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The Effectiveness of *Gracilaria* sp. as a Biofilter in Reducing Aquaculture Waste Based on Planting Location in the Waters of Ujung Betok, East Lombok

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ABSTRACT

Aquaculture waste can increase dissolved inorganic nutrient concentrations, making seaweed-based treatment an important component of integrated biological nutrient management. This study aimed to evaluate strategic planting locations of *Gracilaria* sp. around floating net cages and assess its effectiveness as a natural biofilter for reducing nitrogenous waste in Ujung Betok waters, East Lombok. A Completely Randomized Design (CRD) was applied with three planting-distance treatments and three replicates. Total Ammonia Nitrogen (TAN) concentrations ranged from 0.29–0.31 mg/L at the beginning and 0.24–0.29 mg/L at the end of the 30-day culture period. ANOVA showed no significant difference in initial TAN among treatments ($p = 0.868$), whereas final TAN differed significantly among planting locations ($p = 0.001$). Final total nitrogen content in *Gracilaria* sp. tissue ranged from 0.287–0.330%, with the highest value in T2 (0.330 ± 0.050%), followed by T3 (0.303 ± 0.006%) and T1 (0.287 ± 0.015%). Planting location did not significantly affect tissue total nitrogen content ($p > 0.05$). Tissue nitrogen reduction was 13.03% in T1, 0.00% in T2, and 8.18% in T3. TAN reduction was highest in T1, decreasing from 0.31 to 0.24 mg/L or 22.58%, followed by T2 at 3.33%, while T3 showed no reduction. These results indicate that *Gracilaria* sp. can contribute to nitrogen removal, with the 25 m planting location showing the best biofiltration performance.

INTRODUCTION

Aquaculture is an activity that can boost food production, yet it also concentrates the flow of nutrients into receiving waters when uneaten feed, fecal matter, and dissolved excretions exceed local assimilation capacity. Research in Ujung Betok—where over 150 floating net cage units were reported in 2025 (Asri *et al*., 2025)—estimates that approximately 60–80% of feed and fecal matter enters the marine environment, while only about 20–30% of the nitrogen in the feed is converted into fish biomass. This increase is a management concern because nitrogen and phosphorus enrichment can trigger eutrophication and alter coastal ecological processes. Aquaculture discharges can elevate dissolved inorganic nutrient levels and restructure macroalgal communities, whereas seaweed co-culture can substantially reduce dissolved nutrients under controlled conditions (Choi *et al*., 2021; Gao *et al*., 2022).

Macroalgae are significant because nutrient removal is directly linked to biomass formation, allowing dissolved nitrogen and phosphorus to be converted into harvestable products. In North Lombok, *Gracilaria* and *Halymenia* cultivated in a verticulture system demonstrated strong nutrient uptake capabilities, with *Gracilaria* exhibiting relatively high nitrate and phosphorus absorption (Adam *et al*., 2025). Nutrient-rich fish effluent has supported rapid seaweed growth as well as the removal of 50–75% of ammonia, nitrate, and phosphate (Ashkenazi *et al*., 2022).

Consequently, seaweed-based management has become a crucial component of biologically integrated nutrient management (Adharini *et al*., 2021; Couto *et al.,* 2022). *Gracilaria* sp. seaweed is known for its ability to absorb dissolved nutrients and is frequently utilized as a natural biofilter in waters affected by waste. *Gracilaria* sp. nutrient absorption capability stems from its nature as a filter feeder. According to Dwiyanti (2023), filter feeding involves the ability to directly filter or accumulate elements present in the environment including nitrogen and assimilate them into the organism's tissues. Research conducted by Agustina *et al*. (2017) demonstrated that *Gracilaria* sp. could absorb nitrogen from water contaminated with organic matter, reducing the total nitrogen concentration from 1.2 mg/L to 0.4 mg/L. This absorption capacity underscores the role of *Gracilaria* sp. not merely as a commodity of economic value, but also as an effective bioremediation agent for reducing organic pollution loads in coastal ecosystems (Hasanah *et al*., 2026).

