Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(2): 897 – 916 (2025)
www.ejabf.journals.ekb.eg

Daily Dynamics of Water Parameters in Tanjung Tiram, Ambon Bay: Implications for Mangrove Ecosystems and Aquaculture Activities

Juliana W. Tuahatu[1], Maureen M. Pattinasarany[2], Harold J. D. Waas[1], Elizabeth M. Palinussa[2], Rahman[1*]

[1]Department of Marine Science, Faculty of Fisheries and Marine Science, Pattimura University, Maluku, Indonesia

[2]Department of Aquaculture, Faculty of Fisheries and Marine Science, Pattimura University, Maluku, Indonesia

*Corresponding author: rahmanrajaali@gmail.com

ARTICLE INFO

Article History:
Received: Feb. 26, 2025
Accepted: March 15, 2025
Online: March 18, 2025

Keywords:
Ambon Bay,
Daily fluctuation,
Real-time monitoring,
Water quality monitoring system (WQMS),
Water parameter

ABSTRACT

This study analyzed the daily fluctuations of water parameters in Tanjung Tiram, Ambon Bay, and their implications for the mangrove ecosystem and aquaculture activities. Monitoring was conducted using a real-time system based on a WQMS sensor connected to a digital cloud from October to December 2024. The parameters observed included temperature, salinity, pH, dissolved oxygen (DO), and nitrite. The results showed that the temperature ranged from 29.86 to 31.58°C, with an increase during the day and a decrease at night. Salinity fluctuated between 31.26–34.65 PSU, influenced by tidal movements and rainfall. pH demonstrated relative stability within the range of 8.07–8.33, with an increase during the day due to photosynthesis. DO exhibited significant fluctuations, with the highest value of 8.67mg/ L in October and a drastic decrease to 2.79mg/ L in December, indicating potential hypoxia. Nitrite concentrations increased from morning to afternoon, peaking at 0.52mg/ L in December due to elevated nutrient runoff. These fluctuations have implications for the stability of the mangrove ecosystem, with risks of eutrophication and hypoxia that may disrupt aquatic biota balance. In aquaculture, changes in DO and nitrite levels could potentially increase physiological stress on fish. Therefore, the recommendations include regular monitoring, mangrove ecosystem conservation, and the implementation of additional aeration and waste management to maintain the balance of coastal ecosystems and the sustainability of aquaculture in Tanjung Tiram.

INTRODUCTION

Coastal waters exhibit complex environmental dynamics due to the influence of various physical, chemical, and biological factors. One important aspect of coastal ecosystems is the daily, weekly, and seasonal changes in water parameters **(Alongi, 2008)**. The daily dynamics of water parameters, such as temperature, salinity, dissolved oxygen, nitrite, and pH, can provide insights into ecosystem stability and its potential to support aquatic life **(Hogarth, 2007)**. Studies on the variability of water parameters are crucial for understanding how coastal ecosystems adapt to environmental changes, particularly in areas with a high anthropogenic activity **(Syafrizal & Rasyid, 2021)**.

Tanjung Tiram, located in Ambon Bay, is one of the coastal areas with an unhealthy mangrove ecosystem dominated by *S. alba* and *R. stylosa* **(Suyadi, 2009; Latumahina *et al.*, 2024)** and is highly vulnerable to anthropogenic activities that can trigger greenhouse gas emissions **(Kesaulya & Rahman, 2023; Kesaulya *et al.*, 2023; Tubalawony *et al.*, 2024)**. Mangrove ecosystems play significant ecological roles, such as providing habitats, carbon sequestration, and coastal protection from erosion and waves **(Duke *et al.*, 2007; Rahman *et al*,. 2020)**. However, changes in water parameters due to tidal influences, rainfall, and human activities can affect the sustainability of these ecosystem functions **(Kathiresan & Bingham, 2001)**. Therefore, studying the daily dynamics of water parameters in Tanjung Tiram is essential for evaluating environmental stability and its impact on the mangrove ecosystem.

In addition to the mangrove ecosystem, the waters of Tanjung Tiram are also used for aquaculture activities, such as floating net cages. Aquaculture activities heavily rely on environmental quality, particularly stable physical-chemical water parameters that support the growth of cultured organisms **(Boyd & Tucker, 1998)**. Factors such as temperature changes, dissolved oxygen levels, and turbidity can impact the productivity and health of cultured organisms **(Hargreaves & Tucker, 2003)**. Thus, monitoring the daily dynamics of water parameters is a key step in supporting the sustainability of aquaculture activities in this area.

The influence of tides on water parameters is also an important aspect to consider in this study. Tides are a major factor causing fluctuations in water parameters in coastal areas **(Alongi, 2008)**. This process contributes to changes in salinity, temperature, dissolved oxygen, and sedimentation, which can directly impact mangrove ecosystems and aquaculture activities. Previous studies have shown that tidal variations can affect nutrient distribution and plankton abundance in coastal waters **(Kjerfve, 1990)**. Therefore, analyzing the dynamics of water parameters in relation to tides in Tanjung Tiram is a crucial aspect of this study.

In addition to hydrodynamic factors, changes in water quality can also be influenced by anthropogenic activities. The disposal of domestic and industrial waste, as well as by-products from aquaculture activities, can lead to increased nutrient levels, which may decrease water quality and trigger eutrophication **(Galloway *et al.*, 2008)**. The sustainability of coastal ecosystems and the success of aquaculture depend on maintaining a balance in environmental parameters. Therefore, a comprehensive understanding of the daily dynamics of water parameters can aid in developing mitigation strategies for potential negative impacts from human activities.

The results of this study are expected to provide more detailed information on the patterns of water parameter changes in Tanjung Tiram, as well as their implications for the mangrove ecosystem and aquaculture activities. By understanding the variability of water parameters, coastal management can be conducted more effectively and based on scientific data. This study can also serve as a foundation for formulating sustainable environmental management policies for coastal ecosystems in Ambon Bay.

MATERIALS AND METHODS

1. Description of the study sites and data sampling

This study was conducted from October to December 2024 in the waters of Tanjung Tiram, Inner Ambon Bay, Maluku, Indonesia. Tanjung Tiram is located in the inner part of Ambon Bay at 03º39'19" S and 128º12'3" E (Fig. 1). This area represents a coastal ecosystem characterized by shallow waters and fine sandy substrates. The waters of Tanjung Tiram support a multispecies seagrass meadow dominated by four main species: *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila ovalis*, and *Halodule uninervis* **(Latuconsina *et al*., 2013)**. This seagrass ecosystem plays a crucial role in providing habitat for various marine organisms, including fish, mollusks, and crustaceans, while also contributing to key ecological processes such as carbon storage and nutrient cycling **(Rugebregt *et al*., 2020)**.

