Suitability Analysis of Pond Ecosystems on the East Coast of Sidoarjo for Seaweed Cultivation on Productivity, Quality and Carrageenan Content of *Gracilaria* sp.

T Purnomo*, F Rachmadiarti, D Rohmatin, J Rahayu
Biology Department, Universitas Negeri Surabaya
Surabaya, Indonesia
*tarzanpurnomo@unesa.ac.id

**Abstract.** *Gracilaria* sp. is seaweed that produces agar and carrageenan, which is needed by the food, pharmaceutical, textile, and cosmetics industries. The high demand encourages cultivation. This study aims to determine the suitability of the pond ecosystem on the east coast of Sidoarjo for the cultivation of *Gracilaria* sp. The research was conducted in a pond in Kupang Village, Jabon District, Sidoarjo using *in-situ* observational methods. Water samples were taken from the Aloo river and ponds, samples from *Gracilaria* sp. taken purposively at 3 stations, namely station 1 Dusun Tegal sari, station 2 Dusun Kali Aloo, and station 3 Dusun Tanjungsari. The parameters measured include land suitability (temperature, pH, salinity, water Cd concentration), and *Gracilaria* sp. Productivity (carrageenan content). Analysis of Cd concentrations using the Atomic Absorption Spectrophotometer method. Analysis of carrageenan content using the Kjeldahl method. Data of Cd concentration analyzed descriptively qualitatively and compared with SNI 7387: 2009 and Kepmen LH No. 51/2004. The results showed that the pond ecosystem on the east coast of Sidoarjo was suitable for the cultivation of *Gracilaria* sp., *Gracilaria* sp. yields met the quality standards where the Cd concentration was below the quality standard threshold, the carrageenan content was moderate.

**Key words:** pond, east coast of Sidoarjo, Cd content, carrageenan content, *Gracilaria* sp.

1. Introduction

Seaweed is a commodity with high economic value, its consumption level continues to increase from year to year. Seaweed has many benefits so that it is one of the non-oil and gas export commodities that has an important role for the Indonesian economy [1]. The primary metabolites of seaweed are polysaccharide compounds which are hydrocolloid such as agar, alginate, carrageenan and fulcelaran [2]. The diversification of its use in the fields of food, health, cosmetics, and textiles has made the need for seaweed continues to increase. Seaweed products are needed by various industries because they contain keragenan, agar (agarophyte) and alginate which are widely used as raw materials for the food industry, flavor softeners, ice cream crystallizers and drugs [3]. Seaweed is the main ingredient for gelatin which contains various nutritional elements which function to reduce cholesterol and blood sugar levels, prevent heart disease, hypertension and diabetes mellitus [4]. In addition, seaweed is also widely used in the fields of microbiology and biotechnology. To meet this need, harvest from nature has been obtained, whose productivity and availability are difficult to control. For this reason, seaweed cultivation is a rational solution.

In Indonesian marine waters, the most common seaweed species are Gracilaria, Gelidium, Eucheuma, Hypnea, Sargasum and Turbinaria [3]. Seaweed species that have important economic values generally come from the genera Gelidium, Hypnea, Eucheuma, and Gracilaria. Gracilaria and Eucheuma are very potential to be developed as cultivation business because the two genera can develop well vegetatively [1]. Seaweed is a macroalgae that has a body structure consisting of a tallus, without roots and leaves. Gracilaria sp. belongs to the red algae group, has general characteristics: flattened or cylindrical talus shape, smooth surface, or nodules, and green or yellowish green color. Irregular branching type forms clumps, the base of the talus branching narrows. Gracilaria sp. Has high tolerance to changes in environmental conditions, and is able to live and can grow in marine and brackish waters, so it is very potential to be cultivated in ponds [1]. Classification of gracilaria sp.
namely: Rhodophyta division, Rhodophyceae class, Gigartinales order, Glacilariaceae family, Glacilaria genus, and Gracilaria sp. [2].

