Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(5): 1669 – 1688 (2025)
www.ejabf.journals.ekb.eg

Effectiveness of Aquaculture Zone Waters During the East Season in the Conservation Area of Kei Kecil Island Park, Southeast Maluku Regency, Maluku Province, Indonesia

Simon M. Picaulima [1]*, Nally Y.G.F. Erbabley [2]* and Dion D. Awayal [3]

[1]Fisheries Agribusiness Study Program, Department of Fisheries Product Technology, Tual State Fisheries Polytechnic, Southeast Maluku Regency, Maluku-97611, Indonesia

[2]Aquaculture Technology Study Program, Department of Water Resource Technology, Tual State Fisheries Polytechnic, Southeast Maluku Regency, Maluku-97611, Indonesia

[3]Marine Technology Study Program, Department of Fishery and Marine Engineering, Tual State Fisheries Polytechnic, Southeast Maluku Regency, Maluku-97611, Indonesia

***Corresponding Author: nallyerbabley@gmail.com; spicaulima@yahoo.com**

ARTICLE INFO

Article History:
Received: July 5, 2025
Accepted: Sep. 5, 2025
Online: Oct. 2, 2025

Keywords:
Aquaculture zone,
Conservation area,
Effectiveness,
East season,
Mariculture

ABSTRACT

The aquaculture subzone of the Kei Kecil Island Park conservation area has excellent potential for marine cultivation during the east season. Still, the availability of data, information, and knowledge of coastal communities related to the spatial and temporal utilization of ecological space according to the characteristics of the cultivation land has not been thoroughly inventoried by the manager. As a result, the fisheries subzone is often used by small fishermen as a fishing area in every season. The purpose of this study was to determine the suitability of the waters of the effective aquaculture subzone for marine cultivation commodities during the east season. The study utilized primary and secondary data related to physical, chemical, biological, and oceanographic parameters, collected both *in situ* and *ex situ*, at 15 research stations. Data analysis was carried out on ecological parameters and land suitability using Excel and GIS. This study provides information that the aquaculture subzone of the Kei Kecil Island Park conservation area during the east season is physically, chemically, biologically, and oceanographically feasible, namely: 1) effective land grouper cultivation 2,750 Ha with floating net cage method, 2) effective land seaweed cultivation 2,507 Ha and quite effective 243 Ha with longline and off-bottom method, 3) effective land sea cucumber cultivation 879 Ha, quite effective 261 Ha, ineffective 1,610 Ha with fixed cage method, 4) effective pearl oyster cultivation 2,454 Ha, quite effective 265 Ha, ineffective 35 Ha with longline and floating raft method. Utilizing aquaculture zones according to the type of fishery commodity is the first step towards sustainable marine aquaculture.

INTRODUCTION

The Kei Kecil Pulau Kecil Park (TPK) conservation area is a category of parks designated for the protection, preservation, and utilization of biodiversity and/or fish resources, functioning to maintain and improve the quality of biodiversity **(Indonesian KKP, 2020)**. The conservation area has an area of 150,000 hectares consisting of 3 (three) zones, namely the core zone (4,191.27 Ha), the limited use zone (126,635.33 Ha), and other zones (19,173.40 Ha) **(Indonesian KKP, 2016)**. The limited utilization zone in the small TPK Kei conservation area comprises three sub-zones: the tourism sub-zone, the capture fisheries sub-zone, and the aquaculture sub-zone. The use of three limited-use sub-zones in conservation areas is expected to provide economic and social benefits for the welfare of coastal communities **(Suparyana *et al*., 2023)**.

Marine fisheries cultivation is an economical production activity, so it needs to be carried out effectively and efficiently to produce quality and high-priced fishery commodities. Effectiveness in a production activity is more focused on achieving maximum output, while efficiency is more focused on efforts to reduce production input costs to achieve maximum output **(Picaulima *et al*., 2023)**. The production effectiveness of an aquaculture business can be achieved if the suitability of the location of the fishery cultivation is in accordance with the type of fishery commodity cultivated in each season. Therefore, the season is an important factor in the sustainability of the marine aquaculture business **(Yulianto *et al*., 2025)**.

The TPK Kei Kecil conservation area is located in the western part of Kei Kecil Island and has a water area of 7,556.07 hectares. However, it has not been able to be used effectively by coastal communities, therefore the waters of the fisheries sub-zone are often used by small fishermen as fishing areas in every season **(Picaulima *et al*., 2024)**. This problem is due to the lack of availability of data, information, and knowledge of coastal communities related to the spatial and temporal use of ecological space in accordance with the characteristics of marine aquaculture commodities, especially in the eastern season.

A study on the suitability of marine aquaculture land in conservation areas was previously conducted for marine aquaculture in the Karimunjawa national park area **(Yusuf, 2013)** and seaweed cultivation focusing on the coastal area of Southeast Maluku Regency **(Teniwut *et al*., 2019)**, but the two studies have not been analyzed seasonally. Meanwhile, marine aquaculture is very sensitive to changes in environmental conditions caused by seasonal changes **(Oyinlola *et al*., 2018)**. Spatial and temporal studies related to the effectiveness of marine aquaculture zone waters in small island park conservation areas have never been conducted. Even though the conservation area of Kei Kecil Island Park has space, carrying capacity, and land suitability that are suitable for the cultivation of several fishery commodities of high economic value in every season, especially in the eastern season. The novelty of this study is the effectiveness of the waters of the marine aquaculture zone that are close to the core zone, with different types of water spatially in the eastern season in the conservation area of Pulau Kecil Park. Marine aquaculture around the core zone can take advantage of the diversity of fish resources, and the type of waters greatly affects the development of marine aquaculture **(Hutabarat, 2005)**. To obtain accurate data and information, a spatial approach using geographic information system technology is needed **(Jaya *et al*., 2022)**. This study aimed to determine the suitability of the waters of the fisheries aquaculture sub-zone that are effective for the development of marine aquaculture activities in the small Kei TPK conservation area in the eastern season using a geographic information system. This research is useful for the management of the TPK Kei conservation area in formulating policies for the use of the sub-zone of fishery cultivation that is effective and efficient in each season, as well as improving the welfare of coastal communities in the small TPK Kei conservation area.

MATERIALS AND METHODS

The research was conducted during the eastern season, from June to August 2025, in the waters of the aquaculture sub-zone of the small TPK Kei conservation area, which has an area of 2,750 hectares. The conservation area is administratively located in the western part of the small Kei Island, Southeast Maluku Regency (Fig. 1).