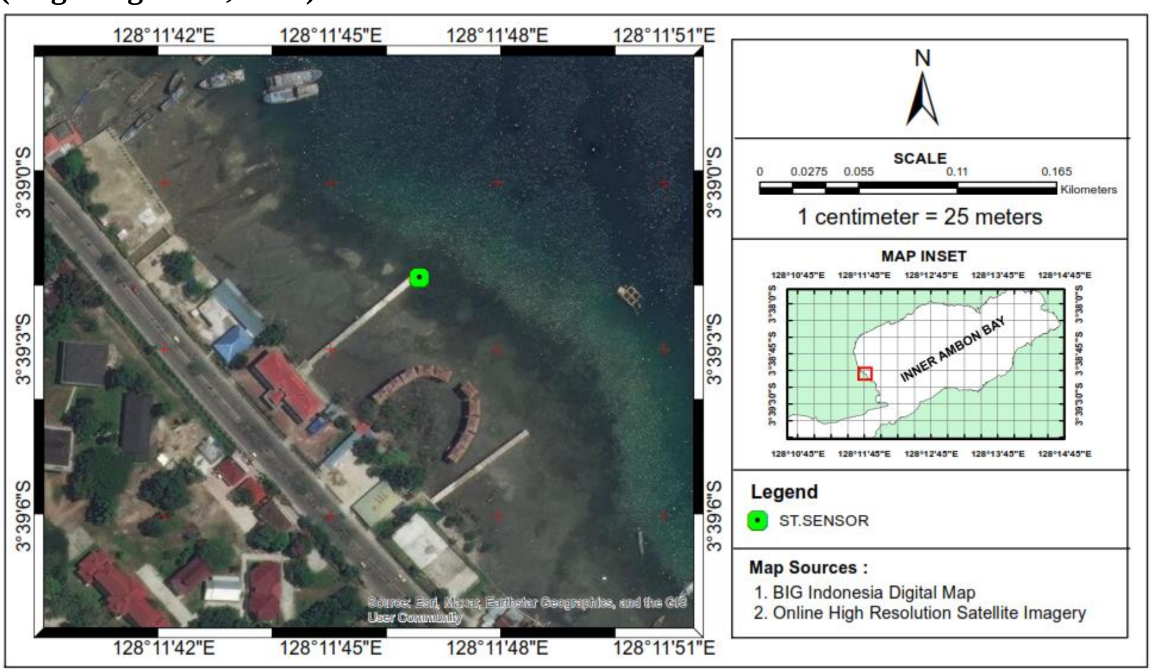

Fig. 1. Map of study sites

Geographically, Tanjung Tiram is situated at the transition zone between Inner and Outer Ambon Bay, where tidal processes strongly influence fluctuations in physicochemical water parameters. During high tide, ocean currents transport larger water masses from Outer Ambon Bay into Inner Ambon Bay, while the reverse occurs during low tide. These hydrodynamic processes affect the distribution and abundance of fish communities in the area **(Latuconsina *et al*., 2013)**.

Anthropogenic activities, including fishing, human settlements, and waste disposal, may impact the environmental quality of the waters in Tanjung Tiram. A study on waste distribution in this area found that plastic waste, such as bottles and food packaging, was the most commonly observed pollutant **(Tupan, 2016)**, along with the presence of heavy metals **(Natan *et al*., 2023)**.

2. Data sampling

This study employed a real-time water quality monitoring approach to obtain an accurate representation of the daily dynamics of water parameters in Tanjung Tiram, Teluk Ambon. Data collection was conducted over three months with measurements taken at one-minute intervals, allowing for continuous data acquisition and increased sensitivity to fluctuations in water parameters. The system used was the Water Quality Monitoring System (WQMS), equipped with various sensors to measure temperature, pH, salinity, dissolved oxygen (DO), and nitrite. These sensors enable automatic and continuous monitoring of water parameters without significant manual intervention. The Water Quality Monitoring System (WQMS), supported by PT. Indosat Ooredoo Hutchison, operates by using sensors to measure key water parameters such as pH, temperature, dissolved oxygen, and turbidity. These sensors transmit data to a processing unit, which then sends the information via a communication network to a user interface for real-time monitoring. The system is powered by solar panels or other electricity sources. Installation involves placing sensors at specific monitoring points, configuring the data transmission system, and setting up the user interface. Operation includes continuous data collection, analysis, and early warning detection.

With measurements taken every minute, the amount of data collected was substantial. Each day, there were 1,440 data points per parameter (60 minutes x 24 hours = 1,440 measurements per day). In one month (30 days), for a single parameter, the total data collected amounted to 43,200 data points (1,440 data points x 30 days). Therefore, the total data collected in one month for the five parameters measured (temperature, pH, salinity, dissolved oxygen, and nitrite) was 216,000 data points (43,200 data points x 5 parameters). Over three months, the total data accumulated reached 648,000 data points per parameter, with a total of 3,240,000 data points for all five parameters.

All data obtained from the WQMS sensors were then stored and uploaded to a cloud system connected to a digital platform. Through this system, the data can be accessed directly via the provided link (http://pantauairmangrove.id/) facilitating remote and real-time monitoring. The advantage of this cloud system is its ability to securely store large amounts of data and allow for efficient data analysis, while providing ease of access for researchers and stakeholders. The use of this platform also supports transparency and ease in sharing information with relevant parties.

The continuous monitoring process, with measurements taken every second, provides a deeper understanding of the daily variability of water parameters. Thus, this study not only examines the overall water quality conditions but also analyzes fluctuations that may occur at specific times. The utilization of real-time sensor technology and cloud-based data storage offers significant advantages in data collection and analysis, enabling the research to focus on exploring the implications of water quality dynamics on the mangrove ecosystem and aquaculture activities in the area.

3. Data analysis

To facilitate analysis and interpretation, the data presented in the graphs were daily data representing the average values of each parameter at seven predetermined measurement times each day: 06:00, 09:00, 12:00, 15:00, 18:00, 21:00, 21:00, and 24:00. These graphs depict water quality trends by showing the daily average values per month for each parameter at the specified times. Each point on the graph represented the average value of the measured parameter at a specific time of day, and the data were summarized over three months to provide a more comprehensive overview of water quality dynamics.

By analyzing the graphs, which encompass daily data over three months, it is expected to identify fluctuations in water quality and significant changes in each parameter over time. This allows for the observation of monthly differences and the analysis of factors that may influence changes in water quality, such as seasonal variations, environmental factors, or human activities around Tanjung Tiram. This method of data analysis provides deeper insights into water dynamics and their implications for the mangrove ecosystem and aquaculture activities in the area.

RESULTS AND DISCUSSION

1. Daily temperature dynamics

The results of the study indicated daily fluctuations in water temperature at the research site during the period from October to December 2024. In October, the water temperature ranged from 29.86 to 30.69°C, while in November and December, the highest temperatures recorded were 31.58 and 31.54°C, respectively, at 15:00. The lowest temperature in December was recorded at 30.88°C at 06:00 (Fig. 2).

The daily temperature fluctuation data for Tanjung Tiram, Teluk Ambon, exhibited a seasonal pattern influenced by climatic and environmental factors. In October, water temperature remained low, gradually increasing and peaking in the late afternoon before declining at night. By November, the overall temperature increased, peaking between 15:00 and 18:00, and a similar but slightly higher pattern was observed in December. This variation is likely driven by seasonal changes in solar radiation, tidal mixing, and local weather conditions such as cloud cover and rainfall. Studies on tropical coastal temperature dynamics, such as those by **Kurniawan *et al.* (2020)** support these observations, highlighting the role of seasonal shifts in influencing water temperature trends.