The seaweed cultivated in the aquaculture area on the east coast of Sidoarjo is *Gracilaria* sp. Its ability to adapt to pond waters and ease of maintenance makes *Gracilaria* sp. chosen by the farmers for cultivation. On the other hand, economic value and clear market share are the next considerations. *Gracilaria* sp. it is very easy to grow despite the environmental conditions of the pond waters which are brackish waters and different from marine waters. The condition of the marine ecosystem as the original habitat of *Gracilaria* sp. And the conditions of the ponds are very different, in marine waters the water quality is sufficiently supportive to meet their daily needs, while the pond waters ecosystem has various levels of fertility and fluctuating water quality. *Gracilaria* sp. can adapt to environmental conditions that are not in accordance with the conditions of their natural habitat because they can tolerate salinity in the range of 15 to 50 %o [5].

One of the substances produced by *Gracilaria* sp. is carrageenan. Carrageenan is seaweed sap extracted with water or an alkaline solution from certain species of the Rhodophyceae class (red algae). Carrageenan functions as a thickener, emulsifier, suspension, and stabilizer. Carrageenan is also used in the food industry to improve the appearance of coffee products, beer, sausages, salads, ice cream, condensed milk, chocolate, jelly. In the pharmaceutical industry carrageenan is used for the manufacture of drugs, syrups, tablets, toothpaste, shampoo and so on. The cosmetics industry uses it as a gelling agent or binding agent. Non-food industries such as textiles, paper, watercolor, crude oil transportation, air fresheners, ceramic coatings, printer paper or printing machines and carpets and so on [6].

Internationally, carrageenan quality specifications have been stipulated as the minimum requirements needed for the processing industry including the quality and quantity of extracted seaweed. The recognized carrageenan quality standards are issued by the Food Agriculture Organization (FAO), the Food Chemicals Codex (FCC) and the commercial carrageenan quality standards [7].

The quality of seaweed affects the levels of agar produced [8]. Agarophytes are agar-producing seaweed species including *Gracilaria* sp., *Gelidium* sp., and *Gelidiella* sp. The potential and widely developed agarophyte species is *Gracilaria* sp. Agar is a polysaccharide complex that can form jelly. The quality of agar can be improved by a refining process, namely by removing the sulfate content, the product is known as agarose.

*Gracilaria* sp. is one of the agar-producing seaweed species which are widely found in Indonesian sea. Agar contains hydrocolloid compounds that are gelatin which is commonly used as a thickening agent in the food industry [9]. *Gracilaria verrucosa* is generally cultivated in ponds. This type has a purplish red talus. *Gracilaria verrucosa* and *Gracilaria gigas* are widely cultivated in the waters of South Sulawesi, West Lombok, the North coast of Java, and others. *Gracilaria verrucosa* is a agar producer with agar levels reaching 47.34% [10].

Seaweed is a marine biota that has certain characteristics and needs as a condition of life, especially related to the fulfillment of nutrient needs and the carrying capacity of its physiological functions including water quality (temperature, pH, salinity, and water nutrient content. According to [11] geographic factors, seasonal changes, nutrient availability and environmental conditions can affect the growth and production of agar produced by *Gracilaria* sp.

In coastal ecosystems, the characteristics are not too different from other coastal waters including bays, river estuaries and aquaculture areas. Thus these areas are very potential as areas for seaweed cultivation. However, not all aquaculture ecosystems are suitable for seaweed cultivation. For this reason, it is necessary to conduct research, especially related to the suitability of pond waters parameters to the carrying capacity of the survival of seaweed. The goal is to support the viability, growth and productivity of cultivated seaweed.