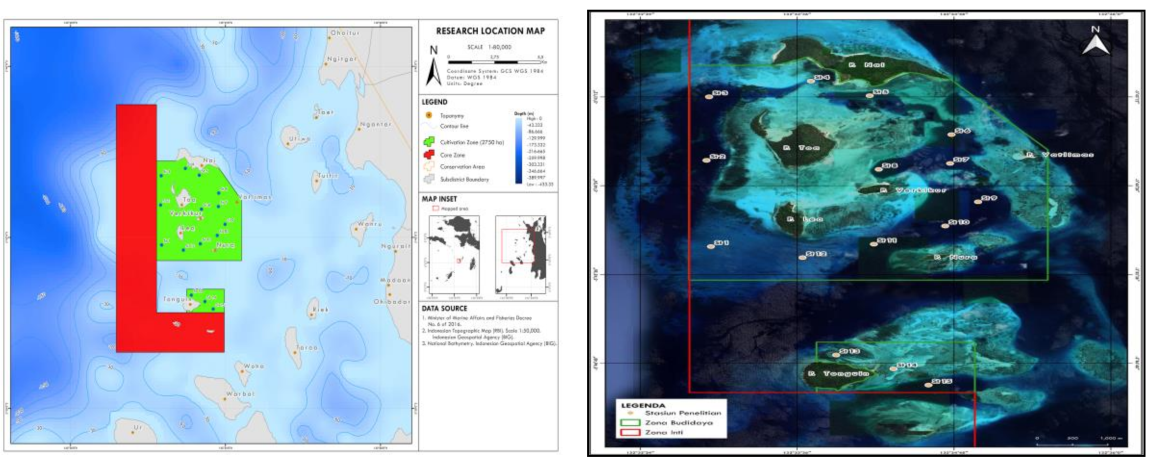


Fig. 1. Map of the study in conservation areas TPK Kei is a small of Southeast Maluku Regency, Indonesia

The types of data used consist of: primary data including ecological aspects, namely physical (current speed, waves, depth, substrate), chemistry (temperature, salinity, pH, DO, nitrates, nitrites, phosphates), biology (chlorophyll), oceanography (coastal ecosystems, currents, and depth, bathymetry) in the eastern season sourced from the coastal waters of the islands of ten TPK Kei conservation areas while secondary data include all documents and study results related to the attributes in this study. The determination of the research station was carried out using a purposive sampling method, based on the research team's assessment of the research area. This approach ensured that the sampling station represented the research area as a whole, with water quality parameter measurements conducted using both in situ and *ex-situ* methods. The In-Situ method is a measurement directly at a research station, while the *ex-situ* method is a measurement that uses laboratory equipment and remote sensing. *In situ* water quality sampling includes temperature, salinity, depth, pH, and dissolved oxygen (DO), which is carried out on the surface and water column through vertical stratification at 15 stations in the aquaculture zone, as well as the boundary of the study area. In contrast, the parameters obtained through laboratory tests include nitrates, nitrites, ammonia, and phosphates, and remote sensing consisting of bathymetry, chlorophyll a, current velocity, and ecosystem habitat. The complete locations of research stations 1 to 15 are shown in Table (1).

Table 1. The location of research stations 1 to 15 is in the aquaculture sub-zone of the TPK Kei Small Conservation Area, Southeast Maluku

No	Research Station	Bujur	Lintang
1	Station 1	132.55	-5.75
2	Station 2	132.55	-5.73
3	Station 3	132.55	-5.72
4	Station 4	132.56	-5.72
5	Station 5	132.57	-5.72
6	Station 6	132.58	-5.73
7	Station 7	132.58	-5.73
8	Station 8	132.57	-5.74
9	Station 9	132.58	-5.74
10	Station 10	132.58	-5.75
11	Station 11	132.57	-5.75
12	Station 12	132.56	-5.76
13	Station 13	132.56	-5.78
14	Station 14	132.57	-5.78
15	Station 15	132.58	-5.78

The materials used in this study include primary and secondary data on the ecological parameters of marine aquaculture (physical, chemical, and biological) and oceanography.

1. Ecological parameters of marine aquaculture

The assessment of ecological parameters of marine aquaculture uses qualitative descriptive analysis to describe the conditions of the research station and the characteristics of the environmental parameters taken at the research station. The study utilized the statistical Excel software tool, and the results were then displayed in graphical form. Spatial parameter characteristic information uses a geographic information system to display a spatial map of ecological parameters.

2. Suitability of marine fisheries commodity cultivation locations

Determination of the suitability of marine fisheries commodity cultivation locations was coducted using qualitative and quantitative descriptive analysis, utilizing Excel software tools and geographic information systems. Data on the physical, chemical, and biological conditions of the waters of the aquaculture sub-zone of the small TPK Kei conservation area were used as a reference in determining the criteria for the suitability of marine fishery commodity cultivation locations. Next, the total value of the parameter was calculated **(Ferdiansyah *et al*., 2019)** as follows:

$$N = \sum (A \times B)$$

Where: N=Total weight, A=Assessment number in each class, B=Weight in each class. Determination of the suitability of marine fisheries commodity cultivation locations was based on the multiplication of scores and weights obtained from each parameter. The suitability of marine aquaculture locations was seen through the percentage of suitability from the sum of the values of all parameters. The formula for calculating the suitability of marine aquaculture land is as follows **(Hutabarat *et al*., 2009)**:

$$I = \frac{(\sum A \times B)}{N\ Max} \times 100\%$$

Where: IK=Suitability index, A=Assessment number in each class, B=Weight in each class, N Max=Maximum value of categorization. The result of multiplying the weight and score assigned to each parameter is adjusted based on its level of importance in determining suitability for the designated type of marine aquaculture commodity. The score within a specific designation reflects this adjustment. The criteria and location suitability matrix can serve as a reference for each designation, including the classification of suitability classes based on the total score. In this study, the suitability of marine fishery commodity cultivation locations is categorized into three classes: appropriate (S1), fairly appropriate (S2), and inappropriate (N), in accordance with the marine fisheries aquaculture classification shown in Table (2).

Table 2. Suitability category of marine fisheries cultivation location

Yes	Score Range (%)	Valuation
1	85-100	Appropriate
2	60-84	Quite Appropriate
3	< 60	Inappropriate

Furthermore, the level of suitability of both water and land areas for the cultivation of marine fisheries commodities was determined spatially using a scoring method, based on several ecological parameters and a multi-level overlay technique. The results of this analysis will produce a suitability map identifying aquatic areas appropriate for marine fishery commodity cultivation, including suitable methods or techniques for each type of cultivator.

RESULTS AND DISCUSSION

Aquatic chemical parameters of the marine aquaculture sub-zone

The measurement results show that the average value of the eastern season temperature ranges from 27.97 to 28.36°C. The variation in temperature values between stations in the aquaculture zone of the small TPK Kei conservation area in the eastern season is not much different because the standard deviation value is 0.11. The lowest temperature occurs at station 6, which is 27.97°C, while the highest temperature is at station 13, which is 28.36°C, as can be seen graphically and on the map in Fig. (2). Temperature is very important for aquatic organisms in the growth, reproduction, and health of marine organisms because it greatly affects the metabolic activity and development of marine organisms **(Hutabarat & Evans, 1985)**. Based on the results of temperature measurements at the research site, it is suitable for the growth, reproduction, and health of marine life because it is still in the range of 27-30°C **(Putriningtias *et al*., 2021)**. The difference in seawater temperature that occurred at the study site was influenced by weather conditions during the measurement, the intensity of sunlight, and the depth of the water **(Selano *et al.*, 2016)**.