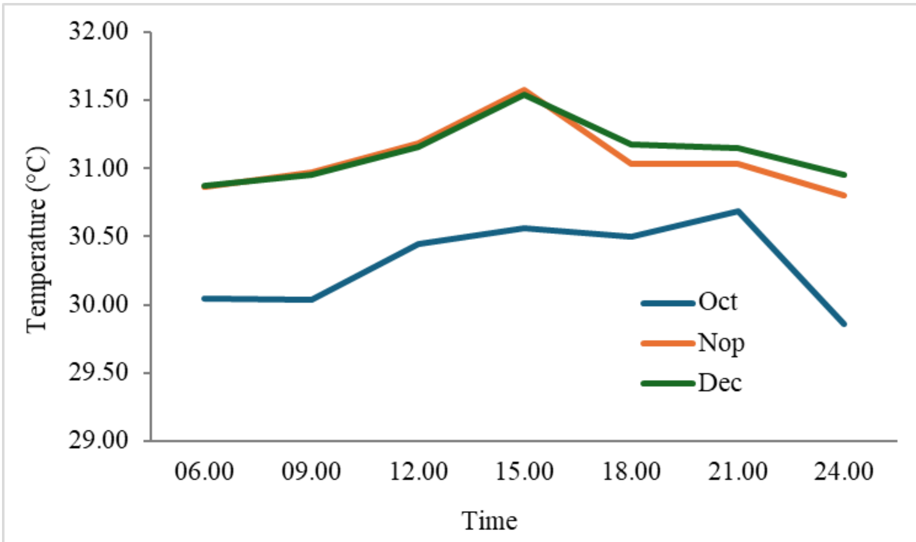

Fig. 2. Daily fluctuations in temperature of Tanjung Tiram, Ambon Bay

The increase in temperature from midday to late afternoon is driven by high solar radiation intensity, while the decrease in temperature from nighttime to early morning results from heat loss from the water column to the atmosphere. This phenomenon may also be influenced by water circulation and wind, which plays a role in heat distribution within the aquatic environment **(Wetzel, 2001)**. Higher temperatures in November and December may be associated with increased rainfall, which enhances surface water mixing and raises the average temperature of the water column.

These temperature fluctuations also impact the aquaculture activities **(Pörtner & Farrell, 2008)** and mangrove ecosystem **(Dalengkade, 2020)**. Elevated temperatures can accelerate the metabolism of aquatic organisms but may also induce thermal stress, particularly in species sensitive to sudden temperature changes. In aquaculture systems, higher temperatures can increase the oxygen consumption rate of fish, exacerbating the effects of low dissolved oxygen (DO) levels **(Schulte, 2015)**.

2. Daily salinity fluctuations

The daily salinity fluctuations in the waters of Tanjung Tiram, Ambon Bay, from October to December 2024 exhibit variation influenced by oceanographic and meteorological factors. In October, salinity ranged from 31.26 PSU (18:00) to 34.07 PSU (24:00). In November, the salinity range was higher, varying between 33.15 PSU (12:00) and 34.65 PSU (03:00). Meanwhile, in December, the salinity range was lower than in the previous months, with a minimum of 31.37 PSU (06:00) and a maximum of 33.17 PSU (15:00) (Fig. 3).

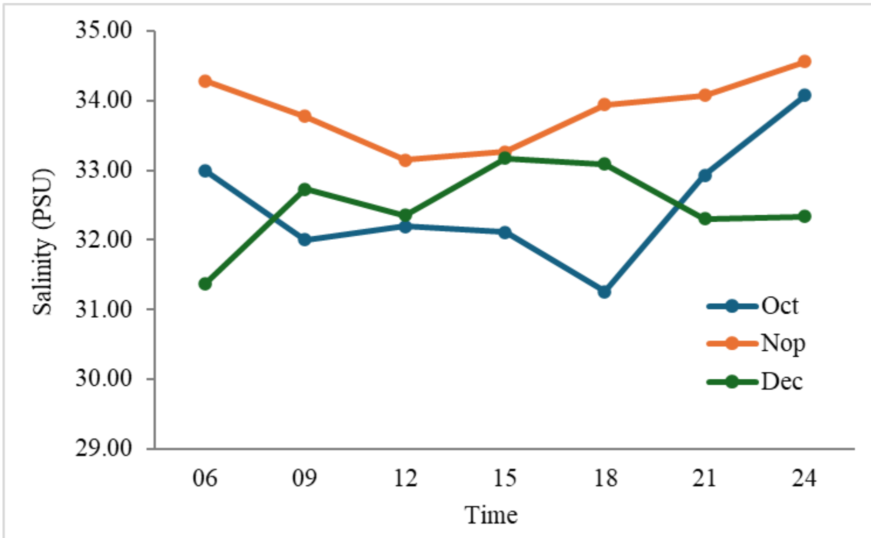

Fig. 3. Daily fluctuations in salinity of Tanjung Tiram, Ambon Bay

The daily salinity dynamics in this area are primarily influenced by tidal patterns, which regulate water mass mixing and freshwater dilution. Coastal waters, such as those in Ambon Bay, frequently experience salinity variations driven by tidal cycles **(Dyer, 1997)**. During high tide, the intrusion of seawater from offshore areas increases salinity, whereas during low tide, freshwater input from terrestrial sources leads to salinity reduction.

Monthly variations in salinity fluctuations are associated with changes in rainfall, which affect freshwater input into the waters. Salinity levels in November tend to be higher than in October and December, likely due to reduced rainfall, which lowers freshwater discharge from rivers and runoff **(Gordon, 2005)**. Conversely, the lower salinity observed in December indicates an increasing influence of rainfall, consistent with the onset of the rainy season in eastern Indonesia.

Daily salinity fluctuations exhibit a characteristic pattern, with higher salinity levels occurring from nighttime to early morning and lower levels from midday to afternoon. This pattern can be attributed to evaporation effects and thermohaline stratification. Higher evaporation rates during the day lead to increased surface salinity, but vertical mixing and freshwater inflow can offset this effect, especially in areas with significant freshwater input **(Wolanski & Spagnol, 2000)**.

Additionally, temperature differences between day and night influence the vertical distribution of salinity. During the daytime, surface heating strengthens stratification, causing lower-salinity water—resulting from freshwater mixing—to remain at the surface. At night, as temperatures drop, convection and turbulence increase, promoting better water mixing and a more homogeneous salinity distribution **(Simpson & Sharples, 2012)**.

Currents also play a crucial role in salinity fluctuations in this region. Ambon Bay experiences complex current dynamics due to tidal interactions and regional circulation patterns. Inflows from the Banda Sea transport higher-salinity water, while outflows carry mixed water containing freshwater from terrestrial sources **(Ilahude & Nontji, 2001)**. As a result, salinity variations occur not only on a daily scale but also over longer timescales, depending on the interactions between ocean currents and meteorological factors.

Compared to previous studies in other coastal waters of Indonesia, the salinity fluctuation patterns in Tanjung Tiram exhibit similarities to semi-enclosed waters influenced by tidal cycles and freshwater input from land **(Susanto *et al*., 2016)**. However, the amplitude of daily fluctuations suggests significant hydrodynamic variability, which should be considered in coastal resource management and further environmental studies.