2. Method

This research is a descriptive study using in situ observation method, the data is taken in the field directly to the research object, namely *Gracilaria* sp. which is cultivated in the ponds of Kupang.
Village, Jabon District, Sidoarjo. This research was conducted in January-March 2019. Water samples were taken from Aloo river water, pond water, each at 3 stations. Sample *Gracilaria* sp. taken in seaweed farming in 3 stations, namely station 1 in Dusun Tegal Sari, station 2 in Dusun Kali Aloo and station 3 in Dusun Tanjung Sari. In each pond 3 stations are taken, 3 sub stations are taken at each station. At each sub station, 1 kg of *Gracilaria* sp. The parameters measured included land suitability (temperature, pH, salinity, water Cd concentration), the quality of *Gracilaria* sp. (Cd and carrageenan content). Analysis of cadmium concentration in river water, pond water, and *Gracilaria* sp. As well as carrageenan levels were carried out at the Surabaya Industrial Research and Standardization Center using the AAS (Atomic Absorption Spectrophotometer) method. Analysis of carrageenan levels in *Gracilaria* sp. by using the Kjeldahl method [12]. The concentration of Cadmium in water and *Gracilaria* sp. analyzed descriptively qualitatively and compared with [13] [14] concerning the maximum limit of heavy metal contamination in food.

3. Result and Discussion

3.1 Concentration of Cadmium (Cd) in River Water and Ponds in Kupang Village, Jabon, Sidoarjo

The water quality on the east coast of Sidoarjo is suitable for the cultivation of *Gracilaria* sp. Based on [14] the threshold value for cadmium (Cd) contamination in seawater is 0.01 ppm. The results showed the concentration of Cadmium in river water and aquaculture pond water of *Gracilaria* sp. in Kupang Village, Jabon, Sidoarjo it is still below the quality standard threshold. Cadmium levels in river water to the three stations are 0.003 and pond water is 0.002 ppm. Results of analysis of cadmium concentrations in river water and pond water for *Gracilaria* sp. in Table 1.

| Location     | Stations | Substations | Cd Concentration (ppm) | Average (ppm) | Quality Standard* |
|--------------|----------|-------------|------------------------|---------------|------------------|
| Aloo river   | 1        | 1           | 0.003                  | 0.004         | 0.01             |
|              | 2        | 1           | 0.004                  |               |                  |
|              | 3        | 1           | 0.004                  |               |                  |
|              | 2        | 1           | 0.004                  |               |                  |
|              | 2        | 2           | 0.003                  | 0.003         |                  |
|              | 3        | 1           | 0.003                  |               |                  |
|              | 3        | 2           | 0.002                  | 0.002         |                  |
|              | 3        | 3           | 0.002                  |               |                  |
| Ponds       | 1        | 1           | 0.003                  | 0.002         |                  |
|              | 2        | 1           | 0.002                  | 0.002         |                  |
|              | 3        | 1           | 0.001                  |               |                  |
|              | 2        | 2           | 0.002                  | 0.002         |                  |
|              | 3        | 1           | 0.002                  | 0.002         |                  |
|              | 2        | 2           | 0.002                  |               |                  |
|              | 3        | 3           | 0.002                  |               |                  |

Cadmium dissolves in water, so that the concentration in the environment can be reduced quite high [15]. The presence of Cd in river water (0.003 ppm) and pond water (0.002 ppm). This was possible because the flow of water from the Aloo River came from the Lapindo mud discharge channel which contained heavy metals. The concentration of Cd in the water sample is below the quality standard threshold [14], this can be caused by several factors, such as oxidation, bioconcentration and mobility of the heavy metal in the water. Cd metal in waters comes from various activities such as the battery
and plastic industry, phosphate fertilizer residues, and fungicides [16]. Environmental conditions also greatly affect the presence of heavy metal Cd in the waters. Based on the research results, it can be seen that the pH of pond water in Kupang village is relatively high, 8.1-8.7. Cadmium in waters that have a low pH will dissolve in water so that the levels are higher, whereas if the pH of the water is relatively high, cadmium will settle on the bottom of the waters and will accumulate in the body of Gracilaria sp. [17].

