Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan (2025), Special Issue The 5th ICFM: 179-189

DEPIK
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Journal homepage: www.jurnal.usk.ac.id/depik

Identification of the distribution pattern of *macroalgae caulerpa racemosa* in Ternate City

Rovina Andriani[1], M Janib Achmad[2], Najamuddin[3], Syahnul Sardi Titaheluw[4,*]

[1]*Department of Aquaculture, Faculty of Fisheries and Marine Sciences Khairun University, Ternate 97719, Indonesia*
[2]*Department of Aquatic Resources Utilization Study Program, Faculty of Fisheries and Marine Sciences, Khairun University, Ternate 97719, Indonesia*
[3]*Department of Marine Sciences, Faculty of Fisheries and Marine Sciences, Khairun University, Ternate 97719, Indonesia*
[4]*Department of Fishery Product Technology, Faculty of Agriculture and Fisheries, University of Muhammadiyah North Maluku, Ternate 97719, Indonesia.*

ARTICLE INFO

Keywords:
Caulerpa racemosa
Ternate
Distribution
Coastal Ecosystem

DOI: *10.13170/depik.0.0.47471*

ABSTRACT

Coastal ecosystems in Ternate have high biodiversity, including the macroalga Caulerpa racemosa, which contributes to ecosystem stabilization and mitigation of ocean acidification. However, environmental degradation due to human activities poses a serious threat, so analyzing the distribution and density of macroalgae is important for sustainable ecosystem management. This study aimed to analyze the distribution pattern and density of C. racemosa in Kastela and Gamalama waters, Ternate City. Data collection was conducted from May to August 2024 using the line transect method with 1x1 m² quadrants in two research locations. Each site had three 50 m long transect lines with five quadrants per transect. Density was calculated based on the number of individuals per unit area, while distribution patterns were analyzed using the Morisita index (Id). Environmental data such as temperature, salinity and pH were also measured to understand the factors affecting macroalgae distribution. Spatial analysis using GIS software visualized distribution patterns. Results showed that C. racemosa had a concentrated distribution pattern (Id > 1) in both study sites, with higher average densities in Kastela waters than Gamalama. Environmental factors, including temperature and substrate type, significantly influenced the distribution of this species. This study provides important data to support ecosystem-based management and sustainable coastal conservation, and fills an information gap on the impacts of ecological pressures on macroalgae in this region.

Introduction

Coastal ecosystems, especially those containing macroalgae such as Caulerpa racemosa, are critical to ecological balance and human livelihoods, especially in biodiverse areas such as Ternate. Macroalgae contribute significantly to habitat provision, sediment stabilization, and nutrient cycling, while also serving as a potential safeguard against ocean acidification (OA) by modifying seawater pH through photosynthesis (Edworthy *et al*, 2023; N. C. James & Whitfield, 2023). The presence of high macroalgal biomass can mitigate the negative effects of OA, which in turn favors marine biodiversity and ecosystem health (Miloslavich *et al*, 2019; Akbar *et al*., 2025a). However, human activities, including coastal land conversion and pollution, pose threats to coastal ecosystems. Research on macroalgal distribution and density to inform sustainable management practices (Rodrigues-Filho *et al*, 2023). Understanding these dynamics is crucial to preserving the ecological functions and services that coastal lagoons provide, which extend beyond local ecosystems to benefit the needs of the wider community (Rodrigues-Filho *et al*, 2023; Akbar & hasan, 2024).

The distribution patterns and density of Caulerpa racemosa in Ternate are poorly documented. This results in significant knowledge gaps that hinder effective coastal ecosystem management. Many studies have shown that macroalgae, including C. *racemosa*, serve as vital indicators of ecological health and can reflect environmental disturbances caused by huma activities (Asriani *et al*, 2024; Kalalembang *et al*, 2024). For example, studies in various coastal areas of Indonesia have used methods such as line

* Corresponding author.
Email address: titaheluw@gmail.com

p-ISSN 2089-7790; e-ISSN 2502-6194
Received 1 April 2025; Received in revised 1 May 2025; Accepted 15 July 2025
Available online 30 July 2025

transects and quadrat sampling to assess macroalgal diversity and density, revealing that environmental factors significantly influence their distribution (Basyuni *et al*, 2024; Turangan *et al*, 2024; Akbar *et al*., 2023). A systematic review of seaweed biodiversity in Indonesia identified more than 325 species, emphasizing the need for local studies to understand the distribution of certain species, such as C. racemosa, which can inform sustainable conservation policies and improve understanding of anthropogenic impacts on marine ecosystems (Mayakun & Prathep, 2023). Therefore, the research to be conducted in Ternate waters is essential to fill this gap and support effective coastal management strategies.

A systematic review identified at least 325 seaweed species across Indonesia, with environmental factors influencing their distribution and abundance (Mayakun & Prathep, 2023). In Ternate, studies have documented the diversity of red algae (Rhodophyta) and their specific habitat preferences, such as corals and sandy substrates, suggesting a rich coastal ecosystem (Yang *et al*, 2021). In addition, research on seagrass diversity at Kastela Beach highlighted the presence of six seagrass species, contributing to overall coastal biodiversity (Srimariana *et al*, 2020). Although research on C. *racemosa* in Ternate is limited compared to areas such as Bali and Java, it provides valuable insights into coastal ecology and biodiversity conservation efforts in Indonesia (Agdialta *et al*, 2023; Samman & Achmad, 2023).

The lack of literature on coastal ecosystem dynamics in Ternate, particularly on the distribution pattern of Caulerpa *racemosa*, led to this study. Studies show that environmental factors such as temperature, salinity, and substrate type significantly affect the distribution and abundance of Caulerpa species in various Indonesian coastal waters (Ulaş *et al*, 2011). For example, nutrient levels, particularly nitrate and ammonia, have been shown to correlate with Caulerpa growth, suggesting that similar investigations in Ternate may explain local dynamics (Pulukadan *et al*, 2013; Akbar *et al*., 2025b). In addition, the impacts of coastal reclamation on physical and ecological parameters in Ternate have been documented, suggesting potential habitat alterations that could affect macroalgal distribution (Rashedy *et al*, 2022). Therefore, a comprehensive study is essential to fill existing knowledge gaps and improve the coastal ecology database for the region (Buana *et al*, 2024; Darmawan *et al*, 2022; Rashedy *et al*, 2022).

This study aims to analyze the distribution pattern and density of *Caulerpa racemosa* in Ternate coastal area. This study is expected to produce scientific data that can support ecosystem based management and sustainable conservation in Ternate waters, as well as answer the existing information gap regarding the impact of ecological pressures on the distribution pattern of *C. racemosa.*

Materials and methods

Location and time of research

This research was conducted from May to August 2024. The research site was located in the coastal waters of Kastela and Gamalama, Ternate City.

