2015). This study was aimed at knowing the effect of water temperature on the seaweed condition. This study is expected to be able to become basic reference for seaweed planting pattern that can assist the seaweed farmers to maximize the production.

Materials and Methods

This study was carried out in Sulamu waters, Kupang regency in April to October 2020. Water temperature was recorded from April to October. Other data were collected through interviews using questionnaires, in which respondents were selected using purposive sampling (Tongco, 2007) from the active groups of seaweed farmers in Sulamu(Figure 1). These data are used to know the production and the growth of seaweed *K. alvarezii*.

Measurements were done on the following parameters:

a) Specific growth rate (SGR) was calculated following Hurtado et al. (2014):

$$SGR : \frac{Ln\ Wt - Ln\ Wo}{t} X\ 100$$

where SGR is specific growth rate, Wt is mean final weight (g), Wo is mean initial weight (g), and t is observation time length (day). SGR was measured each 7 days for 6 weeks.

b) Absolute growth. This measurement was estimated as the difference between weight at the end of rearing and weight at the beginning of rearing (Faisal et al., 2013):

$$W = Wt - Wo$$

Where W = absolute growth (g), Wt = final weight (g), and Wo = initial weight (g)

c) Production. Seaweed production estimation used the formula of Fikri et al. (2015):

$$Pr = \frac{(Wt - Wo) \times B}{A}$$

Where Pr = seaweed biomass (g/m), Wt = final weight (g), Wo = initial weight (g), B = line length (m), and A = planting point

d) Water Quality

Water quality parameter measurements focused on water temperature that was recorded every week during the study.

All data were descriptively analyzed.

Results

Seaweed *Kappapyhcus alvarezii* production

Relationship between water temperature and Production of *Kappapyhcus* in Sulamu waters

Seaweed *K. alvarezii* production in Sulamu waters, NTT, is highly influenced by the environmental conditions, especially water temperature (Table1). According to Fikri et al (2015), seaweed production is dependent upon environmental factors and growth rate. High growth rate will yield high production as well (Irfan, 2017). This finding is in agreement with Serdiarti & Widiastuti(2010) that extremely high or low water temperature can affect the seaweed growth rate and production, and even could cause high mortality. The optimum temperature for the growth of *K. alvarezii* ranges from 26 C^0- 30 C^0 (Joppy & Ngangi., 2014). The higher the water temperature is the lower the seaweed *K. alvarezii* production will be. High water temperature is believed to cause ice-ice disease on the leaf of *K. alvarezii* so that the seaweed production is affected (Prakash et al., 2011)(Figure 2).*K. alvarezii* is a seaweed species that is not resistant to very high temperature (Charan et al., 2017). whereas according to Andi et al.(2016), *K. alvarezii* grown well at the temperature range of 27^0C–30^0C.

Specific growth rate (SGR) of seaweed *Kappapyhcus alvarezii*

In this study, the specific growth rate of *K. alvarezii* decreased with increasing temperature above 30°C, and the highest specific growth rate (6.25 %) was recorded at 27 °C.Seaweed growth of *K. alvarezii* is highly influenced by environmental factors. The effect of water temperature on the seaweed growth is presented in Table 2.

Ittdemonstrates that specific growth rate (SGR) is influenced by increased water temperature. The present study revealed that the SGR was 6.25% at 27^{0}C, 5.19% at 28^{0}C, 4.6% at 29^{0}C, 3.6% at 30^{0}C, 2.08% at 32^{0}C, and 1.9% at 33^{0}C, respectively. This finding is in agreement with Neksidin. et al (2013) and Andi et al (2016), that the optimum temperature for *K. alvarezii* occurs from 27^{0}C to 30^{0}C. In this temperature range, the SGR was recorded as much as 6.25-4.6%. According to Zainuddin & Rusdani (2018), the profitable SGR is higher than 3%. Hasanuzzaman et al (2013) found that water temperature >30^{0}C inhibits photosynthesis and impacts on slow growth**.** According to Oedjoe et al. (2020), optimum water temperature is found in April to June that gives good seaweed growth and quality.

The highest SGRin March/May inthe present study was nearly in agreement with the result of an Aslan et al, 2019 study in Sulawesi Tenggara.The results indicated that the growth rates are influenced specifically by study site and season. The maximum growth rates in the present study were mostlyfound from March - June atrelativelyoptimumtemperature(27 ^{0} C – 30 ^{0} C), whilelowest growth ratein July -October coincidentally occurred at high temperature (31^0 C- 33 ^{0}C.) and salinity (33-34 ppm). As what the result has shown, Aslan et al., 2019 and Oedjoe et. al, 2020.