Overall, the salinity fluctuations observed in Tanjung Tiram during the study period indicate primary control by tides, evaporation, rainfall, and current patterns. These variations have ecological implications, particularly for aquatic ecosystems, where species distribution depends on the stability of physicochemical parameters. Therefore, continuous monitoring of additional environmental factors, such as temperature, pH, and dissolved oxygen, will provide a more comprehensive understanding of oceanographic dynamics in Ambon Bay.

Salinity fluctuations have important ecological implications for the mangrove ecosystem in Tanjung Tiram. Salinity is a key factor influencing mangrove species distribution and growth rates **(Alongi, 2018)**. The relatively stable salinity range of 31–34 PSU suggests that environmental conditions remain suitable for the growth of mangrove species such as *Rhizophora stylosa* and *Sonneratia alba*, which exhibit broad salinity tolerance. However, a sharp decline in salinity due to significant rainfall increases could disrupt mangrove osmoregulation and potentially hinder growth.

Furthermore, salinity fluctuations also impact floating net cage aquaculture (KJA) activities in the area. A stable salinity range of 30–35 PSU is generally ideal for commonly farmed marine fish species such as barramundi (*Lates calcarifer*) and groupers (*Epinephelus* sp.) **(Rimmer *et al*., 2013)**. However, a significant salinity drop due to increased rainfall or high freshwater runoff may cause osmotic stress in fish, increasing susceptibility to disease infections. Therefore, regular salinity monitoring is crucial for aquaculture practitioners to anticipate environmental changes that could affect fish production.

3. Daily pH dynamics

The daily pH fluctuations in the waters of Tanjung Tiram, Ambon Bay, exhibited a consistent variation pattern during the period from October to December 2024. The lowest pH value was recorded in October at 8.07 (at 21:00), while the highest value reached 8.18 (at 18:00). In November, pH ranged from 8.22 (at 06:00 and 24:00) to 8.29 (at 15:00). Meanwhile, in December, the minimum pH was recorded at 8.26 (at 06:00), with a maximum value of 8.33 (at 12:00). Overall, the pH in these waters remained stable, with a slight increase over time (Fig. 4).

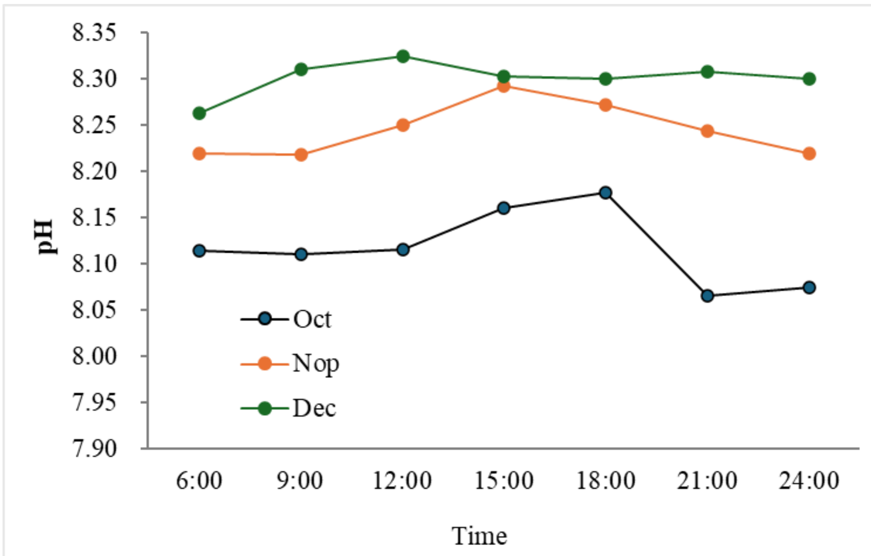

Fig. 4. Daily fluctuations in pH of Tanjung Tiram, Ambon Bay

The dynamics of pH fluctuations can be attributed to various oceanographic and biological factors influencing the aquatic system. One of the primary factors is phytoplankton photosynthesis, which leads to an increase in pH during the daytime due to the uptake of carbon dioxide (CO_2) in the photosynthetic process **(Zeebe & Wolf-Gladrow, 2001)**. This is reflected in the pH peak occurring from midday to late afternoon (around 12:00 to 18:00). Conversely, during nighttime and early morning hours, increased respiration by aquatic organism releases CO_2 into the water, causing a decline in pH.

Differences in pH fluctuations between October, November, and December can be linked to seasonal variations and hydro-oceanographic conditions in Ambon Bay. During this period, the waters undergo a transition from the dry to the rainy season, which influences salinity and freshwater input from land **(Tomascik *et al*., 1997)**. Increased rainfall in November and December may introduce organic material from terrestrial sources, which undergoes decomposition, producing CO_2 and contributing to pH variability.

In addition to biological and hydro-oceanographic factors, tidal cycles also play a role in pH dynamics. Tides influence the distribution of seawater rich in carbonate and bicarbonate, which function as a natural buffering system in coastal waters **(Millero, 2007)**. During high tide, seawater influx tends to stabilize pH levels, whereas during low tide, increased input from coastal environments enriched with organic compounds can lead to more pronounced pH fluctuations.

Although pH levels in Tanjung Tiram remained within the normal range for tropical marine ecosystems, even slight changes in pH can have significant ecological implications. Marine organisms such as mollusks are extremely sensitive to acidification, as it affects their calcification processes **(Gattuso & Hansson, 2011)**. The observed pH stability indicates that the ecosystem remains conducive to marine life; however, continuous monitoring is necessary, particularly concerning climate change and anthropogenic activities.

pH fluctuations also significantly impact the surrounding mangrove ecosystem in Tanjung Tiram. Mangroves serve as natural carbon sinks, and pH variations can influence biogeochemical balance within mangrove sediments. A stable pH supports microbial activity responsible for nutrient cycling, while extreme fluctuations can disrupt the decomposition of organic matter and the release of essential nutrients for mangrove growth **(Alongi, 2002)**. If pH drops too low, the calcification process of mangrove-associated organisms, such as crabs and mollusks, may be hindered, potentially reducing overall ecosystem productivity.

Furthermore, the floating net cage aquaculture activities in Tanjung Tiram are also affected by pH dynamics. Cultured fish species such as groupers (*Epinephelus* spp.) and the Asian seabass (*Lates calcarifer*) require relatively stable pH conditions for optimal growth. Drastic pH fluctuations can induce physiological stress, lower feed conversion efficiency, and increase susceptibility to disease **(Boyd, 2015)**. Therefore, routine pH monitoring is crucial for ensuring the sustainability of aquaculture operations in this area.

4. The dissolved oxygen (DO) dynamics

The research results indicated that the dissolved oxygen (DO) levels in the waters of Tanjung Tiram exhibit daily fluctuations, varying across each month from October to December 2024. In October, the highest DO level was recorded at 8.67mg/ L at 15:00, while the lowest value occurred at 06:00, measuring 6.50mg/ L. In November, the maximum DO level reached 4.79mg/ L at 18:00, whereas the lowest value was observed at 06:00 at 4.03mg/ L. In December, the highest DO level was 3.45mg/ L at 18:00, while the lowest value was recorded at 09:00 at 2.79mg/ L (Fig. 5).