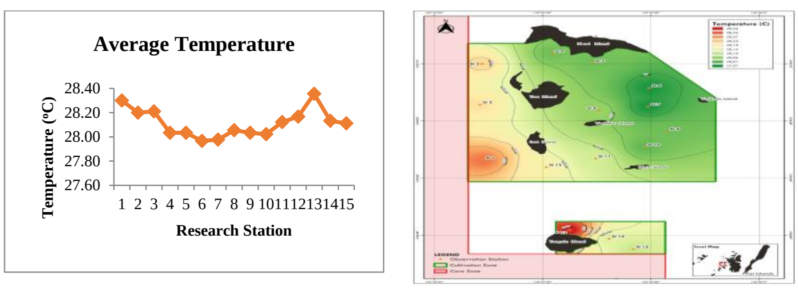


Fig. 2. Average graph and spatial of temperature east season in the conservation area of Kei kecil Island Park

The measurement results show that the average salinity value in the eastern season ranges from 35.50 to 36.33 psu. The variation in salinity values did not differ significantly, as indicated by the standard deviation of 0.23. The lowest salinity value occurs at station 15, at 35.50 psu, while the highest value is at station 10, at 36.33 psu, as shown in the graph and map in Figure 3. Extreme salinity can inhibit photosynthesis and respiration, reducing the availability of oxygen and nutrients, which directly impacts the dispersal, abundance, growth, and density of seawater organisms **(Roting *et al*., 2023)**. The results of salinity measurements show that salinity is good for marine aquaculture because it ranges from 30 to 40 psu **(Wyrtki, 1961; Tubalawony *et al*., 2023)**. The difference in salinity that occurs at each research station is influenced by evaporation, the amount of fresh water entering the waters, "runoff" or surface flow, tides, rainfall, and seasons **(Nurhayati, 2006)**.

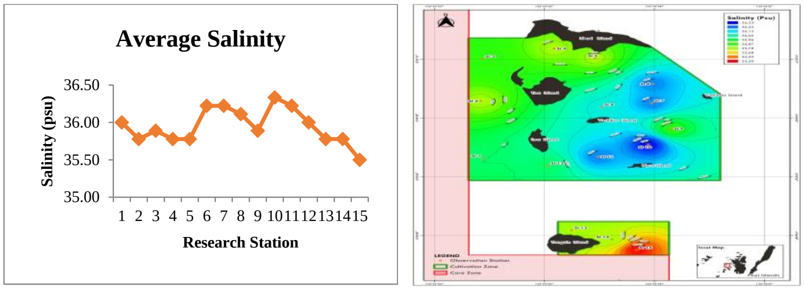


Fig. 3. Average graph and spatial of salinity east season in the conservation area of Kei kecil Island Park

The measurement results showed that the average pH value in the eastern season ranged from 7.04 to 7.47. The variation in pH values is not much different because the standard deviation is 0.12. The lowest pH measurement at station 2 is 7.04, while the highest at station 7 is 7.47, which can be seen graphically and on the map in Fig. (4). pH (Hydrogen Potential) is closely related to the ability to grow and reproduce in marine aquaculture because suboptimal pH can cause fish stress, disease proneness, and low productivity and growth **(Siegers *et al*., 2019)**. The measurement results showed that the pH at the research site was ideal for the growth of marine life because the pH value obtained was still between 7 and 8 **(Ferawati *et al*., 2014)**. The high and low pH at the research site were greatly influenced by fluctuations in O2 and CO2 content in these waters **(Rukminasari *et al*., 2014)**.

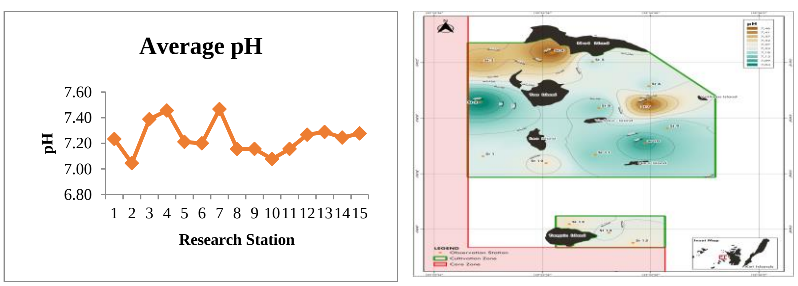


Fig. 4. Average graph and spatial of pH east season in the conservation area of Kei kecil Island Park

The measurement results showed that the average value of DO levels in the eastern season ranged from 4.53 to 5.38. The variation in the DO level is not much different because the standard deviation is 0.20. The lowest DO level occurs at station 11, which is 4.53, while the highest is at station 15, which is 5.38, as shown in the graph and map in Fig. (5). DO (Dissolved oxygen) is the amount of dissolved oxygen in a body of water that is required by seawater organisms for respiration and metabolic processes to produce energy for growth and reproduction. The dissolved oxygen levels at the research site were very good for marine aquaculture since they ranged from 4-7 **(Poernomo, 2005)**. The difference in dissolved oxygen levels at stations 1 to 15 is greatly influenced by temperature, salinity, movement of water masses, atmospheric pressure, phytoplankton concentration, and oxygen saturation levels in the vicinity, as well as water stirring by wind **(Paputungan *et al*., 2022)**.

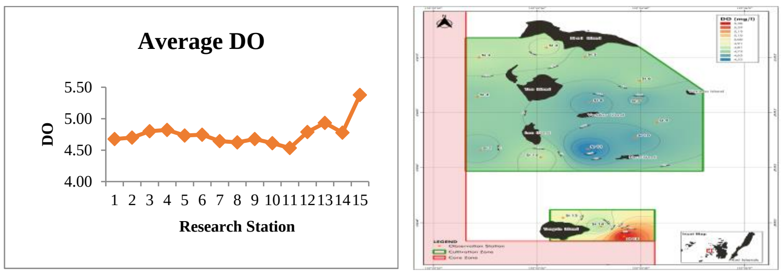


Fig. 5. Average graph and spatial of DO east season in the conservation area of Kei kecil Island Park

The measurement results showed that the average value of nitrates in the eastern season ranged from 0.14 to 0.49. The variation in nitrate values is not much different because the standard deviation is 0.11. The lowest level occurs at station 2, which is 0.14, while the highest level is at station 7, which is 0.49, as shown in the graph and map in Fig. (6). Nitrate (NO3) is the main source of nutrients for the growth of phytoplankton and other aquatic plants that are useful as natural feed for fish **(Haribowo *et al*., 2019)**. The nitrate content at the research site is in the category of good to sufficient or safe because the nitrate content for marine life is categorized as quite in the range of nitrate levels of 0.3-0.9 mg/l **(Patty, 2014)**. The presence of nitrates in aquatic ecosystems is determined by the amount of ammonia and nitrites **(Wetzel, 2001)**. The difference in nitrate content at stations 1 to 15 is naturally influenced by the waters themselves through the process of decomposition, weathering, decomposition of plants, remains of dead organisms, and disposal of landfill waste that will decompose bacteria into nutrients **(Patty *et al*., 2015)**.