Absolute growth

Mean absolute growth of *K. alvarezii* during the culture period of April-October in Sulama waters ranged from 68.070 g to 307.150 g (Table 2). The absolute growth was 307.150 g at 27^{o}C, 292.57 g at 28^{0}C, : 254.840 g at 29^{o}C, 103.320 g at 31^{o}C, 98.410g at 32^{o}C, and the lowest 68.070 g at 33^{o}C (Table 3). This condition is supported by Serdiati & Widiastuti (2010) and Oedjoe et al (2020) that water temperature plays important role in *K. alvarezii'* growth.Temperature is closelyrelated to the intensity of sunlight, because the higherthe sunlight intensity is, the higher the temperatureof water will be. Temperature is an oceanographic factorthat is easily measured and plays an important role inphysical, chemical, and biological processes such as theconcentration of dissolved oxygen and the distributionof aquatic organisms (Kumar et al. 2015.; Nur et al, 2020). Water quality parameters observed during the study were salinity, dissolved oxygen, pH and light intensity (Table 3).

Effect of water temperature om *K. alvarezii* morphology

Morphological features

Different water temperatures change the appearance of the thallus and branching of the seaweed. At temperature 27-30 ^{0}C the appearance of seaweed is fresher, and more branches appear in the thallus (Figure 2a) compared to the less morphological features of the seaweed at higher temperatures (Figure 2b).

Discussion

Water temperature

The results explain that temperature and salinity influence production and growth. The water temperature observed during the study was from 27 ^{0}C to 33 ^{0}C. At water temperature 27 ^{0}C to 30 ^{0}C the production and growth of *K. alvarezii* was not affected by ice-ice disease, while there was ice-ice disease at water temperature 31 - 33 ^{0}C. Temperature ranges from 27 ^{0}C to 30 ^{0}C is very supportive to the growth and production of seaweed. According to Radiarta et al., (2013), the water temperature that supports the growth of seaweed is from 27 ^{0}C to 31 ^{0}C. Temperature and salinity affect the life of biota as they relate to the level of oxygen solubility, the respiration process of aquatic biota, and the rate of degradation of pollutants (Amin et al., 2005). It was also supported by Patang and Yunarti, (2009) which mentioned that temperature, salinity, turbidity, pH, and dissolved oxygen affect the growth and production. Temperature also affects the morphology of the seaweed. Neksidin et al. (2013) explained that the different temperatures will affect the growth and production of seaweed both morphologically and physiologically (Figures 2a and 2b) shown the different responses to temperatures changes). Additionally, Choi et al. (2010) argue that temperature has a significant role in the growth, callus formation, and morphogenetic development of seaweed because of osmoregulation events in cells. They argue that different fluid concentrations between the inside and outside cells encourage the cell's Golgi apparatus to keep trying to balance until it becomes isotonic. As a result, this has an impact on greater energy utilization so that it affects the low growth and development of seaweed (Raikar & Fujita. 200). At high temperatures, water inside of cells seaweed was lower or shrinking, which is an indication of a hypertonic event resulting from the concentration of the water fluid being more concentrated than the concentration of fluid in the seaweed cells. According to Choi et al. (2010), a more concentrated external environment causes the fluid to flow out. The cell then size decreases as it undergoes plasmolysis, marked by the membrane release from the wall. Xiong and Zhu (2002) explain that temperature on plants is very complex, such as ionic stress, osmotic stress, and secondary stress. Ion stress due to high-temperature results in Na^+ poisoning. Excessive Na^+ ions on the thallus surface can inhibit K^+ uptake from the environment, even though K^+ ions play a role in maintaining cell flaccid and enzyme activity. Meanwhile, osmotic stress caused by an increase in temperature which affects the high osmotic pressure so that it inhibits the absorption of water and the elements that take place through the osmosis process. If the amount of water that enters the cell is reduced, it will reduce the amount of water supply in the cell (Choi et al., 2010;Akib et al. (2015) explained that temperature affects plant growth and development; Andi et al. (2016) also discussed further that temperature affects metabolism, photosynthesis, respiration, and plant transpiration.