The fluctuation pattern of dissolved oxygen (DO) indicates that oxygen levels tend to increase from midday to late afternoon and decrease from nighttime to early morning. This phenomenon is closely related to the photosynthetic activity of phytoplankton and aquatic macrophytes, which produce oxygen as a byproduct. During the daytime, when solar radiation is at its peak, photosynthesis becomes more active, leading to higher DO levels **(Wetzel, 2001)**. Conversely, at night, respiration by organisms and the decomposition of organic matter dominate, resulting in a decline in dissolved oxygen levels **(Odum, 1996)**.

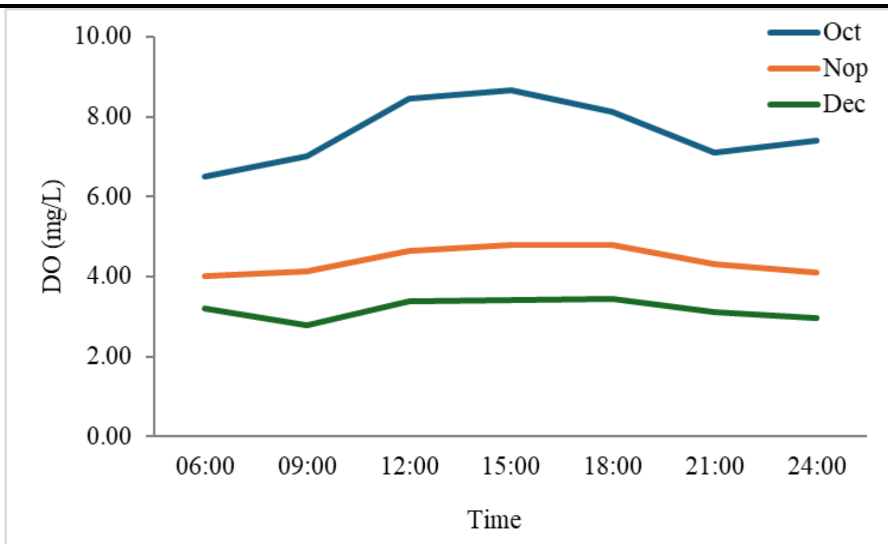

Fig. 5. Daily fluctuations in DO of Tanjung Tiram, Ambon Bay

The greater fluctuations observed in October compared to November and December may be attributed to differences in climatic conditions and water temperature. In October, temperatures tend to be higher due to the transitional phase from the dry to the rainy season. Higher temperatures can enhance photosynthetic activity but also accelerate microbial respiration rates, contributing to more significant DO fluctuations **(Boyd, 1990)**.

In November and December, the lower DO levels suggest the influence of increased rainfall. Higher precipitation can lead to greater surface runoff, carrying organic and inorganic particles into the water, thereby increasing turbidity and reducing light penetration. This negatively affects photosynthetic rates, decreasing oxygen production **(Twilley *et al*., 1992)**. Additionally, the influx of organic matter from terrestrial sources can enhance microbial decomposition activity, which significantly consumes oxygen **(Rabalais *et al*., 2002)**.

The more pronounced DO decline in December may also be linked to stronger thermal stratification in the water column. During the rainy season, the inflow of cooler freshwater from land can create a stable surface layer, inhibiting vertical mixing between the oxygen-rich surface waters and the more oxygen-depleted bottom layers **(Thomaz *et al*., 1997)**. This exacerbates hypoxic conditions, especially during nighttime and early morning when there is no oxygen supply from photosynthesis.

Beyond natural factors, anthropogenic influences may also contribute to the decline in DO levels. Human activities such as domestic and industrial waste discharge, as well as increased fishing and aquaculture activities, can further exacerbate oxygen depletion **(Diaz & Rosenberg, 2008)**. Excess nutrients from waste discharge can trigger eutrophication, increasing phytoplankton biomass that eventually dies and decomposes, leading to elevated oxygen consumption during the decomposition process.

The ecological impacts of declining DO levels can threaten the balance of aquatic ecosystems. Low oxygen concentrations can induce physiological stress in aquatic organisms, particularly fish and invertebrates that rely on dissolved oxygen for metabolism **(Breitburg *et al*., 2018)**. If DO levels drop below critical thresholds, mass mortality events of aquatic organisms may occur, disrupting food chains and reducing ecosystem productivity.

Overall, the findings confirm that DO dynamics in aquatic environments are influenced by natural factors such as photosynthesis, temperature, rainfall, and water stratification, as well as anthropogenic factors like pollution and eutrophication. Therefore, effective water management strategies, including pollution control and the conservation of riparian ecosystems, are essential for maintaining dissolved oxygen balance and supporting the sustainability of aquatic ecosystems.

The fluctuations in DO also have implications for the mangrove ecosystem in Tanjung Tiram, Ambon Bay. Mangrove ecosystems play a crucial role in supporting various aquatic organisms by providing spawning, nursery, and shelter habitats for fish and invertebrates **(Rahman *et al*., 2024)**. A significant decline in DO levels may hinder the growth and development of organisms' dependent on this ecosystem and increase the risk of hypoxia, which can reduce species diversity.

Moreover, extreme DO fluctuations can affect the productivity and carrying capacity of the mangrove ecosystem in the carbon cycle and food web. Prolonged hypoxic conditions may accelerate anaerobic processes in sediments, leading to the production of methane and hydrogen sulfide gases, which are potentially toxic to aquatic organisms **(Alongi, 2014; Tubalawony *et al*., 2024)**. Therefore, regular water quality monitoring is necessary to maintain the stability of the mangrove ecosystem.

Floating net cage aquaculture activities in Tanjung Tiram may also be affected by these DO fluctuations. Farmed fish in net cage systems rely heavily on dissolved oxygen supply, and low DO levels can cause stress, reduce growth rates, and increase disease susceptibility **(Beveridge, 2004)**. In November and December, when DO levels are lower, fish farming operations may require additional aeration or stricter feed management to mitigate the negative effects of hypoxia.

The management of aquaculture in Tanjung Tiram should consider DO dynamics to optimize production and reduce fish mortality. Mitigation measures such as stocking density regulation, efficient feeding strategies, and aquaculture waste management are essential for maintaining oxygen balance in the water **(Boyd & Tucker, 1998)**. With appropriate strategies, the adverse effects of DO fluctuations can be minimized, ensuring the sustainability of aquaculture in this area.

Nitrit (NO_2)

The daily fluctuations in nitrite (NO_2) concentration in the waters of Tanjung Tiram exhibited significant variations over the three-month observation period. In October, the lowest concentration was recorded at 18:00, with a value of 0.21mg/ L, while the highest concentration occurred at 06:00, reaching 0.29mg/ L. In November, the fluctuations were slightly more pronounced, with the lowest concentration of 0.29mg/ L recorded at 09:00 and the highest reaching 0.39mg/ L at 21:00. Meanwhile, in December, the highest nitrite concentration was recorded at 09:00 and 12:00, reaching 0.52mg/ L, whereas the lowest value of 0.45mg/ L was observed at 18:00 (Fig. 6).