The effectiveness of *Gracilaria* sp. as a biofilter depends not only on its nature as a filter feeder but also on the planting location, which dictates factors such as light availability, water flow, and nutrient competition among the thalli. However, information regarding the optimal planting location for *Gracilaria* sp. in the waters of Ujuang Betok which are impacted by aquaculture and domestic waste remains limited. Therefore, this study is crucial for identifying strategic seaweed planting sites in the vicinity of floating net cages. Placing *Gracilaria* sp. within a specific zone or radius of the floating net cages is expected to allow for the optimal utilization of abundant nutrients to stimulate growth, while simultaneously serving as a natural filter (biofilter) to minimize the risk of aquatic environmental degradation.

METHODS

Time and Location

Field research was conducted over a period of 30 days from May to June 2026 in the waters of Ujung Betok, East Lombok a coastal area influenced by aquaculture activities, where floating net cage production and surrounding settlement activities are estimated to contribute to dissolved and particulate nutrient loads. Analyses for Total Ammonia Nitrogen (TAN) and total nitrogen content were performed at the Analytical Chemistry Laboratory of the University of Mataram**.**

Tools and Materials

The tools and materials used in this study were selected in accordance with the principles of the National Standardization Agency. Based on the cultivation method employed specifically the floating raft method with dimensions of 5 meters by 3 meters the materials used to construct the rafts included bamboo, PE (polyethylene) lines, raffia rope, floats, and weights or anchors. A seaweed mass of 100 grams was used, with a planting spacing of 25 cm.

The cultivation period for this study was 30 days. The seaweed species used was *Gracilari*a sp. The *Gracilaria* sp. seedlings met the following criteria: they were fresh, brightly colored, and obtained from young thalli.

Experimental Design

This study employs an experimental method using a Completely Randomized Design (CRD). The treatments involve varying the planting locations of *Gracilaria* sp. based on the distance from the source of cultivation activity or floating net cages (KJA). The study consists of three treatments and three replicates. Planting locations were determined based on the methodology of Dwiyanti *et al*. (2026). The treatments in this study are as follows:

T1 : *Gracilaria* sp. planting site 25 m from cultivation activities.
T2 : *Gracilaria* sp. planting site 50 m from cultivation activities.
T3 : *Gracilaria* sp. planting site 75 m from cultivation activities.

Parameters

The observation parameters in this study consisted of water quality parameters—namely temperature (°C), salinity (ppt), pH, dissolved oxygen (DO, mg/L), transparency (cm), and TAN—as well as the measurement of total nitrogen in seaweed tissue using the Kjeldahl method. Sample measurements were conducted at the beginning and end of the cultivation period, specifically on days 0 and 30.

$$\text{Reduction Effectiveness (\%)} = (C_t - C_0) / t \times 100\%$$ (Kang *et al*., 2008)

Where :
C_t : Nutrient concentration at the end of the cultivation period
C_0 : Nutrient concentration at the start of the cultivation period
T : Cultivation duration

Data Analysis

Data obtained during the study were analyzed using Microsoft Excel and SPSS software. Statistical analysis was performed using one-way analysis of variance (ANOVA) and Duncan's post-hoc test to determine significant differences in the response of each parameter across the various treatments.

RESULTS

Water Quality

The water quality measurement results from this study are presented in the Table 1.

Table 1. Water Quality Resultss

Parameter	Treatment			Standard Value	Literature
	T1 (25 m)	T2 (50 m)	T3 (75 m)		
DO (mg/L)	6.1-7.7	7.1-7.4	6.5-7.7	3-8	Al Mughni & Rifa'i (2024)
Temperature (°C)	28.8-29.1	28.8-29.0	28.8-29.1	27-30	Tarmizi & Diniarti (2022)
pH	7.3-8.0	7.7-8.1	7.7-8.2	7-8.5	Alamsyah (2016)
Salinity (ppt)	35-37	35-40	35-37	30-40	Susanto (2021)
Brightness (m)	1.5-5.5	1.5-5.5	1.5-5.5	>0.45	Al Mughni & Rifa'i (2024)
Current (m/s)	0.8-3.13	0.8-3.13	0.8-3.13	0.2-0.4	Hardan *et al*. (2020)

Total Amonia Nitrogen (TAN)