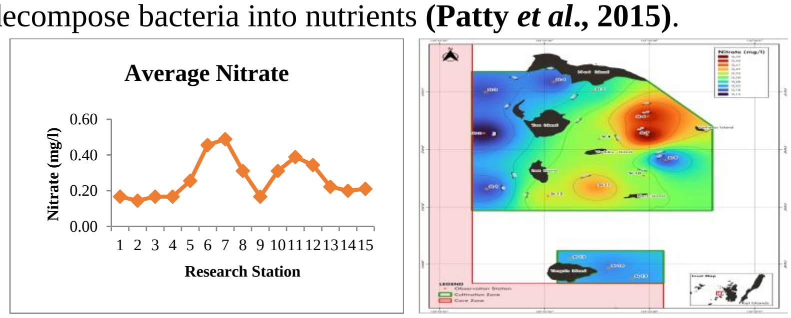


Fig. 6. Average graph and spatial of nitrate east season in the conservation area of Kei kecil Island Park

In situ measurements carried out at the research station showed that the average value of nitrites in the eastern season ranged from 0.05 to 0.10 mg/l. The variation in nitrate values is not much different because the standard deviation of 0.02 can be seen in the graph and map in Fig. (7). Nitrite (NO_2) is part of the nitrogen cycle under environmental and biological conditions **(Amalia *et al*., 2021)**. Nitrites are usually found in small amounts, less than nitrates, because they are unstable in the presence of dissolved oxygen **(Joseph *et al*., 2023)**. The results of nitrite measurements showed that the nitrite concentration in the waters of the study site was good since it ranged from 0.001 to 0.1 mg/l **(Mutiah, 2022)**. The difference in nitrite at the study site vertically is in line with increasing sea depth and lower oxygen concentration, while the horizontal presence of nitrite levels is higher towards the coast **(Hutagalung & Rozak, 1997)**.

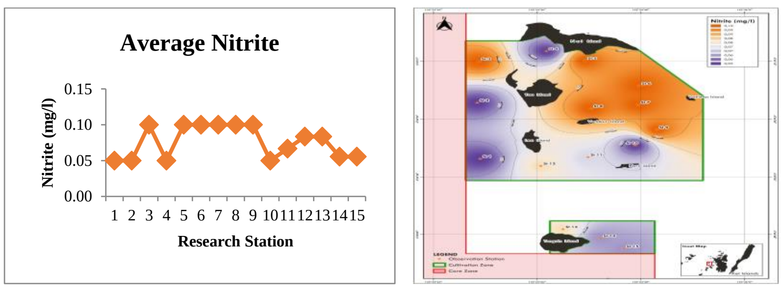


Fig. 7. Average graph and spatial of nitrite east season in the conservation area of Kei kecil Island Park

The measurement results show that the average phosphate value in the eastern season ranges from 0.07 to 0.20 mg/l. The variation in nitrate value is not much different because the standard deviation of 0.03 can be seen in the graph and map in Fig. (8). Phosphate (PO_4) is a nutrient for the growth of aquatic organisms such as phytoplankton and microbes. Excessive phosphate content accompanied by the presence of nitrogen can stimulate algae growth **(Effendi, 2003)**. The measurement results showed that the phosphate values at the research sites at stations 1 to 15 were declared good because they generally did not exceed 0.2 mg/l **(Peraturan Pemerintah, 2021)**. High phosphate levels occur at station 8 because they are influenced by household waste from coastal communities **(Handayani *et al.*, 2010)**.

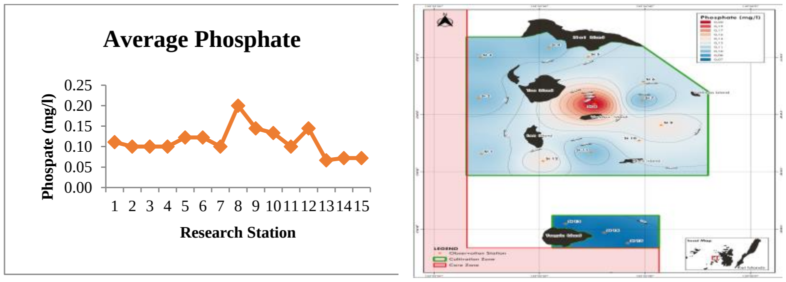


Fig. 8. Average graph and spatial of phosphate east season in the conservation area of Kei kecil Island Park

The measurement results showed that the average ammonia value in the eastern season ranged from 0.20 to 1.20 mg/l. The variation in nitrate value was not much different because the standard deviation was 0.31. The lowest level was recorded at station 9, which was 0.20 mg/l, while the highest level was observed at station 6, which was 1.20 mg/l, as shown in the graph and map in Fig. (9). Ammonia is a nitrogen compound that is included in the toxic element because it can cause aquatic organisms to experience respiratory distress, making it difficult to bind oxygen in blood vessels **(Mawaddah *et al*., 2016)**. The ammonia value at the highest research site at station 6 has even exceeded the standard limit of water quality of 0.3 mg/l **(Peraturan Pemerintah, 2021)**. The high ammonia at station 6 is due to waste from the residents of both large and small islands, the breakdown of organic and inorganic nitrogen compounds in the water, and the process of decomposition of organic matter by microorganisms and fungi **(Hamuna *et al*., 2018)**.

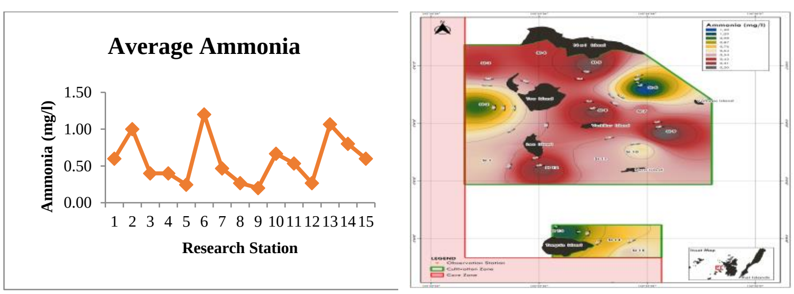


Fig. 9. Average graph and spatial of ammonia east season in the Kei Kecil Island Park conservation area

Physical parameters of marine aquaculture sub-zone waters

The measurement results show that the average value of the current velocity in the eastern season ranges from 0.18 to 0.20 m/s. The variation in the current velocity value is not much different because the standard deviation of 0.19 can be seen on the graph and map in Fig. (10). The speed of ocean currents affects marine life by distributing plankton, dissolved oxygen, and nutrients, as well as influencing the movement and spread of larvae. The movement of currents in the waters is very influential for marine life such as plankton whose movement is very limited **(Adinugroho *et al*., 2014)**. The current speed at the research site is categorized as slow because it ranges from 0 to 0.25 m/s **(Sari, 2012)**. The slow speed of the current at the study site when the measurement occurred was greatly influenced by the monsoon wind blowing at sea level **(Lubis *et al*., 2022)**.