High temperatures on 31 ^{0}C to 33 ^{0}C can damage the enzymes so that metabolism does not work well, as well as low temperatures can cause enzymes to be inactive and metabolism to stop (Yoppy et al., 2015) (as shown in Figure 2b). This is due to the number of cells at high temperatures (> 34 ^{0}C) is lower than it is in 27 ^{0}C-30 ^{0}C. According Chen (2017), if the temperature range has exceeded the life span of algae, the growth and development of algal cells is linear and inversely (negative) with an increase in temperature and salinity. High temperature affects the growth and structural changes of algae, among others, the smaller size of the stomata, so that the absorption of nutrients and water is reduced, ultimately inhibiting algae growth at the level of organs, tissues and cells. The impact of temperature changes that are too high or low causes an increase in pressure for aquaculture, including seaweed farming (Sofri et al., 2018). According to Hung et al (2009)), the enzymes in K. alvarezii cannot function at temperatures that are too hot or too cold. Supported by Joppy& Ngangi (2014), that seaweed has a specific temperature range due to the presence of enzymes in seaweed that cannot function at temperatures that are too cold or too hot. High water temperatures affect the rate of photosynthesis and can damage enzymes and cell membranes which are unstable. At low temperatures, membrane proteins and fats can be damaged as a result of the formation of crystals in cells, thus affecting seaweed life, such as loss of life, growth and development, reproduction, photosynthesis, and respiration (Blanchard, et al. 2012. and Goodwin et al., 2013). The impact of rising sea water temperatures clearly influences seaweed production compared to the optimum temperaturesaround 29 ^{0}C to 31 ^{0}C (Oedjoe et al., 2020).Water temperature highly influences both production and growth. During the study, water temperature ranged from 27^{0}C to 33^{0}C. Good seaweed production and growth occurred in the range of 27 ^{0}C−30 ^{0}C, while at the water temperature of 31 – 33^{0}C, ice-ice disease seemed to infect the seaweed and impact on the growth and production of seaweed. This finding is in agreement with Charan et al (2017); Radiarta et al. (2013) that good seaweed growth-supporting temperatures are 27^{0}C−30 ^{0}C. Lester et al., (2011). Temperature change can increase the physiological pressure on the aquatic organisms, affect productivity, and increase the sensitivity to disease infection. It eventually impacts to profit reduction for the seaweed farmers (Radiarta et al. 2013). This is supported by Amin et al (2005) that coastal area is the mostly impacted area from temperature change. According to Hardan et al., (2020) and Oedjoe et al. (2020), high water temperature can cause ice-ice disease and will impact to seaweed production because the enzymatic performance in new cell formation is disturbed (Figure 2b) and thalli became fragile and fragmented (Yushanthini et al, 2020).

Water temperature also highly affects the aquatic life in relation with oxygen solubility level, respiration, and degradation rate of pollutants. (Kokubu et al., 2015). Water temperature condition is determined by sunlight intensity and water-air heat exchange (Amin et al., 2005). The present study is in line with Radiata et al (2013) good water temperature for seaweed *K. alvarezii* growth and production occurs in the range 27^0C -30^0C. Beyond this temperature range, the seaweed growth and production will be morphologically and physiologically disturbed (Neksidin, et al 2013). Moreover, water temperature, according to Choi *et al.* (2010), highly affects growth, callus formation, and morphogenetic seaweed development. This is closely related to the physiology ofabsorption and circulation of nutrients in seaweed sothat lower and higher temperature will result in seaweeddeath (Bindu and Levine, 2011).Osmoregulation controls the solution concentration in seaweed to be in equilibrium with the environment (Pamungkas, 2012). Furthermore, osmoregulationprocess of the explant body is disrupted because thetemperature is too high. It has difficulty of absorbing thenutrients that are around them, resulting in the slowgrowth of the thallus. According to González et al., 2013; Hayashi et al., 2010, the high temperature causes theGolgi body unable to balance the concentration offluid in the cell with the concentration of fluid outsidethe cell. In the end, many cell fluids are lysis into theenvironment, so that the cell shrinks from its previoussize. The inability of seaweed to control the equilibrium in the body could result in stress and then mortality (Amri & Taslim, 2016). Different density between internal and external cell liquid makes the golgi body continuously work to equalize to be isotonic (Hasanuzzaman et al. 2013). It impacts to the use of larger energy that influences the seaweed growth and production (Raikar & Fujita. 2001). In high temperature waters, the seaweed cell size shrinks indicating that the hypertonic condition due to denser fluid in the water than that in the cell. According to Harley et al. (2012), denser environment causes the fluid flow out and cell shrink so that the cell experiences plasmolysis due to the membrane release from cell wall. According to Xiong and Zhu (2002), effect of temperature on plant is very complex and results in ionic stress, osmotic stress, and secondary stress. Ion stress from high temperature is Na+ toxicity. Excessive Na+ ion on thallus surface can inhibit K+ absorption from the environment, even though K+ ion functions to maintain cell flaccidity and enzymatic activity. Meanwhile, the osmotic stress is caused by increased temperature that influences the osmotic stress and then inhibits water absorption. Osmotic stress could be caused by increased water temperature that inhibits the absorption of water and other elements (Amri & Taslim, 2016). Decreased amount of water entering the cell causes reduction in water supply into the cell (Choi et al., 2010). Physiological processes, such as photosynthesis, respiration, enzymatic activity, water absorption, transpiration, cell division, cell elongation, and changes in cell function will work well (Figure 2a). Akib et al (2015) stated that temperature affects plant growth, while temperature influences the metabolism rate, photosynthesis, respiration, and transpiration (Andi et al., 2016). High temperature, 31^0C - 35^0C can damage the enzyme so that metabolism works well (Yoppy et al., 2015) (Figure 2b), since*K. alvarezii*cells are damaged at high temperature (>30 ^{0}C) and causes mortality (Hayashi L, Reiss R.,2012). According to Rao et al. (2008), when water temperature exceeds the temperature range of algal life, the cell growth and development will be negatively correlated with temperature increment. Temperature reduces growth rate through reduction in cell enlargement at the thallus parts (Harley et al., 2012; Hurtado et al., 2014). Impact of high temperature to growth and structural change of the algae is small size of stomata, so that the absorption of nutrients and water decrease and eventually inhibit the algal growth at the level of organ, tissue, and cell (Hasanuzzaman et al., 2013).