Descriptive analysis of the Total Ammonia Nitrogen (TAN) levels in the water (research medium) indicates that the average TAN content ranged from 0.29–0.31 mg/L at the start of the rearing period and from 0.24–0.29 mg/L at the end. The highest initial TAN content was observed in treatment T1 (planting site 25 m from the cultivation activity source or floating net cages), at 0.31 mg/L. Treatment T2 (planting site 50 m) showed an initial TAN content of 0.30 mg/L, while the lowest value was found in treatment T3 (planting site 75 m) at 0.29 mg/L. At the end of the rearing period, the highest TAN content was found in treatments T2 and T3 (0.29 mg/L each), whereas the lowest content was observed in treatment T1 (0.24 mg/L). The initial and final average TAN values for the Ujung Betok waters are presented in Figure 1. The initial and final average values for total nitrogen content in the seaweed tissue are also shown in Figure 1.

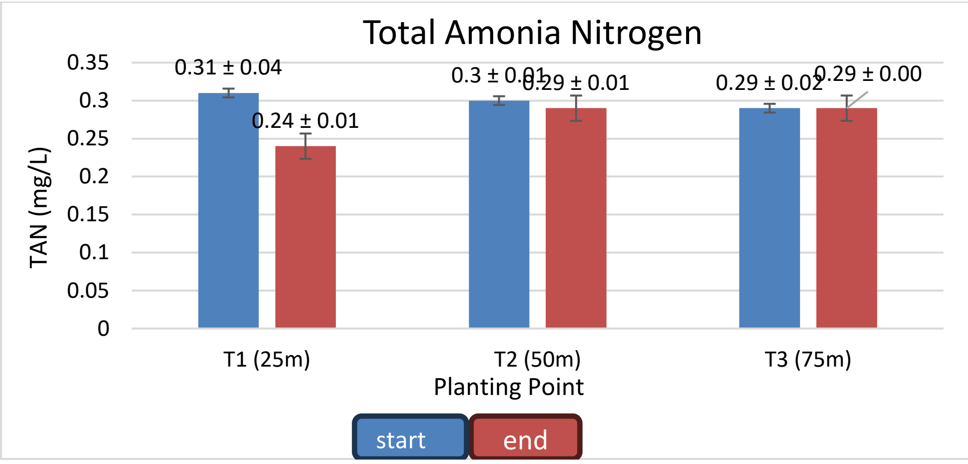

Figure 1. Total Amonia Nitrogen (TAN)

Analysis of Variance (ANOVA) results indicate that the different planting points did not yield significantly different results regarding initial TAN content (significance value 0.868; $p > 0.05$), but did yield significantly different results regarding final TAN content (significance value 0.001; $p < 0.05$). Duncan's post-hoc test results show that treatments T2 and T3 did not differ significantly from each other, but both differed significantly from treatment T1.

Total Nitrogen Content (%)

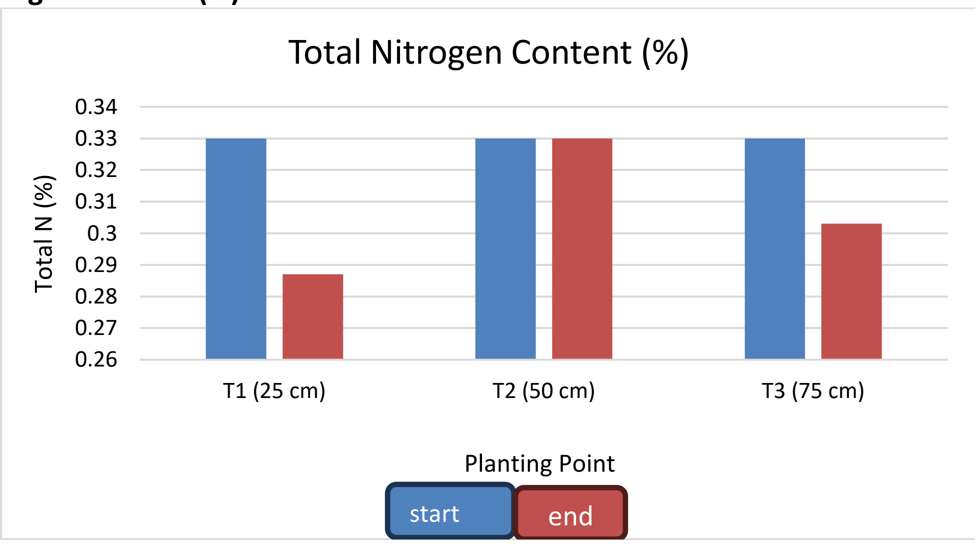

Figure 2. Total Nitrogen Content (%)

