



DEPIK

Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan

Journal homepage: www.jurnal.usk.ac.id/depik



The spatial distribution of coral diversity and connection to the oceanography conditions of Tidore Island Waters

Abdul Motalib Angkotasari^{1,*}, Abdul Ajiz Siolimbona¹, Salnudin¹, Firdaut Ismail¹, Asmar H. Daud², Nyoman M.N Natih³

¹ Marine Science Study Program, Fisheries and Marine Science Faculty, Khaorun University, Ternate-Indonesia. 97719, Indonesia.

² Aquaculture Study Program, Fisheries and Marine Science Faculty, Khaorun University, Ternate-Indonesia. 97719, Indonesia.

³ Department of Marine Sciences and Technology, Faculty of Fisheries and Marine Science, IPB University, Bogor 16680, Indonesia.

ARTICLE INFO

Keywords:
Coral reef
Tidore water
Temperature
Salinity

DOI: 10.13170/depik.0.0.47445

ABSTRACT

The Optimal coral reefs are distributed in shallow waters between 0 and 30 m deep, influenced by the hydro-oceanographic variability of the waters. Globally, corals are distributed in various forms of water predominantly found in the Coral Triangle region. This study aims to examine the spatial distribution of coral biodiversity in the Tidore Island Waters. This study was conducted in the Tidore Island Waters at three research stations, namely Tuguluha Station, Toloa Station and Tanjung Konde Station. This study analyzed the spatial distribution of coral and the relationship between coral biodiversity and the hydro-oceanographic conditions of the Tidore Island waters. The results showed that the highest coral diversity was found at Toloa Station, with the largest area being the Acropora tabulate coral life form. Acropora coral species were found throughout the research location, with the highest percentage of cover found at Toloa Station. Temperature and salinity variables are the main characteristics in the three research locations. Temperature has a role and main characteristics in Toloa Station. The spatial distribution of Acropora corals is related to temperature and salinity variability.

Introduction

Optimal coral reefs are distributed in shallow waters between 0 and 30 m deep, influenced by the hydro-oceanographic variability of the waters. The physical and chemical variability of the waters, namely temperature, salinity, and dissolved oxygen, affect coral growth, optimally occurring at depths of 10 m and 30 m (Monreal *et al.*, 2022). Seawater temperature puts great pressure on coral reefs in shallow waters (Van *et al.*, 2022). Annual variations in total nitrogen, dissolved oxygen, salinity, temperature, and chlorophyll affect the growth and development of coral reefs in shallow waters between 1 m and 5 m (Avendano *et al.*, 2019). Spatial variations in coral cover are correlated with temperature variations. High coral cover (>50%) is related to a highly variable temperature distribution (Rogers *et al.*, 2016). The distribution of corals in the

South China Sea is influenced by temperature variability, photosynthetically active radiation, current velocity, and dissolved nitrate and oxygen (Li *et al.*, 2024).

Coral reef ecosystems are important to study because they have a very large role and function for the sustainability of coastal and marine ecosystems and human survival. It is a provider of various economically important species for the fulfillment of human protein. Coral reefs are beneficial for human life, especially coastal protection, fisheries habitats, and tourism (Guldborg *et al.*, 2019). Coral reefs play an important role in global marine biodiversity and provide important ecosystem services (Bonelli *et al.*, 2024).

Globally, corals are distributed in various forms of water, predominantly found in the Coral Triangle region. Indonesia is the epicenter of the coral triangle

* Corresponding author.

Email address: am.angkotasari@unkehair.ac.id

with high coral distribution (Miller *et al.*, 2021). Corals are distributed in the South China Sea area; 31,360 km² is an area suitable for coral growth based on the environmental conditions of its waters (Li *et al.*, 2024). Geographic scale determines the pattern of spatial distribution estimates of coral diversity. The Western Indian Ocean is predicted to have a higher level of species diversity when compared to the Indo-Pacific coral triangle area (Kusumoto *et al.*, 2020).