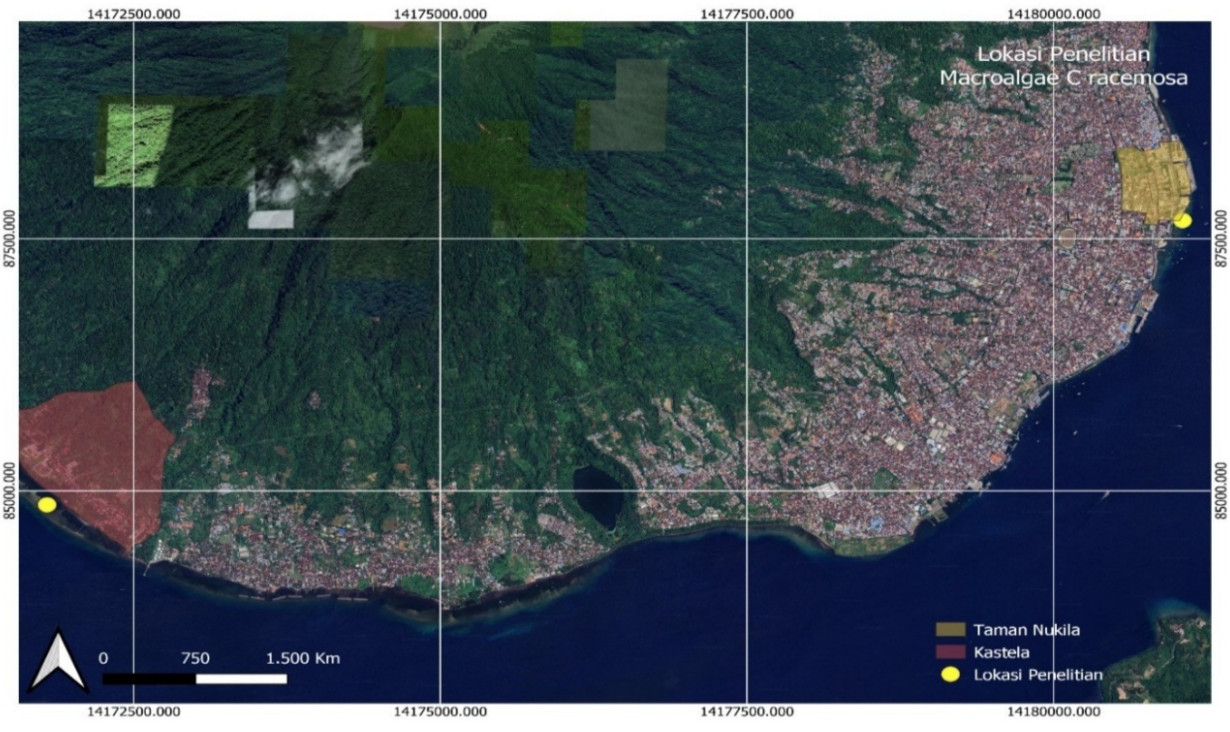

Figure 1: research location

Materials and Methods

Table 1. The tools and materials used in this study

No	Name	Using
1	Hariba Water Inspection	Water quality meter
2	Pipe 1m x 1m	Quadrant
3	Underwater camera	Documentation
4	GPS	coordinate point of research
5	Sterofoam	Storing macroalgae samples
6	Plastic samples	Storing macroalgae samples
7	Stationery	Recording the results of research in the field
8	Label paper	Sample labels

Data collection and analysis method

The methods used in this study include field surveys and spatial data analysis. Field surveys were conducted in several strategic locations in the waters of Ternate City, the location is in the coastal waters of Kastela and Gamalama Ternate City which are known to have high biodiversity.

Sampling methods using line transects and quadrant techniques (English *et al*, 1997). Sampling was conducted at 2 research sites where the transect placement was divided into 3 transect lines of 50 m long which were placed perpendicular (vertical) to the shoreline with 5 quadrants (size 1x1 m^2), the distance between quadrants in one transect line was 10 m and the distance between transects was 50 m. Each quadrant was determined and counted the number of individuals. Each quadrant was determined and counted in number of individuals. The use of transects and quadrants can provide accurate information about the distribution of species in a particular habitat. The data obtained were then analyzed using GIS (Geographic Information System) software to visualize the distribution pattern (Buana *et al*, 2024).

Density of C. *racemosa* macroalgae species

Density is the total number of individuals in a measured unit. Macroalgae density was calculated using (J. Brower & Zar, 1977).

$$Di = ni/A$$

Where:
In = Number of macroalgae (*thallus*) individuals up to – i per unit area
ni = Number of macroalgae (*thallus*) individuals up to –i in the quadrant transect
A = Quadrant transect area

Distribution pattern

The distribution pattern of macroalgae was calculated based on the distribution pattern equation of Morisita (Id) according to (J. E. Brower *et al*, 1990).

$$Id = n\frac{\Sigma x^2 - N}{N(n-1)}$$

Information:
Id = Morisita dispersion index;
n = Number of sampling plots;
N = Total number of individuals in the plot;
x2= Number of individuals in each plot

The distribution pattern criteria (Id) are random distribution pattern Id=1.0, distribution pattern Id<1.0, clustering distribution pattern Id>1.0. To understand the distribution pattern of *C racemosa* in Ternate City. Descriptive statistical analysis was used to describe the distribution characteristics, while spatial analysis helped in identifying areas of high concentration. In addition, environmental data such as temperature, salinity, and depth were also analyzed to understand the factors affecting C. *racemosa* distribution.

Water quality

Water quality is crucial for the sustainability of marine ecosystems, affecting the health and diversity of aquatic life, including fish and plankton. Key parameters such as temperature, salinity, pH, and dissolved oxygen are essential for assessing the physico- chemical conditions of the marine environment, directly affecting the physiological and biochemical activities of marine organisms (Lapa *et al*, 2024). Monitoring these parameters is critical to understanding the impacts of human activities, such as pollution from municipal sewage, which can cause significant ecological disruption (Lapa *et al*, 2024; Zaragoza-Esquerdo *et al*, 2024).

Result

Density of the macroalga C *racemosa*

Macroalgal species density is an important parameter in marine ecology, it reflects the number of individuals of a species per unit area. Low densities usually indicate that the habitat is considered less favorable for the growth of a particular macroalgae species.

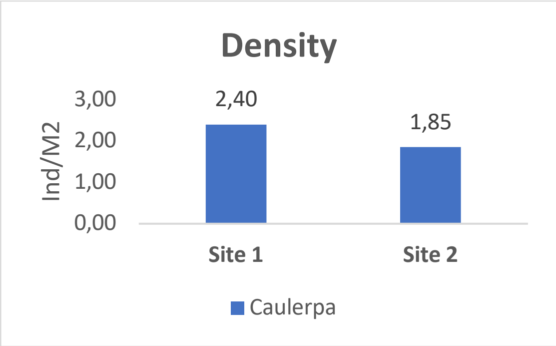

Figure 2. Density of C. *racemosa*.