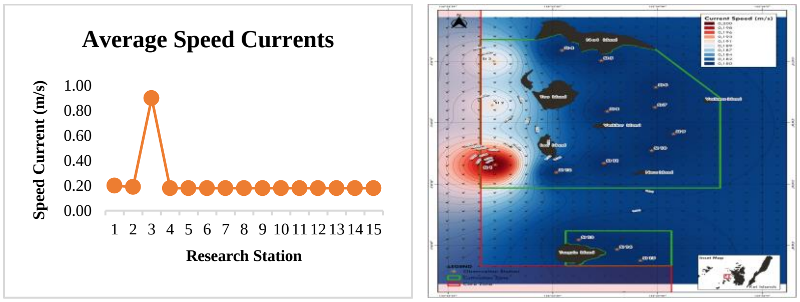


Fig. 10. Average graph and spatial of the speed and direction east season current in the conservation area of Kei Kecil Island National Park

The measurement results show that the average water depth in the TPK Kei conservation area is small, ranging from -0.80 to 35.94 m. The lowest water depth occurs at station 4, which is -0.80 m, while the highest is at station 1, which is -35.94 m, as shown in the graph and map in Fig. (11). The depth of the waters is closely related to the ability of sunlight to penetrate the water column, which is important for the growth of aquaculture commodities **(Hidayah *et al*., 2020)**. The optimal depth for marine aquaculture in coastal areas and its surroundings is 5-20 m, while the offshore area is 25-100 m **(Rizki, 2017)**. The depth of the ocean in marine aquaculture is influenced by the penetration of sunlight for photosynthesis, water circulation, and the types of organisms being cultivated.

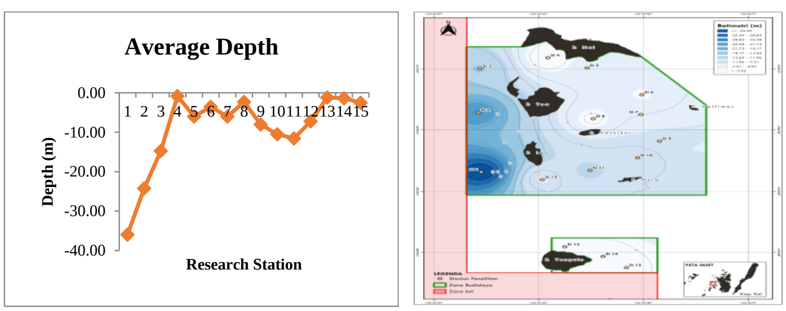


Fig. 11. Graph of average water depth and spatial bathymetry of the east season in the conservation area of Kei kecil Island Park

The coastal and marine habitats of the small TPK Kei conservation area research station, including coral reefs, seagrasses, sand, and rocky areas, can be seen on the map in Fig. (12). Coral habitats, sand, and rocks dominate this region. In some locations, coral reefs in this area have suffered significant damage due to human activities such as bombing and poisoning, but in others, they remain in good condition. With a relatively shallow regional profile and relatively higher utilization activity, as well as fluctuating environmental conditions, coral conditions have deteriorated. The percentage of coral reef closure in the area is dominated by Acropora branching at 42.40% (Acropora) and Coral massive at 8.46% (Non Acropora) **(Abrahams *et al*., 2018)**, and marine life found in the area of this research station includes sea cucumbers, starfish, kima, and various other mollusc organisms.

Fig. 12. Coastal and marine habitats of the east season in the conservation area of Kei kecil Island Park

Biological parameters of marine aquaculture sub-zones

The measurement results showed that the average value of chlorophyll a in the eastern season ranged from 0.10 to 0.83 mg/m^3. The variation in chlorophyll a value was not much different because the standard deviation of 0.23 can be seen both *in-situ* and spatially in Fig. (13). Chlorophyll a is an indicator of productivity and fertility, so it is very important in determining the optimal location for marine aquaculture. The measurement results showed that the chlorophyll a content at stations 1 to 15 was in the good category because it was in the chlorophyll-a < 15 mg/^{m3} **(Kementerian Lingkungan Hidup, 2004)**. The high and low concentration of chlorophyll a at stations 1 to 15 is influenced by nutrients (nitrates and nitrites), temperature, salinity, current, brightness, environmental conditions, and season.

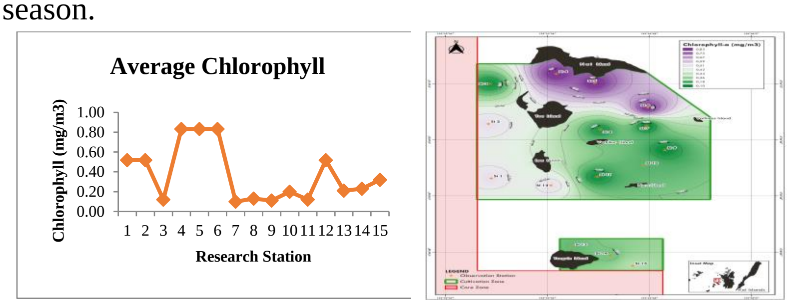
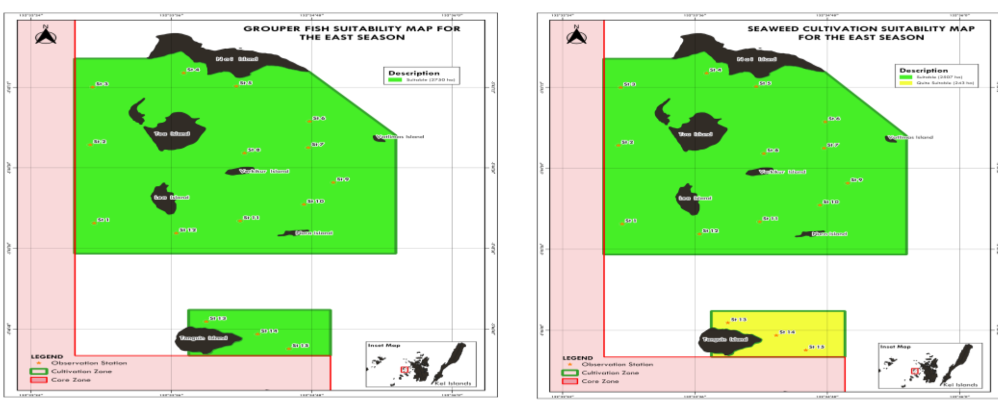


Fig. 13. Average graph and spatial chlorophyll-a of the east season in the conservation area of Kei kecil Island Park

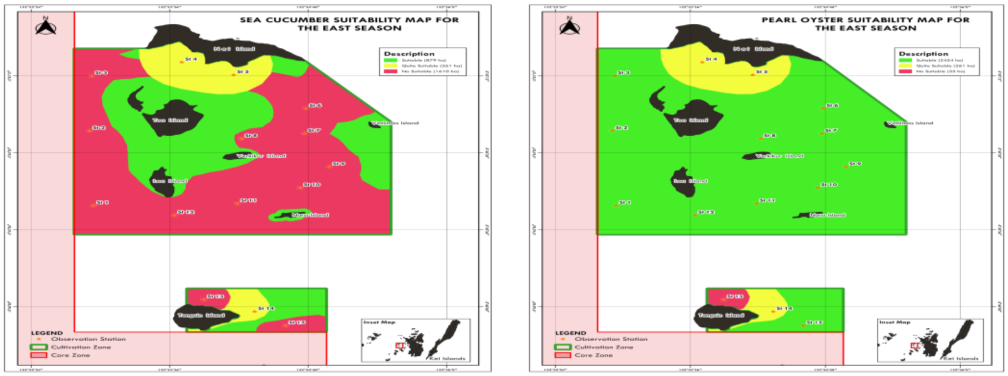
Aquatic effectiveness of the marine aquaculture sub-zone and marine aquaculture technology

The effectiveness of marine aquaculture sub-zones and technologies used in marine fisheries commodities in the eastern season can be determined through the suitability of physical, chemical, biological, and oceanographic aquatic ecological parameters because the growth of marine aquaculture commodities in aquaculture lands depends on natural marine environmental parameters, such as temperature, oxygen, chlorophyll, etc. **(Oyinlola *et al*., 2018)**. The area of the aquaculture zone used as the research location is 2,750 Ha. Determining the right marine aquaculture land based on the type of commodity or species is an appropriate and sustainable planning step **(Adibrata *et al*., 2023)**.