The highest coral biodiversity is found in 14 Indo-Pacific ecoregions. The highest is found in the Raja Ampat Waters, Sulawesi Sea, and Halmahera Island Waters (Veron, 2011). The theory of statistical diversity estimation uses species presence records and completeness of sampling (coverage) to predict diversity in terms of species richness, dominance, and evenness. The spatial pattern of diversity estimation depends on the geographic scale.

The western Indian Ocean is estimated to have the most coral species, with greater diversity than in the Indo-Pacific Coral Triangle (Kusumoto *et al.*, 2020). The Pacific Ocean includes the South China Sea to the west coast of Western Australia and the Panama Coast to the southern coast of the Gulf of California. Coral grows well in the Indo-Pacific region to reach approximately 80 genera. Natural factors that cause coral to grow well in the western Indo-Pacific. *Acropora* in the Caribbean Sea consists of only 3 species, while in the Pacific Ocean it consists of around 80 species. While the *Porites* genus in the Caribbean has 3 species and 20 species for the Indo-Pacific Sea (Suharsono, 2008).

The condition of the coral reef ecosystem in Indonesia is experiencing degradation along with the dynamics of waters, climate change conditions, and anthropogenic activities. The current condition of coral reefs in Indonesia is in the category of very good 5%, good 20%, sufficient 35%, and poor 35%. The condition of these coral reefs is greatly influenced by various pressures that cause damage to the coral reef ecosystem. This pressure occurs as a result of various human and natural activities. Fish bombing activities, water pollution by industrial and household waste, climate change, rising sea levels, high sedimentation, ocean acidity, and rising sea surface temperatures are the main factors driving ecological change (Giyanto *et al.*, 2017).

Coral reefs are currently in danger, changing drastically in composition or being damaged. This happens because of human impacts, ocean acidification, and the biggest threat of increasing water temperatures. These ecological changes are then responded to by various organisms, including coral reefs. The choice is to adapt to changes in

existing environmental conditions; if unable to adapt, then they will die. This will have an impact on the degradation of coral biodiversity in the waters. The condition of coral reefs in a body of water is greatly influenced by the condition of the aquatic environment or oceanography. Geographical location also affects the condition of coral reefs; this is related to the dynamics of climate change that contributes to coral reef damage (Creswell *et al.*, 2017).

Climate change is one of the natural factors that impact coral reefs. Southeast Asian coral reefs have the highest level of biodiversity for marine ecosystems in the world. Indonesia has 12.5% of the world's total coral reef area ($\pm$ 58,000 km²). Indonesia is in the world's coral triangle. North Maluku is one of the waters in Indonesia that is included in the world's Coral Triangle Area (Susiloningtiyas *et al.*, 2018).

The waters of Tidore Island are located in the world's coral triangle area (Coral Triangle) in a tropical region that is geographically close to the equator so that it has the potential for a rich coral reef ecosystem. Tidore Island is located in the North Maluku archipelago, which is dominated by small islands. Tidore Island is a volcanic island, formed from volcanic activity that slowly emerged from the seabed to the surface (Bengen *et al.*, 2012; Mutaqin *et al.*, 2021; Angkotasari *et al.*, 2022). Island morphogenesis and the process of island formation contribute to the distribution of coral biodiversity. Volcanic islands generally have fringing reefs with high levels of coral biodiversity (Tomascik *et al.*, 1996).

Various studies on coral biodiversity in relation to the hydroceanographic conditions of small island waters have been conducted by several previous researchers. Kusumoto *et al.* (2024) studied the global distribution of coral diversity: biodiversity knowledge gradients related to spatial resolution. Predicting the highest coral species diversity is in the Western Indian Ocean. Veron (2011) studied the spatial distribution of corals in the Coral Triangle ecoregion. DeVantier and Turak (2017) studied species richness and relative abundance of reef-building corals in the Indo-West Pacific. It was found that as many as 627 coral species were found in the Indo-Pacific region, 224 of which were found in the Halmahera ecoregion. Mujiyono and Oktaviani (2021) conducted a study on the world's coral triangle: benefits, problems, and efforts. Stated that the coral triangle area is the epicenter of the world's marine biodiversity in the Indo-Pacific. Previous studies on the spatial distribution of coral diversity

have not fully explained the influence of hydro-oceanographic variability on the spatial distribution of coral diversity in each region. On this basis, this study raises the novelty of research related to the relationship between hydro-oceanographic variability and the spatial distribution of coral diversity in the waters of Tidore Island.