3.2. Cadmium (Cd) concentrations in Gracilaria sp.

Gracilaria sp. which is cultivated in the ponds of the village of Kupang, Jabon, Sidoarjo, the quality meets the quality standards for industrial raw material products. In accordance with [13] the maximum limit of heavy metal contamination in food, seaweed has a maximum limit of 0.2 ppm. The results showed the concentration of Cadmium in Gracilaria sp. The results of cultivation in the ponds of Kupang Village, Jabon, Sidoarjo are still below the maximum quality standard. The highest average cadmium concentration was 0.078 ppm at station 2 in Dusun Kali Aloo, while the lowest was 0.056 ppm at station 3 in Dusun Tegalsari as in Table 2.

| Station   | Substation | Cd Concentration (ppm) | Average (ppm) | Quality Standard* |
|-----------|------------|------------------------|---------------|-------------------|
| 1 Tegalsari | 1          | 0.080                  |               |                   |
|           | 2          | 0.078                  | 0.056         |                   |
|           | 3          | 0.009                  |               |                   |
| 2 Kali Aloo | 1          | 0.077                  |               |                   |
|           | 2          | 0.082                  | 0.078         | 0.20              |
|           | 3          | 0.074                  |               |                   |
| 3 Tanjungsari | 1          | 0.068                  |               |                   |
|           | 2          | 0.052                  | 0.060         |                   |
|           | 3          | 0.060                  |               |                   |

Gracilaria sp. the results of cultivation in a pond in Kupang Village, Jabon Sidoarjo contain cadmium but it is still within the safe threshold of below 0.2 ppm [13] [14]. Station 2 has the highest concentration of Cd, followed by stations 3 and 1 which have the lowest concentration of Cd. This is because the ponds in Dusun Kali Aloo receive the Aloo river, which is one of the rivers used for disposal of the Lapindo mudflow which contains various heavy metals [18]. The other two stations are relatively far from the Kali Allo stream. This can happen because the higher the metal enters the waters, the higher the heavy metal concentration [19]. Although the concentration of Cd is still below the maximum threshold based on [13], which is 0.2 ppm, the presence of Cd will continue to be accumulated by Gracilaria sp. can inhibit growth and result in damage to the Gracilaria sp. [4], because seaweed is able to accumulate heavy metals in waters [20]. This is due to the nature of heavy metals which are difficult to decompose resulting in easy accumulation in the body of an organism [21].

3.3. Carrageenan content of Gracilaria sp.

Based on the results of the carrageenan content analysis, it can be seen that the average carrageenan content in Gracilaria sp. which is cultivated in the ponds of Kupang Village, Jabon Sidoarjo at 2.33% of the wet weight. These levels are still low. According to [22] green and red seaweed has protein content of 6-20% of wet weight. Analysis of the results of measuring the carrageenan content of Gracilaria sp. can be seen in Table 3.
Table 3. Carrageenan content of Gracilaria sp. Cultivated in the ponds of Kupang Village, Jabon Sidoarjo

| Station       | Carrageenan (%) | Average (%) |
|---------------|-----------------|-------------|
| 1 Tegalsari   | 2.43            |             |
| 2 Kali Aloo   | 2.12            | 2.33        |
| 3 Tanjungsari | 2.44            |             |

The chemical properties of carrageenan in Gracilaria sp. are moisture content, ash content, fat, protein and carbohydrates [23] (da Costa, et al., 2018). In this study, one of the data obtained from the characteristics of carrageenan seaweed Gracilaria sp. namely protein content. Carrageenan levels at each station are different, this can be due to different harvest times, nutrients received at each station and seasonal factors. Based on Table 3, it is known that the highest protein content was at station 3 at 2.44%, while the lowest was at station 2 at 2.12%. According to the commercial carrageenan standard, the maximum protein content quality requirement is 2.80%, the carrageenan produced by Gracilaria sp. Which is cultivated in the Kupang village ponds has met the quality standard requirements for protein content as industrial raw materials.

3.4. Parameters of Pond Water Quality in Kupang Village, Jabon Sidoarjo

The measurement results of pond water quality parameters show that the pond waters in the east coast of Sidoarjo have a good carrying capacity for the life of Gracilaria sp. The mean value of each parameter is still within the range of quality standards [14]. This can be seen in Table 4. Water temperature ranges from 32.2-34°C, the highest water temperature at station 2 is 34°C in Dusun Kali Aloo, while the lowest is at station 1 which is 33.2°C in Dusun Tegal Sari. The highest degree of acidity (pH) was at station 2 in Dusun Kali Aloo of 8.7, while the lowest was at station 3 in Dusun Tanjung Sari, which was 8.1. The highest salinity was at station 2 in Dusun Kali Aloo, which was 13.8‰, while the lowest was at station 2 in Dusun Tegalsari which was 10.2‰.