Distribution patterns

Macroalgae distribution patterns can provide important information about the health and balance of coastal ecosystems. Through a better understanding of macroalgae distribution patterns, it is possible to further identify areas vulnerable to damage and develop effective management strategies to conserve biodiversity and preserve coastal ecosystems. Distribution patterns are caused by aquatic ecological factors that can control the presence of macroalgae and the biological characteristics of macroalgae. The distribution pattern of C racemosa at the study site is presented in Figure 3.

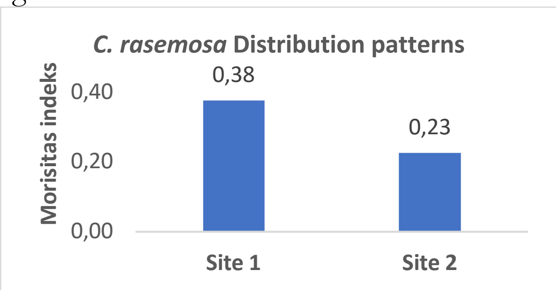

Figure 3. Distribution pattern of C *racemosa* in Ternate City waters

Water quality of C. *racemosa*

Water quality is key to supporting sustainable fisheries management and efficient aquaculture production. Water quality data are also used to detect and mitigate the impacts of pollution in marine waters. Pollution-related studies, such as the introduction of hazardous chemicals, heavy metals or microplastics, require continuous water quality measurements to take appropriate precautions. These data not only help identify pollution sources, but also provide guidance for policymakers to establish effective regulations to maintain the health of marine ecosystems. Therefore, the integration of water quality data in marine research plays an important role in optimizing conservation efforts and mitigating environmental impacts. The results of water quality measurements at the study sites are presented in Table 2.

Table 2. Water quality measurement results of C. *racemosa*.

No	Criterion	Location	
		Site 1	Site 2
1	Salinity (ppm)	30	23,69
2	Ph	8,22	8,31
3	DO (mg/L)	6,03	5,21
4	Temperature (⁰C)	31	29
5	Brightness (m)	1,5	1,5

Discussion

Macroalgae *caulerpa racemosa density*

Caulerpa racemosa (C. racemosa) density is an important indicator of coastal ecosystem conditions and reflects habitat suitability. The density of C. *racemosa* at Station 1 of 2.40 individuals/m² indicates optimal conditions for proliferation. While the lower density of 1.85 individuals/m² at Station 2 indicates that limiting factors such as depth and light availability significantly affect macroalgal distribution (Cebrian & Ballesteros, 2009; Sun *et al*, 2016) and substrate also determines macroalgal abundance, with spatial and temporal variations influenced by seasonal changes and anthropogenic impacts (Cebrian & Ballesteros, 2009).

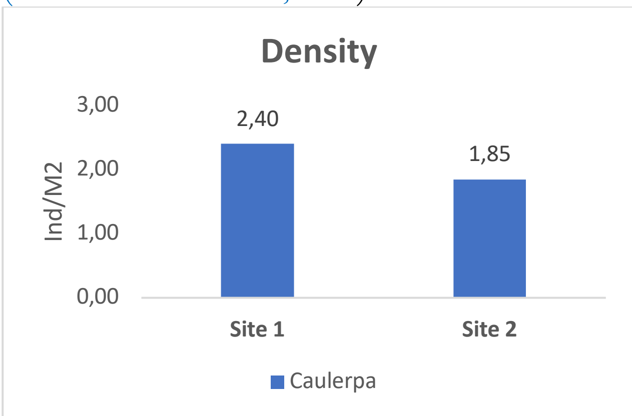

Figure 4: Density C. *racemosa*

The water temperature of 31°C at Station 1 favored optimal metabolism and photosynthesis of tropical macroalgae, which is thought to be the cause of the density of C. *racemosa*, while the temperature of 29°C at Station 2 is thought to be a limiting factor for these processes. Optimal temperatures range from 28-30°C, with significant increases reducing growth and photosynthetic efficiency (Aditya *et al*, 2023; Wu *et al*, 2023). Acclimatization to thermal fluctuations may affect species tolerance to environmental warming (Huang *et al*, 2023). Salinity also affects *C. racemosa* growth, with optimality in the 30-35 ppt range achieved at Station 1. Lower salinity (23.69 ppt) at Station 2 may interfere with osmoregulation, reducing growth potential (Phelps, 2016; Sáez *et al*, 2023; Z. Wang *et al*, 2024).

he response of *C. racemosa* to stable salinity is similar to patterns in other halophyte species (Z. Wang *et al*, 2024), emphasizing the role of salinity in the sustainability of coastal ecosystems. Dissolved oxygen (DO) concentration is also influential, where a (DO) of 6.03 mg/L at Station 1 supports photosynthesis, while (DO) 5.21 mg/L at Station 2 can trigger physiological stress The combination of temperature, salinity, and (DO) factors, as well as the alkaline pH, clarifies the variation in *C. racemosa* density. A thorough understanding of these dynamics is important for the sustainable management and conservation of marine ecosystems (Angell *et al*, 2015; Karsten, 2012; J.-J. Wang *et al*, 2024).

Distribution pattern *of caulerpa racemosa*

The spatial distribution of *Caulerpa racemosa* provides important insights into the ecological stability and environmental conditions of coastal waters. The uniform distribution pattern observed at the two stations, with indices of 0.38 and 0.23 respectively, reflects relatively homogeneous environmental conditions. However, the lower index at Station 2 indicates a more restricted distribution, likely caused by environmental stress (Liu *et al*, 2022). This phenomenon highlights the significant influence of environmental variables on coastal habitats (Liu *et al*, 2022).

In addition, the distribution of *C. racemosa* was influenced by depth and habitat type, with higher densities found on rocky substrates compared to seagrass beds. This suggests the urgency of monitoring invasive species such as *C. racemosa*, which have the potential to threaten native biodiversity and alter benthic communities (James *et al*, 2022).