Coral biodiversity studies related to oceanographic conditions on Tidore Island are very important to see the spatial distribution of coral biodiversity. This data and information are important to be a preference in monitoring the impact of climate change and anthropogenic activities on the degradation of coral biodiversity in the waters of Tidore Island. This study needs to be carried out periodically to collect time series data. Thus, valid information will be collected and become an important part in compiling a scenario for managing coral reef ecosystems in the waters of Tidore Island. This study aims to examine the spatial distribution of coral biodiversity in the waters of Tidore Island.

Materials and Methods

Location and time

This research will be conducted for 8 months, starting from March to November 2024. The research location is in the waters of Tidore Island, namely in the waters of Tugulufa (Station 1), Toloa (Station 2), and Tanjung Konde (Station 3). The location of data collection can be seen on the following research location map:

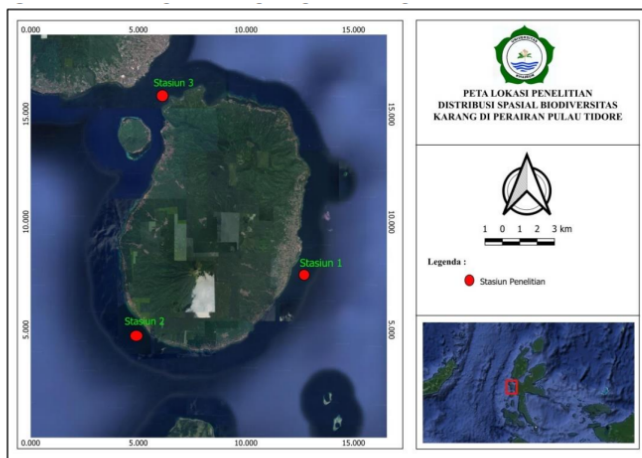


Figure 1. Research site in Tidore Island

Sampling

Coral reef data collection uses diving equipment (SCUBA), a 50 x 50 cm quadrant, and other supporting equipment for underwater recording. Coral data collection uses the Underwater Photo Transect (UPT) method based on guidelines from Giyanto (2013). The line transect method is carried out by stretching the transect (meter) parallel

to the line. The transect is placed along 50 m at a depth of 5 m, 10 m, and 15 m, which is a permanent transect. After the transect is placed, coral observations are then carried out.

The tools and materials needed in oceanographic data collection are the Weather Quality Checker to measure temperature, salinity, pH, DO, and turbidity variables in situ. Computer to download and process data. ODV software to process data.

Data Collection Method Observations are carried out at each point by placing a 50 x 50 cm quadrant (distance between quadrants 1 m) along the transect line as far as 50 m. Each quadrant was photographed using an underwater camera to analyze the distribution of coral life form cover percentage and coral diversity along the transect line. Data were distributed at depths between 5 m, 10 m, and 15 m with varying bottom topography. The results of the quadrant photos were then analyzed using the Coral Point Count with Excel Extensions (CPCe) software. The collection of quadrant photos that have been analyzed using CPCe will be the database in further analysis related to the distribution of coral between locations, between stations, and between depths. Oceanographic data consists of temperature, salinity, pH, DO, and turbidity. The data collection process was carried out directly in the field (in situ) using the Water Quality Checker. For the purpose of analyzing the spatial distribution of temperature and salinity, temperature and salinity data were also downloaded from the website <http://marine.copernicus.eu/>.

