**Nitrogen, Phosphorus Absorption Rate and Growth of *Gracillaria verrucosa* Based on Integrated Multi-Trophic Aquaculture (IMTA) in Ekas Bay Waters, East Lombok, Indonesia**

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**ABSTRACT**

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| The development of marine aquaculture based on Integrated Multi-Trophic Aquaculture (IMTA) is a method designed to overcome environmental problems associated with feed use in aquaculture activities. This study aims to analyze the growth performance, production and absorption rate of N and P of *Gracillaria verrucosa* seaweed cultivated by floating raft method around floating net cages. This study used an experimental method with 3 repetitions with the location of the floating raft system seaweed cultivation around the floating net cage (FNC) system cultivation activities placed at a distance of 40 meters from the FNC in the north (N), in the south (S), in the east (E), in the west (W) and floating rafts at a distance of 250 meters from the FNC as a control (C). The results showed that seaweed cultivated around FNC had better growth and production performance compared to those cultivated without FNC or controls. The N absorption rate of seaweed cultivated around FNC sites with a range between 0.41 - 0.88 g N/m2/day or 1.51 - 3.20 tons of N/ha/year was higher than in the control location of 0.49 g N/m2/day or 1.78 tons N/ha/year. While the level of P absorption of seaweed cultivated around the FNC location with a range between 0.69 - 1.38 g P/m2/day or 2.51 - 5.05 tons of P/ha/year is higher than in the control site of 0.49 g P/m2/day or 1.78 tons P/ha/year. The application of IMTA-based seaweed cultivation of *Gracilaria verrucosa* clearly provides economic and ecological benefits with an increase in biomass and improved environmental conditions. |

Keywords: seaweed; floating raft; uptake rate; nitrogen; phosphate

1. INTRODUCTION

Lobster and seaweed are industrialized commodities of the Ministry of Marine Affairs and Fisheries (KKP). Lobster production in Indonesia in the last three years has decreased, where in 2021 it reached 512.26 tons, 2022 amounted to 483.74 tons and in 2023 only 437.42 tons (KKP, 2025). Compared to lobster, seaweed production showed a very significant increase of 9.0 million tons in 2021 increasing to 9.2 million tons in 2022 and 9.7 million tons in 2023 (MMAF, 2025). In 2023, this seaweed production contributed around 63% of the total mariculture production in Indonesia, while lobster only contributed around 0.002%. Indonesian seaweed production is dominated by *Kappaphycus alvarezii* with a volume of 7.05 million tons accounting for 82.7% of world production and *Gracillaria* with a volume of 1.91 million tons (32.1% of world production) (KKP, 2023).

Since 2000 in the waters of Ekas Bay, East Lombok Regency, West Nusa Tenggara Province, lobster farming in floating net cages (FNC) has developed (Junaidi & Hamzah, 2015), currently one of the lobster farming development areas or lobster villages (lobster estate) in Indonesia (Budiyanto, 2021). Lobster cultivation in FNC can cause nutrient enrichment around the FNC area. The distribution of nutrients can be utilized by other cultivation commodities, such as seaweed, which can extract dissolved inorganic nutrients and shellfish that can utilize particulate organic matter so that there is a balance between biological and chemical processes in the developing system (Radiarta *et al*., 2014). This cultivation system development pattern is known as integrated multi-trophic aquaculture (IMTA). IMTA is an innovative mariculture system that combines various types of fish or non-fish with different trophic levels in one aquaculture activity system (Junaidi *et al*., 2025).

Within the IMTA framework, the presence of seaweed in addition to increasing economic potential also acts as a natural biofilter to reduce pollution in aquaculture environments containing waste materials (Yulianto *et al*., 2006). Based on research by Nobre *et al*. (2010), the application of IMTA in abalone aquaculture with seaweed can reduce water levels of nitrogen (N) and phosphorus (P) by 44% and 23% compared to monoculture of abalone. In addition to reducing the burden of pollution in the waters, IMTA-based seaweed cultivation can increase growth and production, where based on research by Yuniarsih *et al*. (2014) the growth and production of seaweed, *Kappaphycus alvarezii* and *Eucheuma spinosum* cultivated around FNC in the waters of Gerupuk Bay, West Nusa Tenggara Province increased between 211.07%-414.29% higher than the control location. This condition can be caused by the release of dissolved nutrient materials produced by FNC, especially from fish metabolic waste.