Extreme temperature changes result in increased pressure on the coastal and marine ecosystem, Fisheries cultivation industry, such as fish, seaweed, and shrimp culture (Andi et al., 2016*)*. Increased seawater temperature impacts on seaweed production (Ramdhan et al., 2018). Seaweed*K. alvareziiz* culture has specific temperature range, 27^0C−30^0C because the enzyme in *K.alvarezii* cannot function at too high and too low water temperature (Hung et al., 2009); Joppy.&Ngangi, 2014). High water temperature affects photosynthetic rate and can damage the enzyme and labile cell membrane (Hasanuzzaman *et al*. 2013). While low temperature can damage protein and fat membranes as a result of crystal formation inside the cell that influences the seaweed life, such as survival, growth, reproduction, photosynthesis, and respiration (Sofri et al.,2018).

Conclusion.

K. alvarezii that cultivated for six weeks at the temperature range from 27^0C to 30^0C produced 73.07 to 81.07 kg m^{-2} of seaweed, while the specific growth rate was 5.19 to 6.25% week-1 and the absolute growth was 292.57 to 307.15 g, with no appearance of the ice-ice disease. Higher water temperatures yielded lower seaweed production and growth rate.

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References

[1] Amin, M., Rumayar, T.P., Femmin, N.F., Kemur, D., Suwitra ,I.K. (2005).Study of seaweed cultivation (Eucheuma cottonii) with different planting systems and seasons in Bangkep district, Central Sulawesi. *Journal of Agricultural Technology Assessment and Development*, 8 (2): 282-291https://media.neliti.com/media/publications/139251-ID-none.pdf

[2] Amri, N.S & Taslim, A. (2016). Adaptation Strategy of Seaweed Cultivation to Face the Climate Change (Case Study in Segoro Anakan Bay Ngadirojo, Pacitan). *Indonesian Journal of Spatial and Regional Analysis*, 30 (1): 34-44.https://journals.ums.ac.id/index.php/fg/article/viewFile/1114/1532

[3] Andi, I. N., Husain, S.,&Patang . (2016). Effect of Water Quality on the Production of Seaweed (Kappaphycus alvarezii). *Journal of Agricultural Technology Education*, 2:27-40.https://docplayer.info/80341995-Pengaruh-kualitas-air-terhadap-produksi-rumput-laut-kappaphycus-alvarezii-abstract.html

[4] Akib, A,. Litaay ,M., Ambeng., &Asnady, M. (2015). Water Quality Fitness for Cultivation of Eucheuma cottoni based on Physics, Chemistry and Biology aspects in District Islands Selayar. *Journal of the Coastal and Tropical Seas*, 1(1):25-36.https://media.neliti.com/media/publications/125751-ID-kelayakan-kualitas-air-untuk-kawasan-bud.pdf

[5] Aris, M., Fatma, M., & Rusmawati ,L., (2021). Study of Seaweed Kappaphycus alvarezii Explants Growth in the Different Salinity Concentrations. *Scientific Journal of Fisheries and Marine, 13* (1): 97-105. https://e-journal.unair.ac.id/JIPK/article/view/19842/13797. DOI=10.20473/jipk.v13i1.19842 Sinta 2 (Decree No: 10/E/KPT/2018)

[6] Aslan, L., Patadjai, R.S., Ruslaini., Effendy, I.J. (2019). Seasonal variation in growth and carrageenan yield of Kappaphycus alvarezii (Doty) Doty farmed using mass selection in Bungin Permai Coastal Waters, South Konawe District, Southeast (SE) Sulawesi, Indonesia. *The 2nd International Symposium on Marine Science and Fisheries (ISMF2)*: 1-9. https://www.researchgate.net/publication/337717402http://dx.doi.org/10.1088/1755-1315/370/1/012060

[7] Bindu,M. S. & Levine.I.A.(2011) . The commercial red seaweed *Kappaphycus alvarezii* — an overview on farmingand environment. *J Appl Phycol*, 23:789–796. https://www.academia.edu/518570/ DOI 10.1007/s10811-010-9570-2

[8] Blanchard, J.L., Jennings, S., Holmes, R., Harle, J., Merino, G., Allen, J.I; Holt J; Dulvy ,N.K., Barange, M.(2012). Potential consequences of climate change for primary production and fish production in large marine ecosystems. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 367, 2979–2989.https://www.researchgate.net/publication/267283856 doi: 10.1098/rstb.2012.0231

[9] Charan, H., Antoine D.R. N., Yeurt., Viliamu, I., Thierry, C. (2017). The effect of temperature on the growth of two pest seaweeds in Fiji. *2nd International Conference on Energy, Environment and Climate – ICEECC*, 336-341.*https://repository.usp.ac.fj/10314/1/Charan_et_al_2017_ICEECC.pdf*