The results of the analysis of water quality parameters and the overlay of the effectiveness of marine aquaculture land in the eastern season are: 1) Grouper cultivation land in accordance with (S1) or effective 2,750 Ha (Station 1-15) using the floating net cage method (KJA); 2) Suitable (S1) or effective seaweed cultivation land of 2,507 Ha (Station 1-12) and suitable (S2) or sufficiently effective 243 Ha (Station 13-15) using the longline method and releasing the bottom (confinement); 3) Suitable (S1) or effective 879 Ha (near-shore coastal waters), suitable (S2) or quite effective 261 Ha (Stations 4, 5, and 14), not suitable (N) or ineffective 1,610 Ha using the tancap confinement method (PenaCulture); 4) Suitable (S1) or effective pearl oyster cultivation land covering an area of 2,454 Ha (Stations 1-3, 6-12), suitable (S2) or quite effective 265 Ha (Stations 4, 5 and 14), unsuitable (N) or ineffective 35 Ha (Station 13) using the longline method and floating raft can be seen in Fig. (14).



(a) **(b)**



(c) **(d)**

Fig. 14. Effective marine cultivation locations: (a) Grouper Fish, (b) Seaweed, (c) Sea Cucumber, (d) Pearl Oyster Based on Commodity Types During the East Season in the conservation area of Kei kecil Island Park.

The effectiveness of marine aquaculture land for the cultivation of grouper, seaweed, sea cucumber, and pearl oysters in the aquaculture sub-zone of the small TPK Kei conservation area is greatly influenced by water quality. Water quality is the key factor in the success of cultivation **(Dahuri, 2004)**. In the eastern season, all research areas in the TPK conservation area are suitable or practical for grouper fish cultivation using KJA because it is supported by water conditions that have a level of water quality suitable for grouper fish cultivation **(Arifin *et al*., 2014)**. Generally, aquaculture sub-zone waters in the eastern season are suitable for seaweed cultivation using the longline and bottom (confinement) methods because almost all ecological parameters and seaweed cultivation technology are beneficial, hence the category is suitable and suitable enough to be distributed in these waters **(Yulianto *et al*., 2025)**. The area of sea cucumber cultivation land in the unsuitable category is greater than the appropriate category. It is suitable for the tancap confinement method because it is influenced by the depth and basic conditions of coastal waters **(Winanda *et al*., 2021)**. Pearl oyster cultivation using the longline and floating raft methods requires a suitable land area that is larger than the actual land area. Pearl oyster farming is strongly influenced by currents, sea surface temperature, and salinity **(Habib *et al*., 2018)**, and is close to the mainland because it is more protected **(Hadinata *et al*., 2019)**.

CONCLUSION

The waters of the aquaculture sub-zone in the conservation area of Kei Kecil Island Park in the eastern season are physically, chemically, biologically, and oceanographically feasible for marine aquaculture. In the eastern season, the waters of the cultivation sub-zone are fully effective for grouper fish cultivation, namely 2,750 Ha using the floating net cage method, 2,507 Ha effective seaweed cultivation land and 243 Ha using longline and groundless methods, 879 Ha effective taripang cultivation land, 261 Ha effective and ineffective 1,610 Ha using the planting confinement method, and 2,454 Ha effective pearl oyster cultivation land. 265 Ha is quite effective, and 35 Ha is not effective using longline and floating raft methods.

ACKNOWLEDGMENTS

The author would like to thank the Directorate General of Research and Development of Higher Education, Science and Technology, for providing us researchers with the opportunity to obtain the Fundamental Research Bitch 1 scheme in 2023, the Tual State Fisheries Polytechnic for providing support to us researchers, the Maluku Provincial Marine Fisheries Service in this case the Representative of Island Cluster VIII as the manager of the TPK Kei Kecil conservation area who has provided very valuable data and information for this research.

REFERENCES

Adinugroho, M.; Subiyanto, A. and Haeruddin. (2014). Komposisi dan distribusi plankton di Perairan Teluk Semarang. *Jurnal Saintifika*, 16(2): 39–48. Retrieved from https://junej.jurnal.unej.ac.id/index.php/STF/article/view/2412.

Adibrata, S.; Pamungkas, A.; Priyambada, A.; Wahidin, L.O. and Hidayat, S.I. (2023). The Environmental Parameters Suitability For Multispecies-Based Mariculture In Pongok Island Waters, Bangka Belitung. *Indonesian Aquaculture Journal*, 18(2): 133-145. http://dx.doi.org/10.15578/iaj.18.2.2023.133-145.

Amalia, R.A.H.T.; Tasya, A.K. and Rahmadani, D. (2021). Kandungan Nitrit dan Nitrat Pada Kualitas Air Permukaan. *Prosiding SEMNAS BIO Universitas Negeri Padang*, 01: 679-688. https://doi.org/10.24036/prosemnasbio/vol1/87.

Abrahamsz, J.; Sahetapy, D.; Lopulalan, Y.; Dangeubun, L.J.; Thenu, I.M.; Makailipessy, M.M.; Pical, C.; Larwuy, W.; Ruban, F.; Ingratubun, M.A.; Silaban, R. and Tutuhatunewa, Ch.M. (2018). *Potensi Perikanan Kabupaten Maluku Tenggara: Wilayah Pengembangn Perikanan I Edisi Revisi*. Dinas Perikanan Kabupaten Maluku Tenggara.

Arifin, T.; Bohari, R. and Arlyza, I.S. (2014). Analisis Kesesuaian Ruang Berbasis Budidaya Laut di Pulau-Pulau Kecil Makassar: Aplikasi Sistem Informasi Geografis. *Forum Geografi*, 28(1): 91–102.

Dahuri, R. (2004). *Sumber Daya Wilayah Pesisir dan Laut*. PT. Pradnya Paramita, Jakarta.

Effendi, H. (2003). *Telaah Kualitas Air bagi Pengelolaan Sumber Daya Lingkungan Perairan*. Kanisius, Yogyakarta. 243 p.

Ferawati, E.; Widyartini, D.S. and Insan, I. (2014). Studi Komunitas Rumput Laut Pada Berbagai Substrat Di Perairan Pantai Permisan Kabupaten Cilacap. *Scripta Biologica*, 1(1): 55–60.