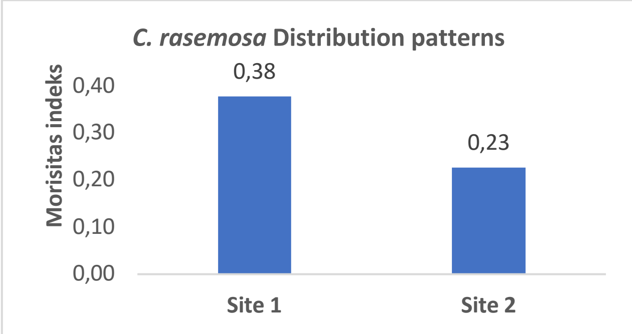

Figure 5. distribution pattern C. *racemosa*

Environmental parameters such as temperature, salinity, pH, and dissolved oxygen (DO) are instrumental in determining the spatial distribution of *C. racemosa* (James *et al*, 2022). High temperatures at Station 1 (31°C) increase metabolism and reproduction, thereby expanding the distribution of the species, while lower temperatures at Station 2 (29°C) can inhibit physiological activities, potentially reducing species density (Ali *et al*, 2022). The lower salinity at Station 2 (23.69 ppt) also provides a challenge, as salinity variations can disrupt osmoregulation and metabolic functions of macroalgae (Cebrian & Ballesteros, 2009; Sun *et al*, 2016). The interaction of these environmental factors shapes habitat preferences and species distribution patterns in diverse ecological contexts (Storz, 2024).

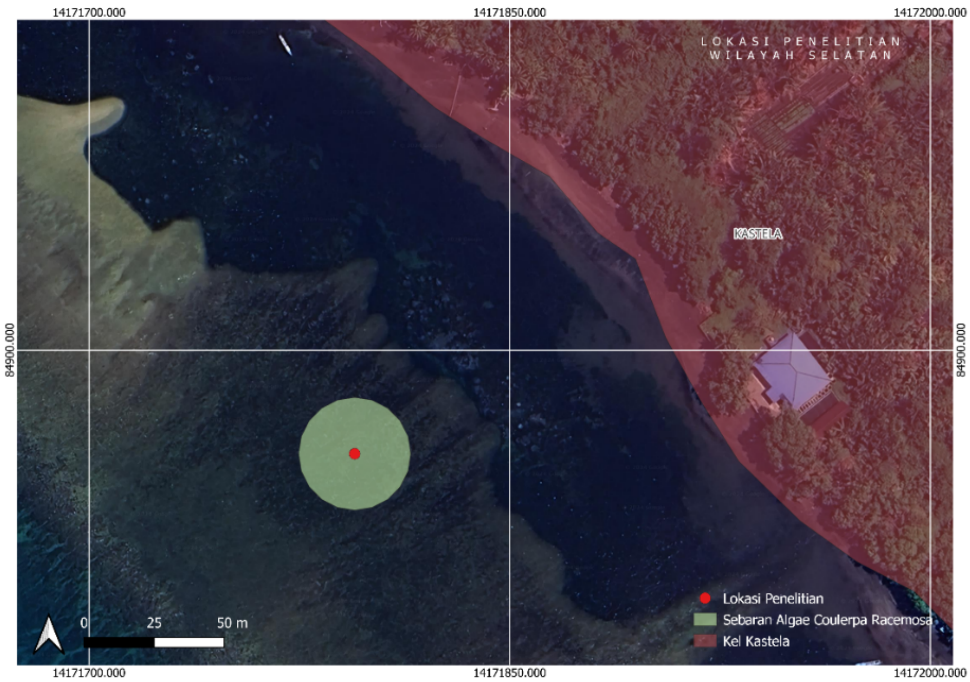

Figure 6. Distribution Pattern *of C racemoca* in the waters of Castela Beach

Dissolved oxygen (DO) concentration affects the metabolic processes of marine species (Aditya *et al*, 2023; Long *et al*, 2024). At Station 1, higher (DO) levels (6.03 mg/L) supported aerobic respiration essential for intensive metabolic activities, thus increasing the colonization potential of *C.* racemosa (Aditya *et al*, 2023). In contrast, lower (DO) concentrations at Station 2 (5.21 mg/L) may limit metabolic processes, thereby affecting the distribution of the species (Aditya *et al*, 2023). The pH values recorded at both stations (8.22 at Station 1 and 8.31 at Station 2) support optimal photosynthesis by providing carbonate ions necessary for macroalgal growth. However, the interaction of temperature, salinity, and (DO) at Station 2 may lead to cumulative stresses that inhibit macroalgae distribution (Huang *et al*, 2023; Wu *et al*, 2023).

Ecologically, uniform distribution patterns among macroalgae indicate efficient spatial utilization and minimal interspecies competition, especially under stable environmental conditions (Singh *et al*, 2021). However, the lower distribution index values at Station 2 reflect higher environmental stress, both due to anthropogenic influences and natural variability (Clausing & Fong, 2016). The integration of abiotic factor analysis, including spatial structure and environmental gradients, is essential for identifying stressed habitats and establishing effective conservation strategies (Lemley *et al*, 2021). This approach provides a foundation for improving macroalgae conservation strategies in the face of increasingly complex environmental challenges (Fulton *et al*, 2019).

Figure 7. Distribution pattern of *C. racemosa* in Gamalama coastal waters

Water quality and its effect on *caulerpa racemosa*

Water quality parameters, such as salinity, temperature, dissolved oxygen (DO), and pH, play a key role in determining the ecological conditions and distribution of macroalgae, including *Caulerpa racemosa*. These parameters directly affect the physiological processes of algae, with optimal pH (6.81-8.33) and sufficient (DO) concentrations required to support healthy algal growth (Buana *et al*, 2024; Phelps, 2016; Sáez *et al*, 2023). Salinity and temperature also influence osmoregulation, metabolism, and distribution patterns of macroalgae, as reflected in the significant relationships between water quality and ecological indicators (Ferrer-Ledo *et al*, 2023; Pang *et al*, 2023; Z. Wang *et al*, 2024).

Temperature significantly affects the metabolism and photosynthesis of *C. racemosa*. At high temperatures (31°C), physiological activity increases, which favors algal distribution and density. However, lower temperatures (29°C) can limit metabolic efficiency, thereby reducing growth (Kumari *et al*, 2015; Nunes & Camargo, 2020). Temperatures outside the optimal range (28-30°C) can cause thermal stress, decrease photosynthesis, and inhibit metabolic performance (Angell *et al*, 2015; Karsten, 2012). For example, *Picochlorum sp.* showed decreased photosynthetic efficiency at high temperatures, despite its increased phagotrophic activity, reflecting a complex adaptive response to temperature change (Karsten, 2012).

Table 3. Results of water quality measurements *of C racemosa*.

No	Criterion	Location	
		Site 1	Site 2
1	Salinity (ppm)	30	23,69
2	Ph	8,22	8,31
3	DO (mg/L)	6,03	5,21
4	Temperature (^{0}C$^)$	31	29
5	Brightness (m)	1,5	1,5

Salinity affects the osmoregulatory capacity and metabolism of algae. *C. racemosa* shows optimal growth at 30 ppt salinity, while physiological stress occurs at 23.69 ppt, due to impaired ion balance and decreased nutrient uptake (Liu *et al*, 2022; J.-J. Wang *et al*, 2024). In *Ulva ohnoi*, higher salinity is associated with increased levels of amino acids, which are important for osmoregulatory adaptations (Liqoarobby *et al*, 2021). These metabolic adaptations, such as the synthesis of salinity-responsive osmolytes and proteins, support the ability of algae to survive in extreme salinity conditions (James *et al*, 2022; Yadollahi *et al*, 2023).