[10] Chen, B., Zou, D., Zhu ,M., Yang, Y. (2017). *Effects of CO_2*levels and light intensities on growth and amino acid contents in red seaweed Gracilaria lemaneiformis. *Aquaculture Research*, 48(6):2683–2690. https://doi.org/10.1111/are.13100

[11] Choi, T.S., Kang, E.J., Kim, J.H., Kim, K.Y. (2010). Effect of salinity on growth and nutrient uptake of Ulva pertusa (Chlorophyta) from an eelgrass bed. *Algae*,25(1): 17 26. **doi:** https://doi.org/10.4490/algae.2010.25.1.017

[12] Daud, R. (2013). Effect of Planting Period on Seaweed Quality, *Kappaphycus alvarezii*. *Aquaculture Media*, 8(2): 135-138. http://ejournal balitbang.kkp.go.id/index.php/ma/article/view/396/398

[13] Faisal, L.O., Rahmad, S.P, Yusnaini. (2013). Growing of Seaweed (Kappaphycus alvarezii) and Rabbit Fish (Siganus gutatus) Policulturedin Fixed Cage. *Jurnal Mina Laut Indonesia*, 1 (1) :104– 111. https://adoc.pub/pertumbuhan-rumput-laut-kappaphycus-alvarezii-dan-ikan-baron.html

[14] Fikri ,M., Rejeki, S,. Widowati, L.L. (2015). Production and Quality of Seaweed (Euchema cottonii) at different depth in Coastal Bulu Jepara District. *Journal of Aquaculture Management and Technology*, 4 (2) : 67-74.https://ejournal3.undip.ac.id/index.php/jamt/article/view/8544

[15] Goodwin, C. E., Strain, E. M., Edwards, H., Bennett, S. C., Breen, J. P. & Picton, B. E. (2013). Effects of two decades of rising sea surface temperatures on sublittoral macrobenthos communities in Northern Ireland, UK. *Marine Environment Research*, 85, 34-44. https://pubmed.ncbi.nlm.nih.gov/23321298/
DOI: 10.1016/j.marenvres.2012.12.008

[16] Gonzalez, A., Castro,J., Vera, J., & Moenne, A. (2013). Seaweed Oligosaccharides_Stimulate Plant Growth by Enhancing Carbon and Nitrogen Assimilation Basal Metabolism and Cell Division. *Journal of Plant Growth Regultion*, 32(2) : 443-448.https://www.researchgate.net/publication/257402960. DOI:10.1007/s00344-012-9309-1

[17] Raikar, S .V., Lima, M &Fujita, Y. (2001) . Effect of temperature, sannity and light intensity on the growth of Grocilorio spp. (Gracilariales, Rhodophyta) from Japan, Malaysia and India. *Indian Journal of Marine Sciences*, 30: 98-104.https://www.researchgate.net/publication/285783434

[18] Moore, J.P & Smale ,A.D. (2020). Impacts of climate change on shallow and shelf subtidal habitats, relevant to the coastal and marine environment around the UK. *MCCIP Science Review*, 272–292. http://archive.mccip.org.uk/media/2016/13_shallow_shelf_habitats_2020.pdf
doi: 10.14465/2020.arc13.ssh

[19] Hardan, Warsidah & Syarif I. N. (2020). Seaweed Growth Rate *Kappaphycus alvarezi*i with Different Planting Method in the Waters of Natuna Sea Village Sepempang.*Journal of the Equatorial Sea*, 3 (1): 14-22. https://jurnal.untan.ac.id/index.php/lk/article/view/35101/pdf_1

[20] Harley, C. D. G., Anderson, K. M., Demes, K. W., Jorve, J. P., Kordas, R. L., Coyle, T. A. and Graham, M. H., 2012. Effects of Climate Change on Global Seaweed Communities. *Journal of Phycology*, 48(5):1064-1078.https://www.zoology.ubc.ca/~kordas/Rebecca_Kordas/Publications_files/Harley%202012%20Journal%20of%20Phycology.pdf. DOI: 10.1111/j.1529-8817.2012.01224.x

[21] Hasanuzzaman, M., Nahar, K., & Fujita ,M.(2013). Extreme Temperature

Responses, Oxidative Stress and Antioxidant Defense in Plants. *Chapter Books Published*: March 13th 2013. https://www.intechopen.com/chapters/43317. DOI: 10.5772/54833.