# In order to study the application of IMTA-based mariculture in Indonesia, it is necessary to study the role of seaweed as a component of IMTA, especially the absorption rate of nitrogen (N) and phosphorus (P) as well as the growth and production of Gracilaria verrucosa grass using the floating raft method. This study aims to analyze the production growth performance and absorption rate of N and P of G. *verrucosa* seaweed cultivated with the floating raft method around floating net cages. This study is expected to be the basic data for the development of IMTA-based mariculture in the waters of Ekas Bay, so as to increase the productivity of mariculture while maintaining aquaculture environmental conditions, so that aquaculture activities can be sustainable.

2. mATERIALS DAN METHODS

This research was carried out in November - December 2024 located in the Ekas Bay Area, Ekas Buana Village, Jerowaru District, East Lombok Regency, West Nusa Tenggara Province. Indonesia (Fig. 1). Ekas Bay is one of the lobster aquaculture development areas and is one of the lobster seed producing locations in Indonesia. Lobster farming activities carried out in Ekas Bay using a floating net cage (FNC) system. This study uses an experimental method with 3 repetitions with the location of seaweed cultivation floating raft system around the FNC system cultivation activities placed at a distance of 40 meters from FNC in the north (N), in the south (S), in the east (E), in the west (W) and floating rafts at a distance of 250 meters from FNC as a control (C).



Fig. 1. Research locations and seaweed farming sites in East Lombok Regency, West Nusa Tenggara Province, Indonesia

**Research procedure**

The seaweed cultivation method used in this study is the floating raft method, where the binding of each clump of seaweed seeds on the ris rope or stretch rope. The ris rope containing the seedlings was then tied to a floating raft made of bamboo. Therefore, the research preparation began with the manufacture of 6 units of floating rafts, where one unit of rafts measuring 10 x 10 m required 5 pieces of bamboo with 9-10 cm dimeter, 315 m of ris rope and 4 anchors. The assembled floating rafts were then taken to the sea to be installed around the FNC location, namely at a distance of about 40 m to the north (N), south (S), east (E), west (W) and at a distance of about 250 m from the FNC as a control (C). One raft unit required 30 ris ropes with 30 cm between the ris ropes. The next preparation activity was the procurement of seaweed seeds, which were obtained around the research site by diving. The seedlings needed for 1 raft unit is about 60 kg, so for 5 rafts with seedlings needed about 600 kg or 6 quintals. One floating raft unit included 3 replicates, where 1 replicate consisted of 10 ris ropes or 400 clumping points of seaweed seedlings. The seaweed cultivation process followed the Indonesian National Standard operational procedures (SOP, 2010). Maintenance was conducted for 42 days, during which monitoring was

**Data Collection**

The main parameters measured in this study were absolute growth, specific growth rate, production, absorption rate of nitrogen (N) and phosphorus (P) and water quality including temperature, pH, salinity and oxygen solubility (DO). Data collection for seaweed growth analysis was carried out sampling 3 clumps of each replicate, then weighed using digital scales with 1 g accuracy. Sampling for the analysis of the level of absorption of N and P was done by taking 4 points of seaweed clumps of each treatment on days 0, 21 and 42. Sampling of seaweed tissue was carried out in each treatment as material for the analysis of N and P, then under the Soil Chemistry Laboratory, Faculty of Agriculture, Mataram University. Determination of N levels in seaweed tissue with the Kjeldahl method and P levels with the wet ignition method (Ramadhan *et al*., 2017). Water quality measurements were carried out on days 0, 14, 28 and 42, where temperature measurements using a thermometer, pH with pH-meter, salinity with refractometer and DO with DO-meter. Calculation of absolute weight growth and specific growth rate using a modified formula from Cokrowati *et al*. (2018) and Lutfiati *et al*. (2022). Seaweed production using a modified formula from Serdiati & Widiastuti (2010). While the absorption rate of N and P seaweed analyzed by the amount of nitroglycerin content.fhosforus

**Data Analysis**

Data obtained during the study were analyzed by analysis of variance (anova) at a real level of 5% to determine the effect of the treatment given to the growth and production of seaweed. If the results of the analysis of variance showed a significant effect then continued with Duncan's test. While data on the level of absorption of N and P, as well as water quality data were analyzed descriptively in the form of tables and graphs.