Data analysis

Coral data analysis is divided into two, namely coral ecological index analysis and coral morphological structure analysis. Each part has its own analysis method; the description of the analysis method of the two parts is as follows: a. Coral species diversity ecological index analysis Based on the taxa names obtained for each frame, the coral diversity value can be known, such as the number of species (S), the Shannon diversity index value = H' (Hutcheon, 1970).

$$H' = - \sum_{i=1}^S \left(\left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right) \right)$$

Description :

H' = Diversity Index

n_i = frequency of presence of species;

Coral Cover Presentage Analysis

This method is an application of sampling, where the population is all coral biota and substrates

contained in the photo, while the samples are randomly selected points in the photo. The data recorded are only coral biota and substrates that are right at the point position that has been randomly determined by the CPCe software. Furthermore, the percentage value of cover for each category of coral biota and substrate can be estimated based on the formula:

$$\text{Total coverage of category} = \frac{\text{Number of points in category}}{\text{Number of random points}} \times 100\%$$

With the criteria for coral cover percentage according to Maduppa and Zamani (2011), namely:

- Coral cover percentage of 0 - 24.9% is categorized as poor
- Coral cover percentage of 25 - 49.9% is categorized as Fair
- Coral cover percentage of 50 - 74.9% is categorized as Good
- Coral cover percentage of 75 - 100% is categorized as Very good

Principal Component Analysis

Analysis of the Relationship between Oceanographic Factors and Coral Biodiversity. A study on the relationship between oceanographic factors and the spatial distribution of coral biodiversity in the waters of Tidore Island using the Principal Component Analysis (PCA) approach (R Theam, 2021).

Results

Species composition

Corals in the waters of Tidore Island were found distributed at depths of 5 and 10 meters at three research stations, namely ST 01 Tugulufa, ST 02 Toloa, and ST 03 Tanjung Konde. These three stations have different bottom topographies; ST 01 and ST 02 have sloping topographies or reef flats, while ST 03 is a reef slope.

Based on the results of the study, it was found that the *Acropora* genus coral was dominantly found on the sloping bottom topography, namely in ST 01 Tugulufa and ST 02 Toloa, while *Porites* coral was dominantly found on the reef slope or reef slope ST 03 Tanjung Konde (Table 1). The results of the study can be seen in the table below:

Table 1. Spatial Distribution of Coral Life Forms

No	Genus	Percent Cover Coral (%) in Site Research				
		ST01 TJK 5m	ST01 TJK 10m	ST02 TGF 5m	ST02 TGF 10m	ST03 TOL 5 m
1	<i>Acropora</i>	3,68	2,32	0,68	0,32	22,56
2	<i>Tubastrea</i>	0,08	0,00	0,00	0,00	0,00
3	<i>Leptoseris</i>	1,82	0,60	0,00	0,00	0,32
4	<i>Pavona</i>	0,40	0,00	0,64	0,78	0,00
5	<i>Montipora</i>	1,86	1,14	0,64	0,00	3,20
6	<i>Leptoria</i>	2,20	2,24	0,00	0,00	0,00
7	<i>Stylocoeniella</i>	2,10	0,00	0,00	0,00	0,08
8	<i>Leptastrea</i>	1,68	0,00	0,00	0,00	0,00
9	<i>Cycloseris</i>	0,08	0,12	0,00	0,00	0,24
10	<i>Madracis</i>	0,56	0,62	0,00	0,00	0,00
11	<i>Echinopora</i>	0,00	0,16	0,00	0,00	0,24
12	<i>Hydnophora</i>	0,00	0,16	0,00	0,00	0,00
13	<i>Pachiseris</i>	0,00	1,30	0,00	0,00	0,00
14	<i>Turbinaria</i>	0,00	0,80	2,44	0,00	0,16
15	<i>Echinophyllia</i>	0,00	0,80	0,00	0,00	0,00
16	<i>Platygyra</i>	0,00	1,28	0,00	0,00	0,00
17	<i>Galaxea</i>	0,00	0,76	0,08	0,16	2,64
18	<i>Cyphastrea</i>	0,00	1,40	0,00	0,24	0,00
19	<i>Fungia</i>	0,00	0,16	2,52	2,92	0,24
20	<i>Acanthastrea</i>	0,00	0,32	0,00	0,00	0,00
21	<i>Porites</i>	0,00	8,40	0,00	2,66	0,40
22	<i>Pocilopora</i>	0,00	0,72	0,00	1,30	0,00