[22] Hayashi, L., Santos, A.A., Faria, G.S.M., Nunes, B.G., Souza, M.S., Fonseca, A.L.D., Barreto, P.L.M., Oliveira, E.C., Bouzon, Z.L. (2011). *Kappaphycus alvarezii* (Rhodophyta, Areschougiaceae) cultivated in subtropical waters in Southern Brazil. *Journal of Applied Phycology*, *23*:337-343.https://biogeoqmar.paginas.ufsc.br/files/2017/07/Hayshi-et-al-2011.pdf DOI 10.1007/s10811-010-9543-5

[23] Hurtado, A.Q., Gerung, G. S., Suhaimi, Y., Alan, T., Critchley. (2013). Cultivation of tropical red seaweeds in the BIMP-EAGA region Anicia.*Journal Appl Phycol*, 26:707–718 https://www.researchgate.net/publication/271633228_Cultivation_of_tropical_red_seaweeds_in_the_BIMP-EAGA_region. DOI:10.1007/s10811-013-0116-2

[24] Hung, Le. Dinh., Hori, Kanji, Nang, H. Q, Kha, T., Hoa,Le. Thi. (2009). Seasonal changes in growth rate, carrageenan yield and lectin content in the red alga Kappaphycus alvarezii cultivated in Camranh Bay, Vietnam. *Journal of Applied Phycology, 21 (3) : 265–272. https://www.researchgate.net/publication/227064380.*DOI:10.1007/s10811-008-9360-2

[25] Irfan, M. (2017). Sustainable cultivation of Seaweed Kappahycus alvarezi in Talimau waters, Kayoa Subdistrich, South Halmahera Regency, North Mollucas Province, Indonesia Nigerian. *Journal of Fisheries and Aquaculture*, 5 : 26-35. https://ejournal.unsrat.ac.id/index.php/platax/article/view/33048/33266

[26] Irfan, M., Abdullah, N., Yuliana., Samadan, M.G. & Subur, R.(2020). Sustainability Status of Seaweed Kappaphycus alvarezii Cultivation in Posi-Posi Waters, South Kayoa Subdistrict, Regency of South Halmahera, Province of North Mollucas, Indonesia. International Journal of Advanced Science and Technology, 29 (8): 806-817. http://sersc.org/journals/index.php/IJAST/article/view/19226/9751

[27] Joppy, D. M., & Ngangi, E.L.A. (2014). Culture pattern of seaweed Kappaphycus Alvarezii at Nain Island Regency of North Minahasa. *Aquaculture Journal,* 2 (2): 27-37. https://ejournal.unsrat.ac.id/index.php/bdp/article/viewFile/4913/4435

[28] Joppy, D. M., Kolopita, M. E. F.,&Rahman, A. (2015).Waters Environment Condition in Culture Area of Seaweed Kappaphycus alvarezii at Jayakarsa Village North Minahasa). *Aquaculture Journal.* 2 (1):172-186.https://ejournal.unsrat.ac.id/index.php/bdp/article/view/6953/6458

[29] Kokubu, S., Nishihara, G. N., Watanabe, Y., Tsuchiya, Y., Amamo, Y. and Terada, R. (2015). The effect of irradiance and temperature on the photosynthesis of a native alga Sargassum fusiforme (Fucales) from KagoshimaJapan. *Phycologia,* 54(3): 235-247. https://www.tandfonline.com/doi/abs/10.2216/15-007.1

[30] Kumar, S.K., Ganesan, K., Rao, S.P.V., Thakur, C.M. (2015). Seasonal studies on field cultivation of *Kappaphycus alvarezii* (Doty) Doty on the northwest coast of India. *J Appl Phycol* . DOI 10.1007/s10811-015-0629-y. https://www.researchgate.net/publication/276270278

[31] Kumar,N.Y.,Sze-W.P., Claire,G., Juliet,B., Ahemad, S., Lim, Phaik-Eem. (2020). Results show growth, photosynthesis, phycocolloid quality, pigment content affected. https://www.globalseafood.org/advocate/physiological-biochemical-responses-of-red-alga-to-high-temperature/

[32] Kumar N.Y, Sze-Wan Poong., Claire, G., Juliet, B., Ahemad, S., Lim, Phaik-Eem. (2020). Impact of elevated temperature on the physiological and biochemical responses of *Kappaphycus alvarezii* (Rhodophyta). PLOS ONE, 1-16.

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0239097. https://doi.org/10.1371/journal.pone.0239097

[33] Labenua, R., &Aris ,M. (2021). Suitability Of Kappaphycus alvarezi Cultivation In Obi Island, North Maluku. Jurnal Ilmiah Platax Vol. 9:(2): 217-223. Indonesia https://ejournal.unsrat.ac.id/index.php/platax/article/view/33048

[34] Ministry of Marine Affairs and Fisheries., (2020). Focus on Building Sustainable and Competitive Cultivation. KKP News,Cooperation and Public Relations.https://news.kkp.go.id/

[35] Mujiyanto., Syam, A. R., Wijaya, D., Purnamaningtyas, S.E., (2012). Suitability water quality parameters for seaweed culture at Muara Gembong coastal area, Bekasi District. Ecological intensification: A new paragon for sustainable aquaculture IOP Conf. *Series: Earth and Environmental Science*, 1-13, IOP Publishingdoi:10.1088/1755-1315/521/1/ . https://iopscience.iop.org/article/10.1088/1755-1315/521/1/012012/pdf

[36] Neksidin., Utama, K., Pengerang & Emiyarti. (2013). Water Quality Assesment for Seaweed Culture (Kappaphycus alvarezii) in Kolono Bay South Konawe. *Journal of Mina Laut Indonesia*,03:147-155. https://docplayer.info/37750201