Ferdiansyah, H.I.; Praktikto, I. and Suryono. (2019). Pemetaan Kesesuaian Lahan untuk Budidaya Rumput Laut di Perairan Pulau Poteran, Kabupaten Sumenep, Jawa Timur. *Journal of Marine Research*, 8(1): 36-40. Retrieved from https://ejournal3.undip.ac.id/index.php/jmr.

Habib, A.H.A.; Fitri, A.W.; Anggraeni, N.P.F. and Sucahyono, D. (2018). Mapping potential areas for pearl oyster (Pinctada maxima) cultivation using satellite imagery based on hydrometeorological parameters on seasonal patterns in Lombok waters, West Nusa Tenggara. *Prosiding Seminar Nasional Fisika dan Aplikasinya*: 1-13. Universitas Sebelas Maret Surakarta.

Hadinata, F.W.; Yulianda, F. and Yonvitner. (2019). Study of the suitability of pearl oyster cultivation areas in the coastal area of North Lombok Regency. *Journal of Aceh Aquatic Science*, 3(1): 39-57.

Handayani, C.I.M.; Arthana, I.W. and Merit, I.N. (2010). Identifikasi Sumber Pencemar dan Tingkat Pencemaran Air di Danau Batur Kabupaten Bangli. *Fakultas Pertanian. Universitas Udayana*, Bali.

Hamuna, B.; Tanjung, R.H.; Suwito, S. and Maury, H.K. (2018). Konsentrasi amoniak, nitrat dan fosfat di perairan Distrik Depapre, Kabupaten Jayapura. *EnviroScienteae*, 14(1): 8-15. https://doi.org/10.20527/es.v14i1.4887.

Haribowo, D.R.; Anisa, S.; Izza, N.D. and Kholidah, N. (2019). Kimia Fisik Perairan dan Ektoparasit Ikan Nila dan Patin Di Situ Gintung, Tangerang Selatan, Banten. *Journal of Marine and Aquatic Sciences*, 5(2): 203-210. https://doi.org/10.24843/jmas.2019.v05.i02.p06.

Hidayah, Z.; Arisandi, A. and Wardhani, M.K. (2020). Pemetaan Kesesuaian Perairan untuk Budidaya Laut di Perairan Pesisir Kabupaten Situbondo dan Banyuwangi Jawa Timur. *Rekayasa*, 13(3): 307-316. https://doi.org/10.21107/rekayasa.v13i3.9858.

Hutabarat, S. and Evans, S.M. (1985). *Pengantar Oseanografi*. Universitas Indonesia Press, Jakarta.

Hutabarat, J. (2005). Studi Penyusunan dan Pemetaan Potensi Budidaya Laut di Perairan Kabupaten Rembang Propinsi Jawa Tengah. *Ilmu Kelautan*, 10(4): 237-244. https://doi.org/10.14710/ik.ijms.10.4.237-244.

Hutabarat, A.A.; Yulianda, F.; Fahrudin, A.; Hartati, S. and Kusharjani. (2009). *Pengelolaan pesisir dan laut secara terpadu*. Pusdiklat Kehutanan Departemen Kehutanan RI Secem-Korea International Cooperation Agency, Bogor.

Hutagalung, H.P. and Rozak, A. (1997). Penetuan Kadar Nitrat. *Metode Analisis Air Laut, Sedimen dan Biota*. Pusat Penelitian dan Pengembangan Oceanologi, LIPI, Jakarta.

Jaya, J.; Laitte, M.H. and Febri, F. (2022). Analisis kesesuaian dan daya dukung lahan budidaya ikan baronang (Siganus sp) di perairan pesisir Kabupaten Maros. *Akuatikisle: Jurnal Akuakultur, Pesisir dan Pulau-Pulau Kecil*, 6(1): 51-56. https://doi.org/10.29239/j.akuatikisle.6.1.51-56.

Jusuf, H.; Adityaningrum, A. and Arsyad, C. (2023). Analisis Kandungan Nitrat (No3), Nitrit (No2), Dan Kandungan Logam Berat Merkuri (Hg) Pada Air Di Danau Perintis Kabupaten Bone Bolango. *Jambura Journal Of Health Science And Research*, 5(4): 1101-1111. Retrieved from https://Ejurnal.Ung.Ac.Id/Index.Php/Jjhsr/Index.

Kementrian Lingkungan Hidup Republik Indonesia (KLH). (2004). *Baku Mutu Air Laut Untuk Biota Laut*. Keputusan Menteri Negara Lingkungan Hidup No. 51 Tahun 2004 Tentang Baku Mutu Air Laut. KLH, Jakarta.

KKP (Kementerian Kelautan dan Perikanan). (2016). *Keputusan Menteri Kelautan dan Perikanan Republik Indonesia Nomor 6/Kepmen-Kp/2016 tentang KAWASAN Konservasi Pesisir Dan Pulau-Pulau Kecil Pulau Kei Kecil, Pulau-Pulau, Dan Perairan Sekitarnya Di Kabupaten Maluku Tenggara Provinsi Maluku*. Indonesia.

KKP (Kementerian Kelautan dan Perikanan). (2020). *Peraturan Menteri Kelautan dan Perikanan Republik Indonesia Nomor 31/Permen-KP/2020 tentang Pengelolaan Kawasan Konservasi*. Indonesia.

Lubis, M.A.; Lestari, R.; Saputra, R.; Hasanudin, M. and Kusmanto, E. (2022). Studi Arus Sejajar Pantai dan Variasi Arus Laut Terhadap Kedalaman di Daerah Perairan Pantai Pasar Palik, Bengkulu Utara. *Jurnal Kelautan Nasional*, 17(1): 27-36. http://dx.doi.org/10.15578/jkn.v17i1.10102.

Mawaddah, A.; Roto, B. and Suratman, A. (2016). Pengaruh Penambahan Urea Terhadap Peningkatan Pencemaran Nitrit Dan Nitrat Dalam Tanah. *Jurnal Manusia Dan Lingkungan*, 23(3): 360–364. https://doi.org/10.22146/jml.22473.

Mutiah, S.; Sumardiyono. and Pujiastuti, P. (2022). Analisis Parameter Nitrit, Nitrat, Amonia, Fosfat Pada Air Limbah Pertanian Dusun Bendungan, Genuk Harjo, Wuryantoro, Wonogiri. *Jurnal Kimia dan Rekayasa*, 3(1): 33-45. https://doi.org/10.31001/jkireka.v3i1.43.

Nurhayati. (2006). Distribusi Vertikal Suhu, Salinitas, Arus Di Perairan Morotai, Maluku Utara. *Oseanologi dan Limnologi di Indonesia*, 40: 29-41.

Oyinlola, M.A.; Reygondeau, G.; Wabnitz, C.C.C.; Troell, M. and Cheung, W.W.L. (2018). Global estimation of areas with suitable environmental conditions for mariculture species. *PLoS ONE*, 13(1): 1-19. https://doi.org/10.1371/journal.pone.0191086.

Paputungan, F.; Pangemanan, N.P.L.; Tumbol, R.A.; Undap, S.L.; Tumembouw, S.S. and Rantung, S.V. (2022). Kajian kualitas air untuk menunjang perikanan budidaya Danau Moaat, Provinsi Sulawesi Utara. *Budidaya Perairan*, 10(2): 134–143. https://doi.org/10.35800/bdp.10.2.2022.37130.