The observed daily variations are likely influenced by biogeochemical activities in the water column and sediment. In general, nitrite levels tend to increase from morning to midday, which may be associated with microbial activity in partial nitrification processes and the potential remobilization of nutrients from sediments due to water movement and biotic activity. According to **Wetzel (2001)**, nitrite is an intermediate compound in the nitrogen cycle, formed by the oxidation of ammonia (NH_3) by nitrifying bacteria such as *Nitrosomonas*. This process is typically influenced by the availability of dissolved oxygen and higher water temperatures during the daytime, which support increased nitrite concentrations.

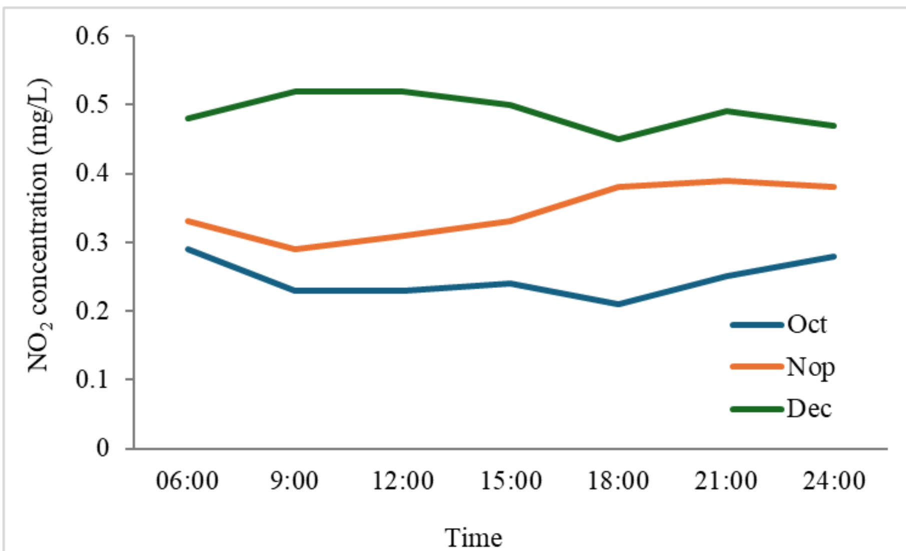

Fig. 6. Daily fluctuations in DO of Tanjung Tiram, Ambon Bay

Hydrodynamic factors, such as tidal fluctuations, also contribute to the daily variations in nitrite levels. During high tide, increased mixing between surface water and sediments may lead to the release of nitrite from the bottom layers. Conversely, during low tide, nitrite accumulation tends to decrease as it is either reabsorbed through nitrification or undergoes denitrification, converting into nitrogen dioxide (NO_2) and nitrogen gas (N_2) **(Jickells & Rae, 2005)**. This process may explain why nitrite concentrations begin to decline from nighttime to midnight compared to daytime levels.

In addition to physical factors, anthropogenic contributions should also be considered. The waters of Tanjung Tiram, located in Ambon Bay, are potentially influenced by runoff from domestic activities, fisheries, and nearby aquatic industries. Organic waste entering the water undergoes decomposition, releasing ammonia, which is subsequently converted into nitrite through nitrification **(Galloway *et al*., 2004)**. In December, higher nitrite concentrations compared to the previous months may indicate an increased nutrient load associated with intensified rainfall and elevated river discharge, transporting more organic material into the water.

The stability of nitrite in aquatic environments is highly dependent on the nitrogen cycle dynamics. Nitrite is an unstable form of nitrogen as it is easily oxidized into nitrate (NO_3^-) under aerobic conditions or reduced to nitrogen gas (N_2) under anoxic conditions through denitrification **(Zehr & Ward, 2002)**. In waters with oxygen stratification, nitrite tends to be rapidly converted into nitrate in oxygen-rich surface layers, whereas in hypoxic or anoxic regions, it is more likely to undergo reduction. Thus, nitrite fluctuations in Tanjung Tiram may reflect the balance between oxidative and reductive processes occurring within the ecosystem.

Overall, the dynamics of nitrite in Tanjung Tiram waters exhibit a fluctuating pattern driven by environmental factors, microbial activity, and potential anthropogenic influences. Although the variations remain within commonly observed coastal ecosystem ranges, the significant increase in December could indicate environmental changes that require further investigation. Long-term monitoring and additional studies on other parameters such as dissolved oxygen, ammonia, and nitrate would provide a more comprehensive understanding of nitrogen balance in this aquatic system.

The observed nitrite fluctuations may also impact the mangrove ecosystem in Tanjung Tiram. Mangroves play a crucial role in the nitrogen cycle, as their roots and sediment-associated microbes help stabilize nitrite levels through assimilation and denitrification processes **(Alongi, 2002)**. However, a significant increase in nitrite concentrations, particularly in December, could disrupt ecosystem balance, heighten the risk of eutrophication, and affect microbial communities and biota that depend on mangroves as a habitat. Elevated nitrite accumulation may also threaten the survival of organism sensitive to excessive nitrogen, such as gastropods and bivalves, which have low tolerance to water quality changes.

Additionally, excessive nitrite concentrations pose a threat to floating net cage aquaculture operations in Tanjung Tiram. Cultured fish species, such as snapper and grouper, are highly sensitive to elevated nitrite levels, as nitrite can impair oxygen transport in the blood through the brown blood disease mechanism **(Tucker & Boyd, 2012)**. High nitrite fluctuations from morning to midday may increase fish stress, reduce growth rates, and heighten susceptibility to diseases. Therefore, regular monitoring of nitrite levels and proper aquaculture management are essential to prevent negative impacts on fish production.

Connectivity among water parameters and its implications for the mangrove ecosystem and aquaculture activities

The interaction among these parameters demonstrates a strong relationship in the dynamics of aquatic ecosystems. Higher temperatures increase the metabolic rate and oxygen consumption of organisms, which can accelerate the decline of dissolved oxygen (DO), especially at night **(Boyd & Tucker, 1998)**. Additionally, oxygen depletion can enhance anaerobic microbial activity, converting ammonia into nitrite, and subsequently increasing nitrite levels **(Camargo & Alonso, 2006)**. Salinity balance also plays a crucial role in maintaining the osmotic homeostasis of aquatic organisms and can influence nutrient availability **(Esteves, 2011)**. These changes can impact primary productivity and the structure of aquatic organism communities.

pH fluctuations, influenced by photosynthesis and respiration, contribute to changes in the carbon dioxide equilibrium in water. During the daytime, increased photosynthesis reduces CO_2 levels, raising pH, whereas nighttime respiration increases CO_2 levels, lowering pH **(Middelburg *et al*., 2005)**. These fluctuations can affect the solubility of essential minerals such as calcium and carbonate, which are vital for the formation of shells and skeletal structures in organisms like mollusks and corals **(Waldbusser *et al*., 2015)**. Extreme pH changes can induce physiological stress, inhibiting growth and reproduction in aquatic organisms **(Fabry *et al*., 2008)**.