Table 4. Water Quality Parameters for Aquaculture Gracilaria sp. in the village of Kupang, Jabon, Sidoarjo

| Parameter      | Station | Quality Standard* | 1 | 2 | 3 |
|----------------|---------|-------------------|---|---|---|
| Temperature (°C)|         |                   | 32.2 | 34.0 | 33.0 | 28-30 |
| pH             |         |                   | 8.2  | 8.7  | 8.1  | 7-8.5 |
| Salinity (‰)   |         |                   | 10.2 | 13.8 | 12.2 | 33-34 |

Gracilaria sp. live and grow in waters with a temperature of 28-30°C, but can still grow at 31°C [14]. The high water temperature in the ponds of Kupang village, Jabon Sidoarjo is due to the time the measurements are taken during the day. Although the water salinity ranges from 10.2-13.8 ‰, Gracilaria is able to grow well. This is different from the explanation of [24] which states that the optimal salinity for seaweed growth is between 31-35‰. This is because the pond is a brackish water ecosystem, due to the entry of fresh water from the river which can cause its salinity to be lower than sea water.

4. Conclusion

Based on the results of the research that has been done, it can be concluded: 1. The pond ecosystem in Kupang village, Jabon Sidoarjo has good carrying capacity for the cultivation of Gracilaria sp.
because the water quality parameters according to the quality standard and the concentration of cadmium in the water is 0.002 ppm, still below the quality standard threshold. 2. Cadmium concentration in *Gracilaria* sp. which is cultivated in the village of Kupang, Jabon Sidoarjo at 0.065 ppm, still below the maximum threshold based on SNI 7387: 2009 which is 0.2 ppm. 3. Carrageenan content of *Gracilaria* sp. cultivated in the ponds of Kupang village, Jabon Sidoarjo, amounting to 2.33% of the wet weight, relatively low compared to those living in the ocean.

5. References

[1] Anton. 2017. Growth and Content of Seaweed (*Gracilaria* sp.) Agar at Several Salinity Levels. Airah's Journal. Vol. 6, No. 2: p. 54-64.

[2] Anggadiredja, J. T. 2006. *Seaweed*. Jakarta: Self-Help Publishers.

[3] Sahat, J. 2013. Newsletter of Indonesian Seaweed Exports. DG PEN / MJL / 004/9/2013http://djpen.kemendag.go.id/app_frontend/admin/docs/publication6201390367517.pdf. Retrieved October 28, 2018.

[4] Teheni, M. T., Nafle, N. L., Dali, S. 2016. Analysis of Heavy Metal Cd in *Eucheuma cottonii algae* in Bantaeng Regency Waters. Ind. J. Chem. Res. Vol. 4, No. 1: p. 348-351.

[5] Aslan, L. M. 1998. Cultivation of Seaweed. Canisius. Yogyakarta. 97 p.

[6] Ega, L., Cynthia, G., Cristina L., and Firat, M. 2016. Assessment of Carrageenan Quality of Seaweed *Eucheuma cottonii* based on physico-chemical properties at different levels of potassium hydroxide (KOH) concentration. Journal of Food Technology Applications. Vol. 5, No. 2: ha ; 38-44.

[7] Murdinah. 2009. The Influence of Extracting and Jending Materials on Carrageenan Quality from *Eucheuma cottonii* Seaweed. Proceedings of the 5th Annual National Seminar on Fisheries and Marine Research Results 2008 Volume 3. Collaboration between the UGM Department of Fisheries and Marine and the Research Basis for Product Processing and Marine Biotechnology and Fisheries.

[8] Sabili, S. 2016. Potential and Characterization of *Gracilaria verrucosa* (Below Standard) Seaweed as Bioethanol Raw Material (Thesis). Bogor: Bogor Agricultural University.