[37] Nur, M.F., Batubara, S.A., Eriani, K ., Tang, M.U., Muhahhadar, A.A., Azizah, N.M., Wilkes, M., Fadli, N.,Rizal, S., Muchlisin, A.Z. (2020). Effect of water temperature on the physiological responses in Betta rubra, Perugia 1893 (Pisces: Osphronemidae). *Int Aquat Res*, 12:209–218 https://doi.org/10.22034/IAR.2020.1900150.1053

[38] Oedjoe, M.D.R., Rebhung, F., Sunadji. (2019). Seaweed (*Kappaphycus alvarezii*) as potential commodity in added value development for the prosperity of Sumba Timur Regency communities, East Nusa Tenggara Province. *Scientific Journal of Fisheries and Marine,* 11(1):62-69.https://e-journal.unair.ac.id/JIPK/index. http://dx.doi.org/10.20473/jipk.v11i1.10992

[39] Oedjoe, M.D.R., Linggi, Y., Tobuku, R. (2020) Effect of the Dry Season on Growth, Production of Seaweed *Kappaphycus alvarezii* in Tesabela Waters, Kupang Regency, East Nusa Tenggara, Indonesia.International *Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, 10 (3): 3167-3172. https://issuu.com/tjprc/docs/2-67-1594793003-300ijmperdjun2020300

[40] Pamungkas,W.(2012). Osmoreguration Activity, Growth Response, and Energetic Cost in Fish reared in a saline environment. http://dx.doi.org/10.15578/ma.7.1.2012.44-51

[41] Prakash, P,. Dhanalakshmi, P,K., Anusha, B.(2011). Effect of Humic Acid on Spirulina plantensis Production and Analysis of Nutrient Contents.*Recent Research in Science and Technology*, 3: 87-89.https://www.researchgate.net/publication/232093034

[42] Pong-Masak, R. P., & Sarira,H.N. (2018). Seaweed Selection to Supply Superior Seeds for Cultivation. *Jurnal Perikanan Universitas Gadjah Mada,* 20 (2): 79-85. https://jurnal.ugm.ac.id/jfs/article/view/36109/23626. DOI: 10.22146/jfs.36109

[43] Radiarta,I.N., Erlania,. & Rusman.(2013). Impact of climate on seaweed, Kappaphycus alvarezii planting periods in Gerupuk Bay, Central Lombok Regency, West Nusa Tenggara. *Journal of Research aquaculture*, *8* (3): 453-464.https://www.researchgate.net/publication/276207177. DOI: http://dx.doi.org/10.15578/jra.8.3.2013.453-464

[44] Ramdhan, M., Taslim, A., &Arlyza, S. I. (2018.)Effect of Location and Conditions of Physic-Chemical Oceanography Parameters on the Production of Seaweed in Takalar District Coastal Waters , Sulawesi Selatan. *National Marine Journal*, 13 (3): 163-171.https://docplayer.info/123623807

http://dx.doi.org/10.15578/jkn.v13i3.6288

[45] Rao, P.V.S., Kumar, K.S., Ganesan, K., and Thakur, M.C.(2008). Fesibility of cultivation of *Kappaphycus alvarezii* (Doty) Doty at different localities on the Northwest coast of India. *Aquaculture Research,* 39: 1107-1114.https://www.academia.edu/13530913/. DOI: 10.1111/j.1529-8817.2012.01224.x

[46] Serdiarti, N., & Widiastuti, I. M.(2010). Growth and Production of Eucheuma Cottonii Seaweed at Different Planting Depths. *Central Sulawesi Research and Development Media,* III(1) : 21 – 26. https://www.scribd.com/doc/214179962/

[47] Sarojini,Y.,&Sujata, B. (2015). The seasonal variations in distribution of photosynthetic pigments in two species of Phaeophyceae and the effect of light, dissolved oxygen and nutrients on their distribution. *Der Pharmacia Lettre*, 7 (5):140-145.https://www.scholarsresearchlibrary.com/articles/. httpts://www.scholarsresearchlibrary.com

[48] Sofri, B., Ma'ruf ,K., &Afu, La Ode. A. (2018). Relationship of Oceanographic Factors on Seaweed Growth with Floating Net Raft Method in Lakorua Waters, Mawasangka Tengah District, Central Buton Regency. *Sapa Laut*, 3(1): 25-36. http://ojs.uho.ac.id/index.php/JSL/article/view/6506
DOI: http://dx.doi.org/10.33772/jsl.v3i1.6506

[49] Sunadji., Tjahjono, A; & Riniwati, H.(2014). Development Strategy of Seaweed Aquaculture Business in Kupang Regency, East Nusa Tenggara Province, Indonesia. *Journal of Aquacultural Studies*, Vol. 2, No.1 27-39.doi:10.5296/jas.v2i1.4631 URL: http://dx.doi.org/10.5296/jas.v2i1.4631