23	Scapophyllia	0,00	0,00	0,08	0,00	0,00
24	Merulina	0,00	0,00	0,00	1,36	0,00
25	Turbinaria	0,00	0,00	0,00	1,20	0,00
26	Goniastrea	0,00	0,00	0,00	1,36	0,24
27	Astreopora	0,00	0,00	0,00	0,24	0,00
28	Favia	0,00	0,00	0,00	0,32	0,24
29	Favites	0,00	0,00	0,00	0,76	0,00
30	Anacropora	0,00	0,00	0,00	1,60	0,00
31	Seriatopora	0,00	0,00	0,00	6,16	0,00
32	Coeloseris	0,00	0,00	0,00	0,24	0,00
33	Ctenactis	0,00	0,00	0,00	0,16	0,00

The results of the analysis showed that 33 genera were found in the Tidore Island Waters at three research stations. At ST01 Tanjung Konde station, we found 22 genera, with the highest percentage of coverage being the genus *Porites* at 8.40%. At ST02_Tugulufa we found 20 genera, of which the genus *Seriatopora* was the one with the highest percentage of coverage at 6.16%. The number of genera found at ST03 Toloa was 12 genera. At this station, the genus *Acropora* had the highest percentage of coverage at 22.56%.

The table above shows that corals from the genus *Porites* with the Coral Massive (CM) life form type are dominantly found in ST 01 Tanjung Konde and ST 02 Tugulufa. Corals from the genus *Acropora* with the *Acropora* Tabulate (ACT) life form are

found dominantly at Toloa station with a percentage cover value of 22,56% (Figure 2). These waters tend to be calm and have gentle topography.

Hidro-Oceanography Condition in Tidore Island Waters

The waters of Tidore Island are the waters of a small island located in the epicenter of the Maluku Sea. Thus, these waters are directly influenced by the oceanographic dynamics of the Maluku Sea, Halmahera Sea, Banda Sea and the Pacific Ocean. Based on the results of the study, it was found that the temperature, salinity and pH conditions are still in good and optimal conditions for the growth and development of coral reefs. Oceanographic data can be seen in the Table 2 :

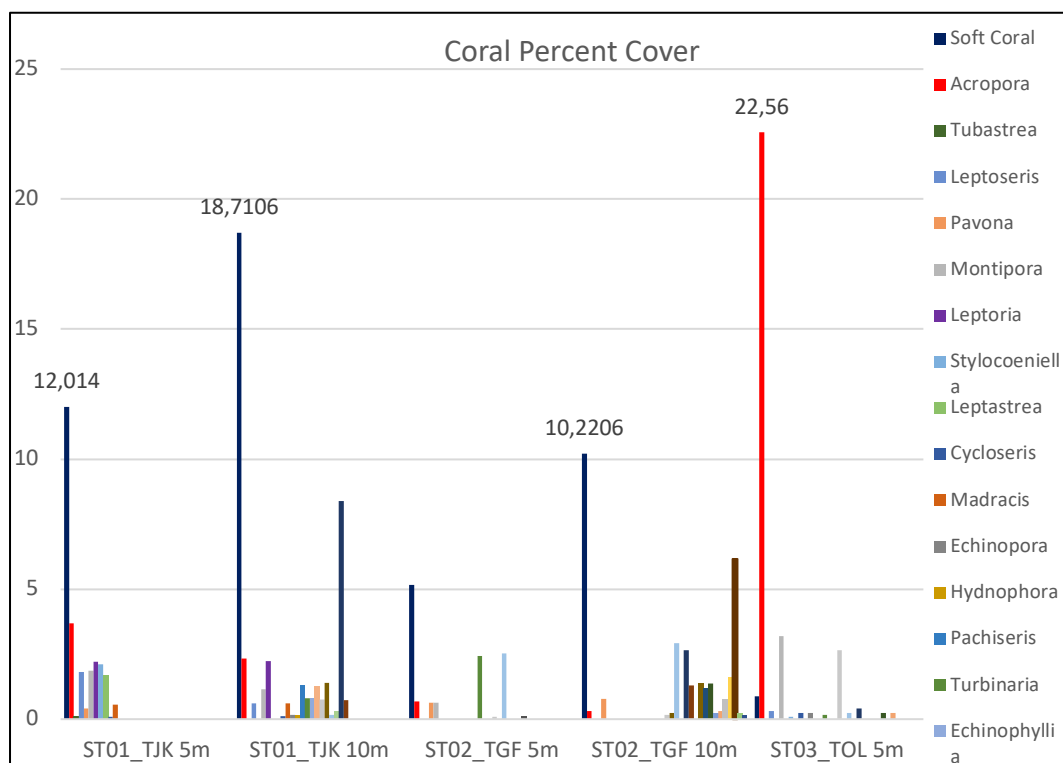
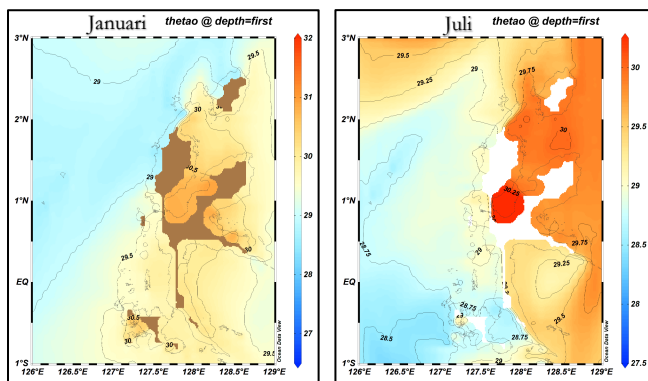