**3.RESULTS AND DISCUSSION**

**3.1. Results**

**3.1.1. Growth**

Based on the analysis of variance (ANOVA) obtained that the cultivation of seaweed floating raft system around the cultivation of FNC system with different locations gives a significant effect (p <0.05) on the absolute growth and specific growth rate of seaweed, G *verrucosa*. Graph absolute growth and specific growth rate based on further test analysis with Duncan method can be seen in Fig. 2.



Fig. 2. Absolute weight growth (a) and specific growth rate (b) of seaweed, G verrucosa cultivated with floating rafts around FNC and controls

The absolute growth of seaweed cultivated in the northern part of the FNC was not significantly different (p>0.05) from that in the southern, eastern and western parts and significantly different (p<0.05) from the absolute growth of seaweed cultivated without FNC (control). The absolute growth of seaweed cultivated in the southern part of the FNC was not significantly different (p>0.05) from that in the eastern and western parts and significantly different (p<0.05) from the control (Fig. 2a). The specific growth rate of seaweed cultivated in the northern part of the FNC was not significantly different (p>0.05) from that in the southern, eastern and western parts and was significantly different (p<0.05) from the specific growth rate of seaweed cultivated without FNC (control). The specific growth rate of seaweed cultivated in the southern part of the FNC was not significantly different (p>0.05) from that in the eastern and western parts and significantly different (p<0.05) from the control (Fig. 2b).

**3.1.2. Production**

Based on the analysis of variance (ANOVA) obtained that the cultivation of seaweed floating raft system around the cultivation of FNC system with different locations gives a significant effect (p <0.05) on the production of seaweed, G *verrucosa*. Production graph based on further test analysis with Duncan method can be seen in Fig. 3.



Fig. 3. Production of seaweed, G *verrucosa* cultivated with floating rafts around FNC and controls

The production of seaweed cultivated in the northern part of the FNC was not significantly different (p>0.05) from that in the southern, eastern and western parts and significantly different (p<0.05) from the absolute growth of seaweed cultivated without FNC (control). Production of seaweed cultivated in the southern part of the FNC was not significantly different (p>0.05) from that in the eastern and western parts and significantly different (p<0.05) from the control (Fig. 3).

**3.1.3. N and P Absorption Rate**

The results of testing the content of N and P in seaweed tissue, G *verrucosa* at the beginning (day 0), middle (day 21) and the end of maintenance (day 42) can be seen in Fig. 4.



Fig. 4. Nitrogen and phosphorus content of seaweed, G. *verrucosa* at the beginning, middle and end of rearing

Nitrogen content in seaweed tissue, G. *verrucosa* cultivated on floating rafts around FNC on day 21 ranged from 3.30 - 4.09 g N/m2 or higher than the control with a nitrogen content of 3.11 g N/m2. On the final day of rearing or day 42, the nitrogen content in seaweed tissue around the FNC was 4.84 - 5.32 g N/m2 or relatively higher than the control with a nitrogen content of 4.06 g N/m2 (Fig. 4a). Phosphorus content in seaweed tissue, G. *verrucosa* cultivated on floating rafts around FNC on day 21 ranged from 0.19 - 0.38 g P/m2 or higher than the control with a nitrogen content of 0.20 g P/m2. On the final day of maintenance or day 42, the phosphorus content of seaweed tissue around the FNC was 0.53 - 0.79 g P/m2 or relatively higher than the control with a phosphorus content of 0.37 P/m2 (Fig.4b).