The implications of parameter connectivity for the mangrove ecosystem are significant. Mangroves serve as buffers, maintaining water quality stability by absorbing excess nutrients and supplying oxygen through root-microbe interactions **(Alongi, 2009)**. However, excessive nitrite accumulation due to anthropogenic activities can lead to eutrophication, potentially disrupting ecosystem balance **(Lapointe *et al*., 1993)**. Additionally, drastic changes in DO and pH can influence the decomposition of organic matter in mangrove sediments, affecting carbon and nutrient cycling within the ecosystem **(Kristensen *et al*., 2008)**.

In the context of floating net cage aquaculture, these parameter fluctuations must be effectively managed. Nocturnal DO depletion can cause fish stress, potentially increasing mortality rates **(Colt, 2006)**. Elevated nitrite levels may also negatively impact fish health, leading to respiratory impairment and immunosuppression **(Russo & Thurston, 1991)**. Therefore, regular water quality monitoring and the implementation of aeration systems can serve as mitigation strategies to ensure sustainable aquaculture production in Tanjung Tiram. Additionally, applying natural biofiltration systems using filter-feeding organisms such as bivalves or macroalgae can help stabilize water quality **(Shpigel & Neori, 2007)**.

The connectivity of these parameters also influences the overall stability of the aquatic ecosystem. Disturbances in a single parameter can trigger cascading effects that broadly impact the ecosystem. Therefore, an ecosystem-based management approach that considers the entire environmental interaction network is essential **(Christensen *et al*., 1996)**. Conservation efforts for mangroves, controlling nutrient inputs from terrestrial activities, and adopting sustainable aquaculture practices can help maintain ecological balance and enhance the resilience of coastal ecosystems against dynamic environmental changes.

CONCLUSION

In conclusion, the daily fluctuations of water parameters in Tanjung Tiram, Ambon Bay, reflect a complex environmental dynamic with significant implications for both the mangrove ecosystem and aquaculture activities. Water temperature increases from midday to the afternoon due to solar radiation, while a decline occurs from nighttime to early morning. Salinity exhibits daily variations influenced by tidal cycles and rainfall, with lower values observed in December due to increased freshwater input. The pH remains stable, with a slight increase during the daytime because of phytoplankton photosynthesis. Meanwhile, dissolved oxygen (DO) tends to be higher during the day and decreases at night, with a sharp decline in December due to increased rainfall and nutrient inflow from terrestrial sources. Nitrite concentrations show a rising trend from morning to midday, influenced by nitrification processes and organic matter input from anthropogenic activities.

These parameter fluctuations have significant implications for the mangrove ecosystem, where extreme changes can affect ecosystem stability and increase the risk of eutrophication. Additionally, low DO levels in certain months may lead to hypoxic conditions, negatively impacting mangrove biota and the surrounding aquatic community. In the context of aquaculture, fluctuations in salinity, DO, and nitrite concentrations can affect the health of fish cultivated in floating net cages, increasing the risk of physiological stress and disease.

As a recommendation, real-time monitoring of water parameters should be continuously conducted to anticipate environmental changes. Mangrove conservation efforts must be strengthened to maintain ecosystem balance, while aquaculture practices should be adapted to environmental dynamics, including the implementation of additional aeration and improved waste management. Furthermore, an ecosystem-based management approach is essential to ensure the sustainability of coastal waters in Tanjung Tiram.

ACKNOWLEDGMENT

We express our sincere gratitude to PT. Indosat Ooredoo Hutchison for funding this research and for providing the Water Quality Monitoring System (WQMS), which enabled real-time and continuous monitoring of water parameters. This support has been instrumental in obtaining accurate and comprehensive data on water quality dynamics in Tanjung Tiram, Ambon Bay. We hope this collaboration will continue in supporting research and sustainable coastal resource management efforts.

REFERENCES

Alongi, D. M. (2002). Present state and future of the world’s mangrove forests. *Environmental Conservation*, *29*(3), 331–349.

Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science, 72*(1-2), 1-13.

Alongi, D. M. (2009). The energetics of mangrove forests. Springer Science **&** Business Media.

Alongi, D. M. (2018). *Mangrove Ecosystems: A Global Biogeographic Perspective.* Springer.

Boyd, C. E. (1990). *Water quality in ponds for aquaculture*. Auburn University

Boyd, C. E., and Tucker, C. S. (1998). *Pond aquaculture water quality management*. Springer Science and Business Media.

Beveridge, M. C. M. (2004). Cage aquaculture. John Wiley and Sons.

Breitburg, D.; Levin, L. A.; Oschlies, A.; Grégoire, M.; Chavez, F. P.; *et al*. and Zhang, J. (2018). Declining oxygen in the global ocean and coastal waters. *Science*, 359(6371), eaam7240.

Camargo, J. A. and Alonso, A. (2006). Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International, 32*(6), 831-849.

Christensen, V.; Pauly, D. and Walters, C. J. (1996). Ecopath with Ecosim: a model for evaluating ecosystem structure and function. *ICES Journal of Marine Science, 53*(3), 350-365.

Colt, J. (2006). Water quality requirements for net pen culture of marine fish. *Aquacultural Engineering, 34*(3), 151-170.

Dalengkade, M. N. (2020). Fluktuasi temporal kelembaban udara di dalam dan luar ekosistem mangrove. *Barekeng Journal*, 14(2), 159 – 166.

Diaz, R. J. and Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems. *Science*, 321(5891), 926-929.

Duke, N. C.; Meynecke, J. O.; Dittmann, S.; Ellison, A. M.; Anger, K.; Berger, U. and Dahdouh-Guebas, F. (2007). A world without mangroves? *Science, 317*(5834), 41-42.

Dyer, K. R. (1997). *Estuaries: A Physical Introduction (2nd ed.)*. John Wiley and Sons.

Esteves, F. A. (2011). Fundamentos de limnologia. Interciência.

Fabry, V. J., Seibel, B. A., Feely, R. A. and Orr, J. C. (2008). Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science, 65*(3), 414-432.

Galloway, J. N., Dentener, F. J., Capone, D. G., Boyer, E. W., Howarth, R. W., Seitzinger, S. P. and Karl, D. M. (2004). Nitrogen cycles: past, present, and future. *Biogeochemistry, 70*(2), 153–226.

Galloway, J. N.; Townsend, A. R.; Erisman, J. W.; Bekunda, M.; Cai, Z.; Freney, J. R. and Sutton, M. A. (2008). Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions. *Science, 320*(5878), 889-892.

Gordon, A. L. (2005). Oceanography of the Indonesian Seas and Their Throughflow. *Oceanography*, **18**(4), 14–27.

Hargreaves, J. A. and Tucker, C. S. (2003). Defining loading limits of static ponds for catfish aquaculture. *Aquacultural Engineering, 28*(1-2), 47-63.

Hogarth, P. J. (2007). *The biology of mangroves and seagrasses*. Oxford University Press.

Ilahude, D. and Nontji, A. (2001). Oceanographic Features of Indonesian Waters. *Indonesian Journal of Marine Science*, **6**(2), 45–56.

Jickells, T. D. and Rae, J. G. (2005). Biogeochemistry of Nitrogen. In *Marine Biogeochemistry*. Springer.