Total Nitrogen Content (%): Descriptive analysis results indicate that the final total nitrogen content of *Gracilaria* sp. ranged from 0.287% to 0.330%. The highest value was observed in T2 (0.330 ± 0.050%), followed by T3 (0.303 ± 0.006%) and T1 (0.287 ± 0.015%). However, the Analysis of Variance (ANOVA) results indicate that the planting site did not significantly affect tissue total nitrogen content ($p > 0.05$).

DISCUSSION

In this research, the total tissue nitrogen content of *Gracilaria* sp. represents the amount of nitrogen stored within the seaweed's tissues. This nitrogen originates from dissolved inorganic nitrogen in the water primarily ammonium (NH_4^+) and nitrate (NO_3^-)—which is absorbed by the seaweed and subsequently assimilated into organic compounds such as proteins, amino acids, chlorophyll, enzymes, and other cellular components (Long *et al*., 2024). The results indicate an initial average nitrogen content of 0.330% prior to planting, while the final average nitrogen content across all locations following the treatment was 0.307%. This decrease suggests that the various planting sites for *Gracilaria* sp. contributed to nitrogen reduction in the study waters. Regarding reduction effectiveness, treatment T1 achieved 13.03% and T3 achieved 8.18%, whereas T2 showed 0.00%. Rahim (2026) stated that the tissue nitrogen content of *Gracilaria verrucosa* is significantly influenced by cultivation conditions and biomass density. At optimal density, tissue nitrogen content increases due to higher nutrient accumulation efficiency; conversely, excessively high density reduces nitrogen content as a result of competition for light and nutrients.

The varying effectiveness of nitrogen reduction at planting points T1, T2, and T3 in this study is attributed to differences in nutrient distribution and hydrodynamics at each location. This aligns with findings by Ikhsan *et al*. (2025), who stated that *Gracilaria* sp. can utilize dissolved inorganic nitrogen from the culture medium and accumulate it within its tissues. Nitrogen accumulation efficiency is influenced by nutrient availability, seaweed biomass, salinity, and aquatic environmental conditions. Furthermore, Muktiani *et al*. (2022) noted that high nitrogen levels in the water originate from various sources, including organism decomposition, aquatic biota metabolic waste, and leftover feed from cultured organisms. The nitrogen-absorbing capability of *Gracilaria* sp. has been widely documented; for instance, Jaiswar *et al.* (2025) reported that *Gracilaria corticata* and *G. dura* could reduce ammonium and nitrate levels from shrimp farm effluent in under 96 hours, with absorption effectiveness influenced by nutrient availability, seaweed biomass, light, salinity, and aquatic environmental conditions. Additionally, Shalehah *et al*. (2025) reported that *Gracilaria verrucosa* cultivated near floating net cages in Ekas Bay absorbed nitrogen at a rate of 0.41–0.88 g N/m^2/day, whereas the control site exhibited an absorption rate of approximately 0.49 g N/m^2/day

The TAN content at the beginning of the maintenance did not show any significant difference between treatments, indicating that the TAN conditions at the planting points of 25 m, 50 m, and 75 m from the KJA were relatively the same. However, at the end of the maintenance the TAN content showed a significant difference, with the lowest value in the T1 treatment of 0.24 mg/L, while T2 and T3 were each 0.29 mg/L with a total ammonia nitrogen reduction rate of 3.3% in T2 and 0% in T3. Research by Harini *et al*. (2025) showed that *Gracilaria foliifer* was able to remove 64% of total ammonia nitrogen during the filtration period, as well as research by Lohroff *et al.* (2021) where the seaweed *Agardhiella subulata* removed 68.8% of ammonia. The high TAN values at T2 and T3 are thought to indicate that planting points closer to the source of cultivation waste have a greater potential to experience a decrease in TAN. Meanwhile, the decrease in TAN values in the T1 treatment is thought to be due to the spread of dissolved ammonium by the movement of water masses around the KJA and coastal areas.