Based on the analysis of nitrogen content in seaweed tissue, seaweed biomass and seaweed cultivation area with integrated mariculture system showed the level of nitrogen absorption of seaweed cultivated around the FNC site on day 21 ranged from 0.40 - 0.88 g N/m2/day or 1.47 - 3.07 tons N/ha/year, while the level of nitrogen absorption in the control site was 0.16 g N/m2/day or 0.57 tons N/ha/year. While at the end of maintenance, namely the 42nd day, the level of nitrogen absorption of G. *verrucosa* seaweed cultivated around the FNC site with a range between 0.41 - 0.88 g N/m2 / day or 1.51 - 3.20 tons of N/ha / year was higher than in the control site of 0.49 g N/m2 / day or 1.78 tons N/ha / year (Fig. 5a). The phosphorus absorption rate of G. *verrucosa* seaweed cultivated around the FNC site on day 21 ranged from 0.35 - 0.67 g P/m2/day or 1.29 - 2.45 tons P/ha/year, while the phosphorus absorption rate at the control site was 0.31 g P/m2/day or 1.14 tons P/ha/year. While at the end of maintenance, namely the 42nd day, the level of phosphorus absorption of G. *verrucosa* seaweed cultivated around the FNC site with a range between 0.69 - 1.38 g P/m2/day or 2.51 - 5.05 tons of P/ha/year was higher than in the control site of 0.49 g P/m2/day or 1.78 tons of P/ha/year (Fig. 5b).



Fig. 5. Nitrogen and phosphorus uptake rates of seaweed, G. *verrucosa* cultivated with floating rafts around FNC and controls

**3.1.4.** **Water quality**

The measurement results of water quality parameters during seaweed cultivation. G. verrucosa with floating rafts can be seen in Table 1.

Table 1. Water quality conditions during seaweed cultivation. G. *verrucosa* with floating rafts

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| --- | --- | --- |
| Parameters | location of cultivation of FNC | Standard value  |
| Nort | South | Easth | West | Control |
| Temperature (°C) | 27.5 – 31  | 28 – 31  | 28 – 31  | 27.7 – 31  | 28 – 31  | 26-321) |
| pH | 7.8 – 9  | 7.8 – 9 | 8 – 9  | 7.7 – 8.9 | 7,9 – 8.9 | 7 – 8.5 1) |
| DO (mg/L) | 8 – 8.2  | 8.7 – 9  | 8 – 9 | 7.2 – 9  | 8 – 9 | >52) |
| Salinity (ppt) | 25 – 30  | 26 – 29  | 25 – 30  | 25 – 30  | 25 – 30 | 28 – 341) |
| Brightness (m) | 2.3 – 6.5  | 2.5 – 3  | 2.3 – 2.9  | 2.3 – 5  | 2.2 – 2.3  | >53)  |
| Nitrate (NO3-N) (mg/L) | 0.04 - 0.05 | 0.04 - 0.05 | 0.04 - 0.05 | 0.03 - 0.05 | 0.05 - 0.17 | 0.02 - 0.044) |
| Phosphorus (PO4-P) (mg/L) | 0 - 0.23 | 0.05 - 0.19 | 0 - 0.06 | 0 - 0.03 | 0 - 0.23 | 0.02- 0.14) |

Note : 1) BSN (2010): 2) Jalil e*t al*. (2020); 3) Ullah *et al*. (2023); 4) Sarjito *et al*. (2022)

**3.2. Discussion**

**3.2.1. Growth**

Growth is defined as a change in the size of an organism that can be in the form of weight or length in a certain time. The growth of seaweed, G. v*errucosa* is strongly influenced by two factors, namely external factors and internal factors. Internal factors that affect the growth of seaweed include type, strain, thallus parts and age, while external factors that affect include the physical and chemical environment of the waters (Indrayani *et al*., 2021). However, in addition to these factors, there are other factors, namely management factors carried out by farmers, for example with monoculture systems or integrated systems (Yuniarsih *et al*., 2014). The growth performance of cultivated species with integrated systems shows very good results, especially inorganic material absorbing species, such as seaweed (Radiarta & Erlania, 2016).