Kathiresan, K. and Bingham, B. L. (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology, 40*, 81-251.

Kesaulya, I.; Rahman.; Haumahu, S. and Krisye (2023). Global warming potential of carbon dioxide and methane emission from mangrove sediment in Waiheru Coastal, Ambon Bay. *IOP Conference Series: Earth and Environmental Science, 1207,* 012030, 10.1088/1755-1315/1207/1/012030

Kesaulya, I. and Rahman. (2023). Global warming potential of nitrous oxide fluxes from sediments of mangrove ecosystem in Waiheru coastal area, Ambon Bay. *Indian Journal of Geo-Marine Sciences, 52*(11), 503-509.

Kjerfve, B. (1990). Manual for investigation of hydrological processes in mangrove ecosystems. *UNESCO Technical Papers in Marine Science, 39*, 1-19.

Kristensen, E.; Bouillon, S.; Dittmar, T. and Marchand, C. (2008). Organic carbon dynamics in mangrove ecosystems: A review. *Aquatic Botany, 89*(2), 201-219.

Kurniawan, F.; Paramita, V. and Pribadi, R. (2020). Phytoplankton biomass dynamics in tropical coastal waters of Jakarta Bay over a two-decade period: The impacts of nutrient and light availability**.** *Journal of Marine Science and Engineering*, *8*(9), 674.

Lapointe, B. E.; Littler, M. M. and Littler, D. S. (1993). Modification of benthic community structure by natural eutrophication: The Belize Barrier Reef. *Marine Ecology Progress Series, 105*, 147-157.

Latuconsina, H. and Ambo-Rappe, R. (2013). Variabilitas harian komunitas ikan padang lamun perairan Tanjung Tiram-Teluk Ambon Dalam. *Jurnal Iktiologi Indonesia*, 13(1), 35-50.

Latumahina, F. S.; Susilawati, S. and Rahman. (2024). Mangrove forets health assessment on small island in Maluku, Indonesia. *International Journal on Advanced Science, Engineering and Information Technology*, 14(6), 2031 – 2028.

Middelburg, J. J.; Duarte, C. M. and Gattuso, J. P. (2005). Respiration in coastal benthic communities. *In Respiration in Aquatic Ecosystems* (pp. 206-224). Oxford University Press.

Natan, J.; Limmon, G. V.; Hendrika, N. and Rahman. (2023). Correlation of some water quality parameters and Pb in sediment to gastropod diversity in Ambon Island Waters. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, 13(4), 656-670.

Odum, E. P. (1996). *Fundamentals of Ecology*. W.B. Saunders Company.

Pörtner, H. O. and Farrell, A. P. (2008). Physiology and climate change. *Science*, *322*(5902), 690-692.

Rabalais, N. N.; Turner, R. E. and Wiseman, W. J. (2002). Beyond science into policy: Gulf of Mexico hypoxia and the Mississippi River. *BioScience*, 52(2), 129-142.

Rahman, Effendi, H.; Rusmana, I.; Yulianda, F. and Wardiatno, Y. (2020). Pengelolaan ekosistem mangrove untuk ruang terbuka hijau sebagai mitigasi gas rumah kaca di kawasan Sungai Tallo Kota Makassar. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, 10(2), 320-328.

Rahman.; Lokollo, F. F.; Manuputty, G. D.; Hukubun, R. D.; Krisye.; Maryono.; Wawo, M. and Wardiatno Y. (2024). A review on the biodiversity and conservation of mangrove ecosystems in Indonesia. *Biodiversity and Conservation*, 3(33): 875-903.

Rimmer, M. A.; Williams, K. C. and Phillips, M. J. (2013). *Aquaculture of Marine Fishes and Crustaceans in the Tropics.* CABI Publishing.

Rugebregt, M. J.; Matuanakotta, C. and Syafrizal, M. (2020). Keanekaragaman Jenis, Tutupan Lamun, dan Kualitas Air di Perairan Teluk Ambon. *Jurnal Ilmu Lingkungan*, 18(3), 589-594.

Schulte, P. M. (2015). The effects of temperature on aerobic metabolism: towards a mechanistic understanding of the responses of ectotherms to a changing environment. *Journal of Experimental Biology, 218*(12), 1856-1866.

Shpigel, M. and Neori, A. (2007). The integrated culture of seaweed, abalone, fish, and clams in modular intensive land-based systems: I. Proximate composition and growth. *Aquaculture, 270*(1-4), 140-151.

Simpson, J. H. and Sharples, J. (2012). *Introduction to the Physical and Biological Oceanography of Shelf Seas.* Cambridge University Press.

Susanto, R. D.; Gordon, A. L. and Zheng, Q. (2016). Upwelling along the coasts of Java and Sumatra and its relation to ENSO. *Journal of Geophysical Research: Oceans*, **106**(C4), 6223–6234.

Suyadi, S. (2009). Kondisi hutan mangrove di Teluk Ambon: Prospek dan tantangan**.** *Berita Biologi*, *9*(5), 481-481.

Syafrizal, A. and Rasyid, I. (2021). Interaksi variabilitas iklim dengan ekosistem terumbu karang dan sumber daya ikan karang**.** *Jurnal Penelitian Perikanan Indonesia*, *27*(3), 215-230.

Thomaz, S. M.; Bini, L. M. and Bozelli, R. L. (1997). Effects of reservoir water level fluctuation on the dynamics of macrophyte stands in a large sub-tropical reservoir. *Hydrobiologia*, 357(1-3), 1-12.

Tubalawony, S.; Mailoa, M. N.; Rahman. and Pasanea, K. (2024). Fluxes of Methane Gases (CH_4) in sediments of mangrove and seagrass ecosystems in Tanjung Tiram, Ambon Bay, Indonesia. *Egyptian Journal of Aquatic Biology and Fisheries*, *28*(4), 951-963.

Tucker, C. S. and Boyd, C. E. (2012). Water quality management in pond fish culture. *Elsevier Science*.

Tupan, C. I. (2016). Status Padang Lamun Perairan Tanjung Tiram, Poka, Teluk Ambon Dalam. *Prosiding Seminar Nasional Kelautan dan Perikanan ke III*, 94-100.

Twilley, R. R.; Chen, R. H. and Botero, L. (1992). The role of mangroves in the carbon and nutrient dynamics of the coastal zone. *Incofish*, 23, 325-345.

Waldbusser, G. G.; Hales, B.; Langdon, C. J.; Haley, B. A.; Schrader, P. and Brunner, E. L. (2015). Saturation-state sensitivity of marine bivalve larvae to ocean acidification. *Nature Climate Change*, *5*(3), 273-280.

Wetzel, R. G. (2001). *Limnology: Lake and River Ecosystems*. Academic Press.

Wolanski, E. and Spagnol, S. (2000). Environmental Hydrodynamics of Mangrove Swamps, Seagrass Beds, and Coral Reefs. *Estuarine, Coastal and Shelf Science*, **50**(3), 811–825.

Zehr, J. P. and Ward, B. B. (2002). Nitrogen cycling in the ocean: new perspectives on processes and pathways. *Applied and Environmental Microbiology*, *68*(3), 1015–1024.