Patty, S.I. (2014). Karakteristik fosfat, nitrat dan oksigen terlarut di perairan Pulau Gangga dan Pulau Siladen, Sulawesi Utara. *Jurnal Ilmiah Platax*, 2(2): 74-84. https://doi.org/10.35800/jplt.3.2.2015.9579.

Patty, S.I.; Arfah, H. and Abdul, M.S. (2015). Zat Hara (Fosfat, Nitrat), Oksigen Terlarut dan pH Kaitannya Dengan Kesuburan di Perairan Jikumerasa, Pulau Buru. *Jurnal Pesisir Dan Laut Tropis*, 3(1): 43-50. https://doi.org/10.35800/jplt.3.1.2015.9578.

Picaulima, S.M.; Rahakbauw, S.D.; Ngamel, A.K.; Ohoiwutun, E.C. and Kilmanun, A.D. (2023). Efesiensi Biaya Produksi dan Efektivitas Produksi Usaha Perikanan Jaring Insang Dasar Skala Kecil Setiap Musim di Desa Labetawi, Kota Tual. *AGRIKAN - Jurnal Agribisnis Perikanan*, 16(2): 339-347. https://doi.org/10.52046/agrikan.v16i2.339-347.

Picaulima, S.M.; Makalipessy, M.M. and Thenu, I.M. (2024). Competition Pattern of Small-Scale Cluster-Based Capture Fisheries in Each Season in the Small Island Park Conservation Area of Southeast Maluku Regency, Indonesia. *Egyptian Journal of Aquatic Biology & Fisheries*, 28(2): 1183–1195. https://doi.org/10.21608/ejabf.2024.374105.

PP RI (Peraturan Pemerintah Republik Indonesia). (2021). *Peraturan Pemerintah Republik Indonesia Nomor 22 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup*. PP RI, Jakarta.

Poernomo, H.; Rahardjo. and Suyatno, T. (2005). Reduksi Merkuri Dalam Air Limbah Penambangan Emas dengan Zeolit dan Secara Pengendapan. *Prosiding PPI*: 133-139.

Putriningtias, A.; Bahri, S.; Faisal, T.M. and Haraha, A. (2021). Kualitas perairan di daerah pesisir Pulau Ujung Perling, Kota Langsa, Aceh Water quality in coastal area of Ujung Perling Island, Langsa City, Aceh. *Habitus Aqua J*, 2(2): 95–99. https://doi.org/10.29244/HAJ.2.1.95.

Rizki, M.S. (2017). *Analisis Kesesuaian Wilayah Untuk Budidaya Laut dengan Menggunakan Pendekatan Data Citra Satelit Aqua Modis dan Insitu Di Kabupaten Gresik Jawa Timur*. Skripsi Program Studi Ilmu Kelautan, Jurusan Pemanfaatan Sumberdaya Perikanan dan Kelautan, Fakultas Perikanan dan Ilmu Kelautan Universitas Brawijaya Malang.

Rothig, T.; Tackett, S.M.T.; Voolstra, C.R.; Ross, C.; Chaffron, S.; Durack, P.J.; Warmuth, L.M. and Sweet, M. (2023). Human-induced salinity changes impact marine organisms and ecosystems. *Global Change Biology*, 29: 4731-4749. https://doi.org/10.1111/gcb.16859.

Rukminasari, N.; Nadiarti, A. and Khaerul, A. (2014). Pengaruh Derajat Keasaman (Ph) Air Laut Terhadap Konsentrasi Kalsium dan Laju Pertumbuhan Halimeda Sp. *Torani (Jurnal Ilmu Kelautan dan Perikanan)*, 24(1): 28-34. https://doi.org/10.35911/torani.v24i1.119.

Sari, T.E.Y. and Usman. (2012). Studi Parameter Fisika dan Kimia Daerah Penangkapan Ikan Perairan Selat Asam Kabupaten Kepulauan Meranti Propinsi Riau. *Jurnal Perikanan dan Kelautan*, 17(1): 88-100.

Selanno, D.A.J.; Tuhumury, N.Chr. and Handoyo, F.M. (2016). Status Kualitas Air Perikanan Keramba Jaring Apung Dalam Pengelolaan Sumber Daya Perikanan Di Teluk Ambon Bagian Dalam. *Jurnal TRITON*, 12(1): 42–60. https://ejournal.unpatti.ac.id/ppr_iteminfo_lnk.php?id=1849.

Siegers, W.H.; Prayitno, Y. and Sari, A. (2019). Pengaruh Kualitas Air Terhadap Pertumbuhan Ikan Nila Nirwana (Oreochromis Sp.) Pada Tambak Payau. *The Journal of Fisheries Development*, 3(2): 95–104. http//jurnal.uniyap.ac.id/index.php/Perikanan.

Suparyana.; Fauzi, A.; Kusumastanto, T. and Yulianto, G. (2023). Economic Analysis For Sustainable Management Of Marine Protected Areas In Ujung Kulon National Park. *Journal of Economic and Social of Fisheries and Marine*, 11(01): 28-39. http://dx.doi.org/10.21776/ub.ecsofim.2023.011.01.03.

Teniwuta, W.A.; Marimin. and Djatnab, T. (2019). GIS-Based multi-criteria decision making model for site selection of seaweed farming information centre: A lesson from small islands, Indonesia. *Decision Science Letters*, 8: 137-150. http://dx.doi.org/10.5267/j.dsl.2018.8.001.

Tubalawony, S.; Kalay, D.E.; Hukubun, W.G. and Hukubun, R.D. (2023). Distribusi Spasial Suhu dan Salinitas di Perairan Selat Haruku. *Jurnal Sumberdaya Akuatik Indopasifik*, 7(1): 13-22. https://doi.org/10.46252/jsai-fpik-unipa.2023.Vol.7.No.1.213.

Yulianto.; Sutarno.; Astuti, S.; Setyono, P.; Johan, Y.; Salim, D.; Tony, F. and Nursalam. (2025). Suitability analysis of land based seaweed cultivation on seasons in Tanjung Selayar, Kotabaru Regency, South Kalimantan. *AACL Bioflux*, 18(2): 903-915. Retrieved from http://www.bioflux.com.ro/aacl.

Yusuf, M. (2013). Analisis Kesesuaian Lokasi Untuk Budidaya Laut Berkelanjutan di Kawasan Taman Nasional Karimunjawa. *Ilmu Kelautan*, 18(1): 20–29. Retrieved from http://www.ijms.undip.ac.id.

Wetzel, R.G. (2001). *Limnology: Lake and River Ecosystem (Third Edition)*. Academic Press, San Diego.

Winanda, M.; Idiawati, N. and Nurdiansyah, S.I. (2021). Kepadatan dan Pola Distribusi Teripang (Holothuroidea) Di Teluk Cina Pulau Lemukutan. *Jurnal Laut Katulistiwa*, 25(1): 1-7.

Wyrtki, K. (1961). *Physical Oceanography of the South-East Asian Waters*. Naga Report 2.