In this study, the growth performance of G. *verrucosa* cultivated in the vicinity of floating net cages (FNC) or integrated systems was significantly different from that of G. *verrucosa* cultivated without FNC (control), whether the floating rafts were located in the north, south, east and west. The higher growth performance (growth and specific growth rate) of seaweed cultivated at the FNC site compared to the control site was positively correlated with the level of nitrate and phosphorus uptake (Fig. 5). Nitrogen and phosphorus are needed by seaweed to grow optimally (Zainuddin & Nofianti, 2022). Nitrogen is a macro element that is useful to stimulate the growth of a plant. Lack of N will inhibit seaweed growth because it is an element used in the photosynthesis process. Element P is a constituent of pyrophosphate bonds of ATP (Adenosine Tri Phosphate) which is rich in energy and is the fuel for all biochemical activities in the cell (Setiaji *et al*., 2012).

The addition of nutrients N and P into seaweed cultivation media, especially in the cultivation system to meet the needs of seaweed to grow well (Zainuddin & Nofianti, 2022). According to Alamsyah *et al*. (2009), the combination of NPK and TSP fertilizer with a dose of 2 g / L on the cultivation of seaweed, G. *verrucosa* significant effect on growth. In seaweed cultivation with an open system carried out in a body of water, for example in the waters of Ekas Bay, the supply of nutrients N and P as obtained by FNC cultivation waste. Based on research by Yuniarsih *et al*. (2014) the growth of seaweed, *Kappaphycus alvarezii* and *Eucheuma spinosum* cultivated around FNC in the waters of Gerupuk Bay, West Nusa Tenggara Province is higher than the control location. This condition can be caused by the release of dissolved nutrient materials produced by FNC, especially from fish metabolic waste. Jamal *et al*. (2013) suggested that fish farming activities can produce carbon (C), nitrogen (N), and phosphorus (P) waste, where dissolved inorganic N (NH3) is released through the excretion process and inorganic C such as CO2 is released through the respiration process. This indicates that seaweed, G. *verrucosa* can assimilate dissolved inorganic nitrogen that is abundant in the FNC location into organic matter that plays an important role for growth through the process of photosynthesis.

**3.2.2. Production**

Seaweed production is the end result of growth that refers to the amount of seaweed harvested. Production of G. *verrucosa* cultivated around floating net cages (FNC) or integrated systems differed significantly from the growth of G. *verrucosa* cultivated without FNC (control), both floating rafts located in the north, south, east and west. Production of G. *verrucosa* seaweed cultivated on floating rafts around the FNC sites ranged from 1 400 - 2 000 g/m2 or 14 - 20 tons/ha higher than those cultivated on control floating rafts which reached 1 020 - 1040 g/m2 or 10.2 - 10.4 tons/ha (Fig. 5). The results of this study are in line with the results of the implementation of an integrated seaweed cultivation system applied in Gerupuk Bay which showed very significant production and production increases compared to the control/monoculture (Radiarta *et al*., 2014).

Furthermore, based on the calculation of Radiarta *et al*. (2014) the production of *Kappaphycus alvarezii* seaweed with an integrated cultivation system ranged from 15.5-18.8 tons/ha compared to the control whose production only reached 8.9-10.8 tons/ha, thus an increase in production of about 74%. Even the production of seaweed from this study was higher than the production of G. *verrucosa* seaweed cultivated in ponds which was only 318 - 590 g/m2 (Widiastuti, 2011). This can be used as an early indication of the exposure of nutrients derived from FNC waste to seaweed cultivated around the FNC. According to Neori *et al*. (2000), the idea is that the high growth of seaweed is supported by the presence of ammonia excreted by fish into the environment; in addition, seaweed also plays a role in filtering ammonia from the aquatic environment. Gordillo *et al*. (2002) suggested that the growth and production of G. *verrucosa* seaweed corresponded and had a positive correlation with an increase in the rate of N and P absorption.