[9] Murdinah, Sinurat, E. 2011. Improving the Functional Properties of Agar with the Addition of Various Types of Gum. Journal of Postharvest and Marine and Fisheries Biotechnology. Vol. 6, No. 1, page: 91-100.

[10] Nurrahmawan, M. E., and Nurul, J. 2017. Growth Rate of Seaweed (*Gracilaria verrucosa* (Hudson) Papenfuss) explants by in vitro. ITS Journal of Science and Arts. Vol. 6, No. 2, pp: 2337-3520.

[11] Eder C, S., Roberta de P, M., Alexandra, L., Marcelo, M., Paulo A, H., & Zenilda L, B. 2012. Effects of cadmium on growth, photosynthetic pigments, photosynthetic performance, biochemical parameters and structure of chloroplasts in the agarophyte *Gracilaria domingensis* (Rhodophyta, Gracilariaceae). American Journal of Plant Sciences.

[12] Musa, S., Grace, S., Henny A. D. 2017. Chemical Composition, Bioactive Compounds and Total Plate Numbers in *Gracilaria edulis* Seaweed. Journal of Fisheries Product Technology Media. Vol. 5, No. 3: p. 184-189.

[13] Indonesian National Standard SNI 7387: 2009. 2009. Maximum Limit of Heavy Metal Contamination in Food.

[14] Decree of the State Minister for Population and Environment. 2004. Decree of the State Minister for Population and Environment No. Kep-51 / MNKLH / I / 2004 concerning Guidelines for Determining Sea Water Quality Standards. State Minister for Population and Environment. Jakarta.

[15] Achiyani, R., Weliyadi, E., Rismawati. 2013. Analysis and Evaluation of Heavy Metal Contamination in Sediment, Water and Seaweed *Euchema Cottoni* in Tarakan City. Harpodon Borneo Journal. Vol. 6. No.1, page: 1-11.

[16] Campbell, N. A. & J. B. Reece. 2008. *Biology*, Volume Eighth Edition 3. Translation: Damaring Tyas Wulandari. Jakarta: Erlangga.

[17] Teheni, M. T., Syamsidar, HS. 2012. Determination of Levels and Spatial Distribution of Heavy
Metal Cadmium (Cd) in Seaweed *Euchema cottonii* from Waters of Kab. Takalar with Atomic Absorption Spectrophotometer (AAS) Method. Journal of Al-Kimia. Thing. 30-41.

[18] Purnomo, T and F. Rachmadiarti. 2018. The Change of Environment and Aquatic Organism Biodiversity in East Coast of Sidoarjo Due to Lapindo Hot Mud. International Journal of GEOMATE, Aug., 2018 Vol. 15, Issue 48, pp. 181-186 Geotec., Const. Matt. & Env., DOI: https://doi.org/10.21660/2018.48.IJCST60 ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

[20] Sudarshan S., Seedevi P., Ramasamy S.N. 2012. Heavy Metal Accumulation in Seaweed and Seagrasses along Southeast Coast of India. Journal of Chemical and Pharmaceutical Research. Vol. 4, No. 9.

[21] Ika, T. I., & Said, I. 2012. Analysis of Lead (Pb) and Iron (Fe) Metals in Seawater in the Coastal Zone of Taipa Ferry Port, North Palu District. Journal of Chemistry. Vol. 1, No. 4: p. 181-186.

[22] Burtin, P. 2003. Nutritional Value of Seaweed. Journal of Agricultural Food Chemistry. Vol. 2, No. 4: pp. 1-6.

[23] da Costa, J. F., Windu, M., and Ferly, R. O. 2018. Proximate Analysis, Antioxidant Activity, and Pigment Composition of *Ulva lactuca* L. from Kukup Beach Waters. Journal of Food Technology and Nutrition. Vol. 17, No. 1: p. 1-17.

[24] Satheesh, S., Wesley, S. G. 2012. Diversity and Distribution of Seaweeds in The Kudankulam Coastal Waters, South- Eastern Coast of India. Biodiversity Journal. Vol. 3, No. 1, pp: 79-84.

**Acknowledgments**

The author would like to thank the seaweed farmers in Kupang Village, Jabon District, Sidoarjo, East Java.