[50] Tongco, M.D.C. (2007). Purposive sampling as a tool for informant selection. *Ethnobotany Research & Applications,* 5:147-158. www.ethnobotanyjournal.org/vol5/i1547-3465-05-147.pdf

[51] Xiong, L.,& Zhu, J.K.(2002) . Salt Tolerance. *The Arabidopsis Book 1-24*http://faculty.ucr.edu/~jkzhu/articles/2002/zhu.pdf

[52] Zainuddin, F.M., &Rusdani, M. (2018). Performance of Kappaphycus alvarezii Seaweed from Maumere and Tembalang in Longline System Cultivation . *Journal of Aquaculture Science, 3 (3): 116 – 127. https://media.neliti.com/media/publications/276573*

[53] Zavalas, R., Ierodiaconou, D., Ryang, D., Rattray, A., & Monk, J.(2014). Habitat Classification of Temperate Marine Macroalgal Communities Using Bathymetric LiDAR. *Remote Sensing*, 6: 2154-2175. https://www.academia.edu/20877172.doi: 10.3390/rs6032154

Figure 1

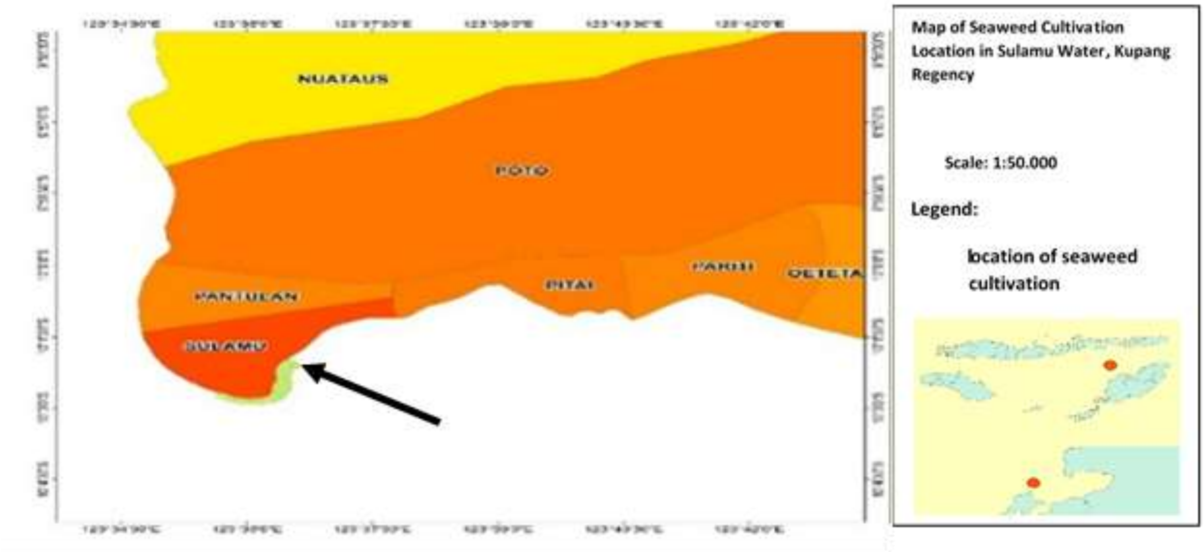

Figure 1: Study site

Table 1:

Relationship between Water Temperature and Production of *Kappapyhcus alvarezii* Seaweed at Sulamu waters.

Temperature	Production (g)
27	81.7
28	73.07
29	64
30	60.8
32	30.47
33	18.57

Table 2. :

Relationship between Water Temperature and Absolute growth (g) and Spesific growth rate (%) of *Kappapyhcus alvarezii* Seaweed at Sulamu waters.

Temperature	Absolute growth (g)	Spesific growth rate (%)
27	307.150	6.25
28	292.570	5.19
29	254.840	4.6
30	103.320	3.6
32	98.410	2.08

33	68.070	1.9

Table 2. Demonstrated positive growth rates at temperatures of 27–30°C on March to June(Fig 5a). Nevertheless, the specific growth rates showed a decreasing at temperature 32 ^{0}C -33^{0}CinJuly to December (Fig.5b)

Table 3. Observation results of water quality parameters

Parameters	Range Value parameters	
	March - June	July - October
Salinity (mg/L)	30-32	33 -35
Dissolved oxygen (mg/L)	5-7	4-5
pH	7,6 – 7,8	5-6
Brightness (m)	3-10	2-3

Figure 2a

Figure 2a. Condition of K.alvarezii at temperature 27 ^{0}C to 30 ^{0}C, salinity 30 to 31 ppt at Sulamu Waters on March to June 2020.

Figure 2b

(a) 31 ^{0}C at July (b) 32 ^{0}C at August (c) 33 ^{0}C at September at October

Figure 2b. (a)Condition of*K. alvarezii* at Temperature 31 ^{0}C and salinity 33ppt; (b) 32 ^{0}C and 34ppt; (c) 33 ^{0}C and 35ppt; on Juli to October 2020. Thalli became fragile and fragmente