DO is essential for aerobic respiration and supports a healthy aquatic ecosystem. Higher (DO) at Station 1 (6.03 mg/L) promoted *C. racemosa* growth compared to Station 2 (5.21 mg/L), which may indicate hypoxic conditions, limiting algal growth and increasing the risk of eutrophication (Becherucci *et al*, 2021; Houngnandan *et al*, 2019). (DO) anomalies highlight the importance of sustainable management to prevent ecosystem degradation (Katsanevakis *et al*, 2010).

Moderate pH conditions (8.22 at Station 1 and 8.31 at Station 2) favor photosynthesis, increase carbonate ion availability, and promote algal growth (Bernardeau-Esteller *et al*, 2011). Alkaline environments also favor lipid accumulation, as demonstrated in microalgae with increased pH promoting photosystem efficiency and mitigating coastal acidification (Chandler, 1942).

Uniform water clarity (1.5 meters) facilitated algal photosynthesis. However, variations in temperature, salinity and (DO) determine the distribution pattern of *C. racemosa*. Research shows the adaptive ability of *C. racemosa* to variations in light intensity, which enhances its success in diverse ecosystems (Muhaemin *et al*, 2022; Najamuddin *et al*, 2023). Thus, studies on the interaction of water clarity with other environmental parameters are essential to understand the distribution dynamics of macroalgae (Buana *et al*, 2024; Chauhan *et al*, 2022).

Synthesis and implications

The integration of environmental parameters with biological observations revealed that C. racemosa thrived optimally at Station 1 in Ternate waters, characterized by favorable conditions such as higher temperature, salinity, and dissolved oxygen (DO) levels, which correlated with increased species density. In contrast, Station 2 presented environmental constraints, especially lower salinity and (DO), which adversely affected the ecological performance of C. racemosa, leading to reduced density and distribution. This pattern is in line with findings on the influence of oceanographic parameters on marine life, where variations in temperature and salinity significantly impact species distribution and health, as evidenced in studies of coral bleaching and macroalgal diversity in coastal ecosystems (Holman *et al*, 2013; Singh *et al*, 2021; Smyth & Elliott, 2016).

The study found that measurable management interventions are needed to reduce environmental stress at Station 2, particularly through monitoring salinity fluctuations and improving water circulation. Salinity is a key factor influencing the distribution and health of aquatic ecosystems, as it affects the physiological tolerance of various species, with euryhaline organisms benefiting from lower salinity while stenohaline species face stress (Clausing & Fong, 2016). Effective management strategies, such as spatially targeted water level adjustments, can significantly reduce salinity impacts in coastal aquifers, improving ecological balance (Fulton *et al*, 2019). In addition, maintaining homogeneous environmental conditions is essential to support macroalgal growth, which is critical for ecosystem resilience (Fulton *et al*, 2019; Lemley *et al*, 2021). Implementing catchment-scale interventions, such as restoring hydrodynamic variability, can also improve biodiversity and ecosystem health in affected areas (Ji & Gao, 2021).

Findings regarding the ecological dynamics of macroalgae, particularly C. racemosa, demonstrate the significant influence of abiotic factors such as nutrient availability, temperature, and ocean acidification on their growth and community structure in tropical marine ecosystems. Research shows that nutrient limitation can shift rapidly between nitrogen and phosphorus depending on environmental conditions, highlighting the complexity of nutrient dynamics in these ecosystems (Lapa *et al*, 2024; Tetali *et al*, 2024; Zaragoza-Esquerdo *et al*, 2024). In addition, climate change factors, including ocean warming and UV radiation, may promote growth in some macroalgal species while adversely affecting others, especially calcifying species that are sensitive to acidification (Phelps, 2016). These insights are critical for developing evidence-based conservation strategies aimed at conserving biodiversity and sustaining ecosystem services, as they emphasize the need for habitat connectivity and adaptive management in response to ongoing environmental changes (Ji *et al*, 2016). Future research should focus on long-term monitoring of environmental parameters and their interactions with macroalgal physiology, incorporating advanced methodologies such as remote sensing and molecular analysis. Such an approach could improve our understanding of macroalgal ecology and inform adaptive management practices in response to changing environmental conditions.

Conclusion

The density and distribution pattern of C. *racemosa* were significantly influenced by environmental parameters such as temperature, salinity, dissolved oxygen (DO), and pH. Station 1 with a temperature of 31°C, salinity of 30 ppt, (DO) 6.03 mg/L, and pH 8.22 showed optimal conditions for C. racemosa proliferation, with a density of 2.40 individuals/m² and a uniform distribution reflecting a favorable habitat. In contrast, Station 2 with a temperature of 29°C, lower salinity of 23.69 ppt, (DO) 5.21 mg/L, and pH 8.31 experienced higher environmental stress, resulting in a lower density of 1.85 individuals/m² and a more restricted distribution.

Water quality parameters have a significant role in determining the physiological and ecological adaptations of these macroalgae. Optimal temperature (28-30°C) supports metabolism and photosynthesis, while stable salinity allows efficient osmoregulation. Lower (DO) variation at Station 2 may trigger physiological stress, limiting macroalgal growth and distribution. Uniform distribution patterns indicate efficient habitat utilization under stable environmental conditions. Whereas lower distribution index values reflect environmental stress due to anthropogenic and natural factors.

This study emphasizes the importance of integrating abiotic factor analysis in the sustainable management of coastal ecosystems, while providing critical insights for developing conservation strategies in the face of complex environmental change.

Acknowledgment

The author would like to thank Khairun University for funding this research through the PKUPT scheme of the Faculty of Fisheries and Maritime Affairs in 2024.

Reference

Aditya, L, Vu, H. P, Abu Hasan Johir, M, Mahlia, T. M. I, Silitonga, A. S, Zhang, X, Liu, Q, Tra, V. T, Ngo, H. H, & Nghiem, L. D. 2023. Role of culture solution pH in balancing CO2 input and light intensity for maximising microalgae growth rate. *Chemosphere*, *343* (140255). https://doi.org/10.1016/j.chemosphere.2023.140255

Agdialta, R, F. S. Ariwibaowo, I. M. Radjawane, L.I. Bernawis.2023. Karakteristik suhu dan salinitas vertikal terhadap massa air selama periode IOD (+), IOD (-), musim barat, dan musim timur di Selat Mentawai. Maspari Journal: Marine Science Research, 15(1): 41–54. https://doi.org/10.56064/maspari.v15i1.21

Akbar, S. A., A. N. Lestari, R. R. Fazli, G. Gunawan. 2025a. Harnessing macroalgae for heavy metal phytoremediation: a sustainable approach to aquatic pollution control. BIO Web of Conferences, 156: 02013.