Ammonium derived from uneaten feed and the metabolic byproducts of cultured organisms does not necessarily remain at the point closest to the floating net cages (KJA); instead, it can be transported to more distant locations by water mass movement. This aligns with the findings of Smart *et al*. (2022), who stated that ammonium input from fish farming activities can extend its influence beyond the primary cultivation area, while its distribution and uptake by macroalgae are influenced by local water conditions. The observed differences in TAN values across treatments indicate the utilization of inorganic nitrogen by *Gracilaria* sp. Seaweed can absorb ammonium and other forms of dissolved nitrogen through the surface of its thallus, subsequently assimilating them into amino acids, proteins, pigments, and new tissue

Water quality measurements taken during the study indicate that most parameters remained within ranges suitable for the cultivation of *Gracilaria* sp. (Table 1). The parameters measured included dissolved oxygen (DO), temperature, pH, salinity, water clarity, and current velocity. Monitoring water quality is crucial because aquatic environmental conditions can influence seaweed physiological processes, such as photosynthesis, respiration, nutrient uptake, growth, and survival. This aligns with Cindra *et al*. (2025), who stated that evaluating physical and chemical water parameters is essential for *Gracilaria* sp. cultivation, as water quality is a key factor in successful seaweed farming. DO levels during the study ranged from 6.1 to 7.7 mg/L. This range supports the life and growth of *Gracilaria* sp., given the vital role dissolved oxygen plays in the respiration of aquatic organisms. These results are consistent with findings by Al Mughni & Rifa'i (2024), who reported DO levels of 7.4–10 mg/L in *Gracilaria* sp. cultivation waters in Muara Pagatan. Although the DO levels in the current study were relatively lower, the conditions remained favorable for *Gracilaria* sp. growth. Temperatures ranged from 28.8 to 29.1°C, a range suitable for the growth of G*racilaria* sp.

Temperature plays a role in regulating the metabolism, respiration, and photosynthesis of seaweed. This range aligns with the findings of Tarmizi & Diniarti (2022), who noted that the optimal temperature for *Gracilaria* sp. cultivation is 27–30°C. pH values ranged from 7.3 to 8.2; these conditions still allow the physiological processes of *Gracilaria* sp. to proceed effectively. pH influences water stability and nutrient availability. According to Alamsyah (2016), the suitable pH range for *Gracilaria* sp. cultivation is 7–8. Thus, most pH values recorded in the study fell within the appropriate range, although a few measurements slightly exceeded that limit. Salinity values ranged from 35 to 40 ppt. These conditions remain tolerable for *Gracilaria* sp., which possesses the ability to adapt to salinity fluctuations. Salinity plays a role in maintaining cellular osmotic balance; consequently, extreme changes can disrupt physiological processes and growth. This is consistent with Susanto (2021), who stated that *Gracilaria* sp. exhibits a broad salinity tolerance.

Water clarity values ranged from 1.5 to 5.5 m. These conditions indicate that light could still penetrate the water column and support photosynthesis in *Gracilaria* sp. Sufficient clarity allows the thallus to receive the light needed for energy production and biomass accumulation. Hardan *et al.* (2020) noted that a clarity range of 2–5 m is favorable for seaweed cultivation. Meanwhile, current speeds ranged from 0.8 to 3.13 m/s, which is considered high compared to the ideal range of 0.2–0.4 m/s cited by Hardan *et al.* (2020). Currents play a role in supplying oxygen and nutrients while minimizing the accumulation of sediment and organisms on the thallus. However, excessively strong currents can cause the thallus to break, rub against the cultivation substrate, or detach, thereby hindering the growth of *Gracilaria* sp.

CONCLUSION

The study concludes that *Gracilaria* sp. was effective in reducing nitrogen levels by 13.3% in treatment T1, 8.8% in T2, and 0.0% in T3; however, analysis revealed that the planting location did not significantly affect total nitrogen content. Regarding TAN values, the concentration in T1 decreased from 0.31 to 0.24 mg/L, representing a 22.58% reduction. Meanwhile, T2 (at a distance of 50 m) showed a TAN reduction of 3.33%, whereas T3 (at a distance of 75 m) showed no reduction in TAN.

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