**3.2.3. N and P Absorption Rate**

Nitrogen (N) and phosphorus (P) are limiting factors for seaweed growth and production in most natural environments (Indrayani *et al*., 2021). Nitrogen in the water is in the form of nitrate (NO3-), while phosphorus is in the form of orthophosphate (PO4) (Mustofa, 2015). Seaweed cultivated in an integrated manner with intensive aquaculture activities has a role as a biofilter that will absorb nutrients N and P. In this study, the level of N and P absorption of seaweed cultivated around the FNC location was higher than in the location of the monoculture system or control. The results of this study are in line with the results of research in Gerupuk Bay, Central Lombok Regency showing that the level of N absorption of seaweed cultivation in the IMTA system reached 80.49 - 82.05% higher than that of seaweed cultivated outside FNC (Yuniarsih *et al*., 2014a).

Meanwhile, the level of P absorption in seaweed tissue reared around FNC in Gerupuk Bay, West Nusa Tenggara Province, reached 39% higher than that of seaweed reared outside FNC. The results of research by Neori *et al*. (2004) found that different seaweed species have different abilities to absorb nutrients (N and P). The absorption rate of G. *verrucosa* seaweed cultivated around the FNC location in this study ranged from 1.51 - 3.20 tons N/ha/year lower than the nitrogen absorption rate of K. *alvarezii* seaweed with a range of 80.03 - 86.95 tons/ha/year and *Eucheuma spinosum* with nitrogen absorption rates ranging from 35.14 - 69.78 tons N/ha/year (Yuniarsih *et al*., 2014). The level of phosphorus absorption of G. *verrucosa* seaweed cultivated around FNC sites with a range between 2.51 - 5.05 tons of P/ha/year is lower than that of K. *alvarezii* which reaches 20.56 tons of P/ha/year, while E. spinosum phosphorus absorption rate is relatively no different at 4.39 tons of P/ha/year.

According to Raj *et al*. (2022), within the IMTA framework seaweed has a role as bioremediation to remove inorganic nutrients from wastewater, where based on research the efficiency of reducing NH3, NO2, NO3, and PO4 seaweed K. *alvarezii*, G. *verrucosa*, and E. *spinosum* reached 80% in intensive shrimp farming ponds (Syahrir, 2024). The results of the research on the level of N and P absorption of seaweed conducted in Ekas Bay indicate that seaweed is one of the activities that support the implementation of the blue economy policy that is currently a concern. Marine and fisheries development based on blue economy policies is based on several approaches, namely the existence of harmonious integration; development based on the region; clean production system (zero waste); benefit for the whole community; and sustainable by maintaining a balance between the utilization of natural resources and environmental conservation and between production and consumption (Zamroni *et al*., 2018).

**3.2.4. Water quality**

Water quality parameters are very important factors for success in seaweed cultivation activities. One indicator of the success of seaweed cultivation is the suitability of physical and chemical parameters of the waters. Physical parameters include temperature, salinity and brightness while chemical parameters include pH, DO, nitrate and phosphorus levels. The measurement results of temperature, salinity, brightness, pH and DO obtained during seaweed cultivation, both with the IMTA system and monoltur (control treatment) are still considered optimal for the seaweed rearing process based on the requirements set (BSN, 2010; Jalil *et al*., 2020; Ullah *et al*., 2023). The main impact of the presence of fish or lobster farming in FNC that use artificial feed and small fish feed on the quality of the surrounding waters is an increase in the accumulation of particles and dissolved nutrients in the water column (Nobre *et al*., 2010). Nutrients N and P are needed by seaweed in order to grow optimally (Zainuddin & Nofianti, 2022). The test results of nitrate and phosphorus concentrations in the waters showed slightly exceeded the threshold value for nitrate 0.02 - 0.04 mg/L and phosphorus 0.02 - 0.10 mg/L (Sarjito *et al*., 2022). The highest nitrate concentration was at the monoculture seaweed farming site (control treatment) at 0.17 mg/L and the highest phosphorus concentration on the north side of the FNC at 0.23 mg/L. The differences in nutrient distribution observed during the study can be attributed to the

# 4. CONCLUSION

Gracilaria verrucosa seaweed cultivated around floating net cages has better growth and production performance as well as N and P absorption compared to that cultivated without floating net cages or control.

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