Akbar, S. A., M. Hasan. 2024. Evaluation of bioactive composition and phytochemical profile of macroalgae Gracilaria edulis and Acanthophora spicifera from the Banda Aceh Coast, Indonesia. Science & Technology Asia, 29(1): 194–207.

Akbar, S. A., M. Hasan, S. Afriani, C. Nuzlia. 2023. Evaluation of phytochemical composition and metabolite profiling of macroalgae Caulerpa taxifolia and C. peltata from the Banda Aceh coast, Indonesia. Biodiversitas Journal of Biological Diversity, 24(10): 5283–5292.

Akbar, S. A., M. Hasan, S. Afriani, C. Nuzlia. 2025b. Phytochemical profiling of H. durvillei ethanol extract and the potential activity as antibacterial agents on fish. Asia Pacific Journal of Science and Technology, 30(3): 1–11.

Ali, B, A. Mishra. 2022. Effects of dissolved oxygen concentration on freshwater fish: A review. International Journal of Fisheries and Aquatic Studies, 10 (4) : 113–127. https://doi.org/10.22271/fish.2022.v10.i4b.2693

Angell, A. R, L. Mata, R. de Nys, N.A. Paul. 2015. Indirect and direct effects of salinity on the quantity and quality of total amino acids in Ulva ohnoi (Chlorophyta). Journal of Phycology, 51 (3) : 536–545. https://doi.org/10.1111/jpy.12300

Asriani, N, I. A. Tasanbaramo, A. Pariakan, M. Gazali. 2024. Preliminary study: macroalgae species in Tanggetada Village Waters, Kolaka Regency, Southeast Sulawesi. Jurnal Ilmiah Platax, 12 (2) : 189–198. https://doi.org/10.35800/jip.v12i2.57617

Basyuni, M, M. Puspita, R. Rahmania, H. Albasri, I. Pratama, D. Purbani, A.A. Aznawi, A.Mubaraq, S.S. Al Mustaniroh, F.Menne, Y.I. Rahmila, S.G. Salmo, A. Susilowati, S.H. Larekeng, E. Ardli, T. Kajita. 2024. Current biodiversity status, distribution, and prospects of seaweed in Indonesia: A systematic review. Heliyon, 10 (10) : https://doi.org/10.1016/j.heliyon.2024.e31073.

Becherucci, M. E, P. Pereyra, M. Narvarte, E. Fanjul, O. Iribarne, P.Martinetto.2021. Tidal action and macroalgal photosynthetic activity prevent coastal acidification in an eutrophic system within a semi-desert region. Estuarine, Coastal and Shelf Science, 256,

107374.
Bernardeau-Esteller, J, L. Marín-Guirao, J. M. Sandoval-Gil, J.M. Ruiz. 2011. Photosynthesis and daily metabolic carbon balance of the invasive Caulerpa racemosa var. cylindracea (Chlorophyta: Caulerpales) along a depth gradient. Scientia Marina, 75 (4) : 803–810. https://doi.org/10.3989/scimar.2011.75n4803
Brower, J. E, , J. H.Zar, C. Von Ende. 1990. General ecology. field and laboratory methods. Wm. C. Brown Company Publisher, Dubuque, Lowa.
Brower, J, J. Zar.1977. Field and laboratory methods for general ecology brown Co. In Pub, lowa, USA, 194pp. WCB McGraw-Hill Boston. https://scholar.google.com/scholar?q=brower+zar&btnG=&hl=en&as_sdt=0%2C5#5
Buana, M. C, W. Patty, R. O. S. E. Mantiri. J. Budiman, J. R. T. S. L. Rimper, J. K. Rangan, D.A. Sumilat. 2024. Spatial And Temporal Analysis Of Sea Surface Temperature Variability And Chlorophyll-A Over Two Decades In North Sulawesi Waters. Jurnal Ilmiah Platax, 12 (2): 139–145. https://doi.org/10.35800/jip.v12i2.55621
Cebrian, E, E. Ballesteros. 2009. Temporal and spatial variability in shallow- and deep-water populations of the invasive Caulerpa racemosa var. cylindracea in the Western Mediterranean. Estuarine, Coastal and Shelf Science, 83 (4) : 469–474. https://doi.org/10.1016/j.ecss.2009.04.026
Chandler, D. C. 1942. Limnological Studies of Western Lake Erie: II. Light Penetration and Its Relation to Turbidity. Ecology, 23 (1) : 41–52. https://doi.org/10.2307/1930871
Chauhan, P. K, S.K. Upadhyay, M. Tripathi, R. Singh, D. Krishna, S.K. Singh, P. Dwivedi. 2022. Understanding the salinity stress on plant and developing sustainable management strategies mediated salt-tolerant plant growth-promoting rhizobacteria and crispr/Cas9. Biotechnology and Genetic Engineering Reviews, 39(2): 311-347.
Clausing, R. J, P. Fong. 2016. Environmental variability drives rapid and dramatic changes in nutrient limitation of tropical macroalgae with different ecological strategies. Coral Reefs, 35 (2) : 669–680. https://doi.org/10.1007/s00338-016-1403-6
Darmawan, M, Putri Zamani, N, Eko Irianto, H, & H. Madduppa, H. 2022. Diversity and abundance of green seaweed Caulerpa (Chlorophyta) across Indonesian coastal waters with different nutrient levels: Bintan Island, Jepara, and Osi Island. Jurnal Ilmu dan Teknologi Kelautan Tropis, 14 (2) : 273–290. https://doi.org/10.29244/jitkt.v14i2.37745
Edworthy, C, P.P. Steyn, N.C. James. 2023. The role of macroalgal habitats as ocean acidification refugia within coastal seascapes. Cambridge Prisms: Coastal Futures, 1, e22. https://doi.org/10.1017/cft.2023.9
English, S, C. Wilkinson, V. Baker. 1997. Survey manual for tropical marine resources.
Ferrer-Ledo, N, L. Stegemüller, M. Janssen, R.H. Wijffels, M.J. Barbosa. 2023. Growth and fatty acid distribution over lipid classes in Nannochloropsis oceanica acclimated to different temperatures. Frontiers in Plant Science, 14 : 1078998. https://doi.org/10.3389/fpls.2023.1078998
Fulton, C. J, R. A. Abesamis, C. Berkström, M. Depczynski, N. A. J. Graham, T.H. Holmes, M. Kulbicki, M.M. Noble, B.T. Radford, S. Tano, P. Tinkler, T.Wernberg, S.K. Wilson 2019. Form and function of tropical macroalgal reefs in the Anthropocene. Functional Ecology, 33 (6) : 989–999. https://doi.org/10.1111/1365-2435.13282
Holman, I. P, K. R. Rushton, T.B. Simpson. 2013. The benefits of spatially targeted water level management for salinity reduction in a coastal aquifer. Water Resources Management, 27 (1) : 169–186. https://doi.org/10.1007/s11269-012-0175-1
Houngnandan, F, J. Deter, S. Kefi. 2019. How anthropogenic pressures and environmental variables influence the spatial configuration of the seagrass Posidonia oceanica in France? Oceans 2019 - Marseille, Oceans Marseille 2019, 2019-June, 1–7. https://doi.org/10.1109/OCEANSE.2019.8867163
Huang, E, Y. Chen, S. Yu. 2023. Climate factors drive plant distributions at higher taxonomic scales and larger spatial scales. Frontiers in Ecology and Evolution, 11, 1233936. https://doi.org/10.3389/fevo.2023.1233936
James, N. C, A. K. Whitfield. 2023. The role of macroalgae as nursery areas for fish species within coastal seascapes. Cambridge Prisms: Coastal Futures, 1, e3. https://doi.org/10.1017/cft.2022.3
James, R. K, C. D. Hepburn, D. Pritchard, D.K. Richards, C.L. Hurd. 2022. Water motion and pH jointly impact the availability of dissolved inorganic carbon to macroalgae. Scientific Reports, 12 (1) : 21947. https://doi.org/10.1038/s41598-022-26517-z
Ji, Y, K. Gao. 2021. Effects of climate change factors on marine macroalgae: A review. Advances in Marine Biology, 88, 91–136. https://doi.org/10.1016/bs.amb.2020.11.001
Ji, Y, Z. Xu, D. Zou, K. Gao. 2016. Ecophysiological responses of marine macroalgae to climate change factors. Journal of Applied Phycology, 28 (5) : 2953–2967. https://doi.org/10.1007/s10811-016-0840-5
Kalalembang, D, D. R. H. Kumampung, E.D. Angkouw, R. A. J. Lintang, M. T. Lasut, S. Darwisito. 2024. Study of the existence of algae, diversity of species, density, and distribution patterns in Meras waters. Jurnal Ilmiah Platax, 12 (2) : 163–170. https://doi.org/10.35800/jip.v12i2.52979
Karsten, U. 2012. Seaweed Acclimation to Salinity and Desiccation Stress. In Seaweed biology: Novel insights into ecophysiology, ecology and utilization. Springer, New York (pp. 87–107). https://doi.org/10.1007/978-3-642-28451-9_5
Katsanevakis, S, M. Salomidi, A. Panou. 2010. Modelling distribution patterns and habitat preference of the invasive green alga Caulerpa racemosa in the Saronikos Gulf (Eastern Mediterranean). Aquatic Biology, 10 (1): 57–67. https://doi.org/10.3354/ab00267
Kumari, A, P. Das, A.K. Parida, P.K. Agarwal. 2015. Proteomics, metabolomics, and ionomics perspectives of salinity tolerance in halophytes. Frontiers in Plant Science, 6 (JULY): 537. https://doi.org/10.3389/fpls.2015.00537
Lapa, K, E. Meli, K. Lushnjari. 2024. Assessment of water quality in vlora bay by measuring physico-chemical parameters. Časopis Pomorskog Fakulteta Kotor - Journal of Maritime Sciences, 25 (1) : 111–119. https://doi.org/10.56080/jms240508
Lemley, D. A, S. J. Lamberth, W. Manuel, M. Nunes, G.M. Rishworth, L. van Niekerk, J.B. Adams. 2021. Effective management of closed hypereutrophic estuaries requires catchment-scale interventions. Frontiers in Marine Science, 8, 688933. https://doi.org/10.3389/fmars.2021.688933
Liqoarobby, R, Sunardi, Y.Suparman, K. Fadilah. 2021. Aqueous Systems of dissolved oxygen in reservoir. paper presented at the 10th International Conference on Sustainability Science (CSS2020) 7 April, Bandung, Indonesia. Paper available at https://www.e3s-conferences.org/articles/e3sconf/pdf/2021/25/e3sconf_css2021_03015.pdf. https://doi.org/10.1051/e3sconf/202124903015
Liu, J, W. Yin, X. Zhang, X. Xie, G.Dong, Y. Lu, B. Tao, Q. Gong, X. Chen, C. Shi, Y. Qin, R. Zeng, D. Li, H. Li, C. Zhao, H. Zhang. 2022. RNA-seq analysis reveals genes related to photosynthetic carbon partitioning and lipid production in Phaeodactylum tricornutum under alkaline conditions. Frontiers in Microbiology, 13, 969639. https://doi.org/10.3389/fmicb.2022.969639
Long, C, Y. Zhang, Z. Wei, L. Long. 2024. High nutrient availability modulates photosynthetic performance and biochemical components of the economically important marine macroalga Kappaphycus alvarezii (Rhodophyta) in response to ocean acidification. Marine Environmental Research, 194 (106339). https://doi.org/10.1016/j.marenvres.2023.106339
Mayakun, K, S. Prathep. 2023. Distribution and diversity of macroalgae in seagrass and coral reef ecosystems on the coast. Bioeduscience, 7 (3) : 326–332. https://doi.org/10.22236/jbes/12402
Muhaemin, M, T.Arifin, N. Mahdafikia, H. Fihrin. 2022. Pengaruh parameter oseanografi fisik terhadap indikasi pemutihan karang (coral bleaching) di taman wisata perairan (TWP) Kapoposang Spermonde Selat Makassar. Journal of Marine Research, 11 (4) : 587–597. https://doi.org/10.14710/jmr.v11i4.33401
Najamuddin, H. Umasangaji, H. Herawati, I. Tahir, N. Akbar, R.E. Paembonan, F. Ismail. 2023. Tingkat pencemaran perairan pantai Kota Ternate berdasarkan bioindikator fitoplankton. Jurnal Ilmu Kelautan Kepulauan, 6 (1) : 788–802. https://doi.org/10.33387/jikk.v6i1.6455
Nunes, L. S. C, A. F. M. Camargo.2020. Effects of salinity on growth,

competitive interaction and total nitrogen content of two estuarine macrophyte species cultivated on artificial substrate. Aquatic Ecology, 54 (4) : 973–983. https://doi.org/10.1007/s10452-020-09787-5
Pang, M, K. Liu, Z. Gao, C. Kang, H.Liu. 2023. Temperature-light shapes the nutritional strategy of a mixotrophic green alga, Picochlorum sp. GLMF1 (Trebouxiophyceae). Marine Ecology Progress Series, 713: 39–53. https://doi.org/10.3354/meps14322
Phelps, C.2016. Predicting the impact of future climate on ecologically important macroalgae. School of Science, MSc thesis.
Pulukadan, I, R. C. Keppel, G. S. Gerung. 2013. A study on bioecology of macroalgae, genus Caulerpa in northern Minahasa Waters, North Sulawesi Province. Aquatic Science & Management, 1 (1) : 26. https://doi.org/10.35800/jasm.1.1.2013.1965
Tetali, R.R, K. Salomi, G. BNV Sai Durga, P. Sharon Pushpa, E.R. Gope. 2024. Analysis of water quality parameters across diverse sources. Journal of Pharma Insights and Research, 2 (3) : 210–216. https://doi.org/10.69613/3jxm7e23
Rashedy, S. H, S. M. El-Mahdy, I. M. El-Manawy, L. Pereira. 2022. Spatial and temporal variations of macroalgal vegetation in the north-western Red Sea. Botanica Marina, 65 (6) : 405–418. https://doi.org/10.1515/bot-2022-0046
Rodrigues-Filho, J. L, R.L. Macêdo, H. Sarmento, V. R. A. Pimenta, C. Alonso, C. R. Teixeira, P. R. Pagliosa, S. A. Netto, N. C. L. Santos, F. G. Daura-Jorge, O. Rocha, P. Horta, J. O. Branco, R. Sartor, J. Muller, V. M. Cionek. 2023. From ecological functions to ecosystem services: linking coastal lagoons biodiversity with human well-being. Hydrobiologia, 850 (12–13): 2611–2653. https://doi.org/10.1007/s10750-023-05171-0
Sáez, C. A, M. Troncoso, C. Navarrete, F. Rodríguez-Rojas, N. Navarro, A. Trabal, C. Lavergne, D. Pardo, M.T. Brown, I. Gómez, F. L. Figueroa, P. S. M. Celis-Plá. 2023. Photoprotective responses of three intertidal Antarctic macroalgae to short-term temperature stress. Frontiers in Marine Science, 10: (1223853). https://doi.org/10.3389/fmars.2023.1223853
Samman, A, M. J. Achmad. 2023. Diversitas dan distribusi alga merah (Rhodophyta) di Perairan Pulau Ternate. Jurnal Kelautan Tropis, 26 (1) : 148–154. https://doi.org/10.14710/jkt.v26i1.13342
Singh, G. G, J. Rhodes, E. McDonald-Madden, H. P. Possingham, E. Hammill, C. C. Murray, M. Mach, R. Martone, B. Halpern, T. Satterfield. 2021. Prioritizing management for cumulative impacts. BioRxiv, 2010–2021. https://doi.org/10.1101/2021.10.07.463502
Smyth, K, M. Elliott. 2016. Effects of changing salinity on the ecology of the marine environment. Stressors in the Marine Environment, 161–174. https://doi.org/10.1093/acprof:oso/9780198718826.003.0009
Srimariana, E. S, M. Kawaroe, D. F. Lestari, A. H. Nugraha. 2020. Biodiversity and utilization potency of macroalgae at Tunda Island. Jurnal Ilmu Pertanian Indonesia (JIPI), Januari, 25 (1) : 138–144. http://journal.ipb.ac.id/index.php/JIPI
Storz, M. A. 2024. Macroalgae as alkalizing marine drugs with a low potential renal acid load. Journal of Food Biochemistry, 2024 (1) 1-11: https://doi.org/10.1155/2024/9683391
Sun, Y, W. Guo, F. Wang, F. Peng, Y. Yang, X. Dai, X. Liu, Z. Bai. 2016. Transcriptome and multivariable data analysis of Corynebacterium glutamicum under different dissolved oxygen conditions in bioreactors. PLoS ONE, 11 (12) : 1-17. https://doi.org/10.1371/journal.pone.0205785
Turangan, S, R. C. Kepel, S. V. Mandagi, R. O. S. E. Mantiri, F. S. I. Menajang, A. D. Kambey. 2024. Macroalgae communities in the waters of Tateli Village, Mandolang, and Mokupa Village Waters, Tombariri, Minahasa District, North Sulawesi Province. Jurnal Ilmiah PLATAX, 12 (1) : 164–170. https://doi.org/10.35800/jip.v12i1.49441
Ulaş, A, F.O. Düzbastilar, C. Aydin, A. Lök, C. Metin. 2011. Determining density of caulerpa racemosa (Forsskål) J. Agardh and its effects on catch compositions of fishing gears. Turkish Journal of Fisheries and Aquatic Sciences, 11 (3) : 385–391. https://doi.org/10.4194/trjfas.2011.030
Wang, J.J, X. J. Ma, H. Zheng, S. J. Yu, H. Xu, H. J. Feng. 2024. Review on mechanism and remediation strategies of dissolved oxygen abnormal in surface water. Ying Yong Sheng Tai Xue Bao= The Journal of Applied Ecology, 35 (2) : 523–532. DOI: 10.13287/j.1001-9332.202402.029
Wang, Z, S. Tong, D. Xu, X. Huang, Y. Sun, B. Wang, H. Sun, X. Zhang, X.Fan, W. Wang, K. Sun, Y. Wang, P. Zhang, Z. Gu, N.Ye. 2024. Effects of temperature and nitrogen sources on physiological performance of the coccolithophore Emiliania huxleyi. Marine Environmental Research, 196: 106405. https://doi.org/10.1016/j.marenvres.2024.106405
Wu, H, C. Wang, H. Li, J. Chen, J. Zhang, Z. Luo, F. Cheng, J. Xu. 2023. High light intensity and co2 enrichment synergistically mitigated the stress caused by low salinity in pyropia yezoensis. Journal of Marine Science and Engineering, 11 (11) : 2193. https://doi.org/10.3390/jmse11112193
Yadollahi, F, S. Shokravi, M. Mahmoudjanlo, M. Ebadi. 2023. The effect of short term alkalinity on photosynthesis apparatus in soil Cyanobacterium Fischerella sp. FS 18 – Ecophysiological Approach. International Journal on Algae, 25 (1) : 95–106. https://doi.org/10.1615/InterJAlgae.v25.i1.60
Yang, F, Z. Wei, L. Long. 2021. Transcriptomic and physiological responses of the tropical reef calcified macroalga amphiroa fragilissima to elevated temperature. Journal of Phycology, 57 (4) : 1254–1265. https://doi.org/10.1111/jpy.13158
Zaragoza-Esquerdo, M, A. Ivars-Palomares, L. Parra, S. Sendra, J. Lloret, M. Pulido-Velazquez. 2024. Underwater IoT system for water quality monitoring at the marine outfall. 2024 11th International Conference on Internet of Things: Systems, Management and Security, IOTSMS 2024: 248–253. https://doi.org/10.1109/IOTSMS62296.2024.10710263

How to cite this paper:
Andriani, R., M. J. Achmad, Najamuddin, S. S. Titaheluw. 2025. Identification of the distribution pattern of macroalgae Caulerpa racemosa in Ternate City. Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan, Special Issue The 5th ICFM: 179–189.