Figure 2. Bar Chart of Coral Percentage in Tidore Island Water

Table 2. Data of Oceanography Variable

Station Name	Temperature	Salinity	DO	pH	Visibility
ST01_Tj Konde	26,52	30,03	9,16	7,64	25
ST02_Tugulufa	26,47	29,71	9,2	7,63	24
ST03_Toloa	26,71	28,57	9,01	7,8	25

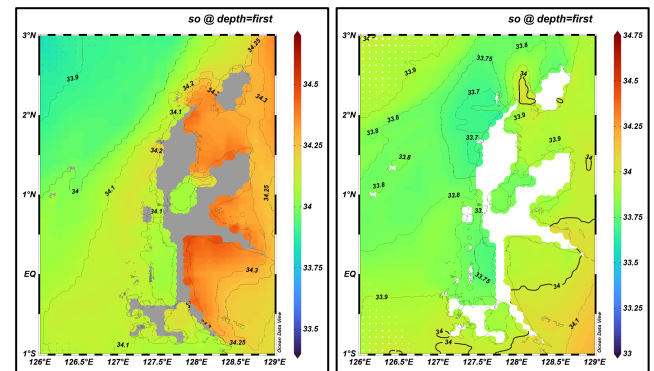
The water conditions on Tidore Island are also very dynamic when viewed in July and January 2024. Based on the results of the analysis of spatial distribution data on temperature and salinity using data from www.marinecopernicus.eu processed using ODV software (Figure 3), it shows that the temperature in July is higher than the temperature in January.


Figure 3. Spatial Distribution of Temperature in the Maluku Sea and Tidore Island

Based on the results of field data collection in the table above, it was found that the seawater temperature at the three research stations ranged between 29°C and 31°C. This means that the water temperature at the three data collection locations is still in the good and optimal category for the sustainability of coral life.

Based on the results of field data collection in the table above, it was found that the sea water temperature at the three research stations ranged between 29°C - 31°C. This means that the water temperature at the three data collection locations is still in the good and optimal category for the sustainability of coral life.

The highest salinity was found at ST 03 Tanjung Konde station at 34.2 in January and 33.88 in July (Figure 4). However, if we look at the salinity data, the three stations are still in the optimum water salinity conditions for coral growth and development.


Figure 4. Spatial Distribution of Salinity Variables in the Maluku Sea and Tidore Island

The results of the analysis of the relationship between coral reef conditions and oceanographic conditions can be seen in the vector matrix image of the results of the analysis with exclestat using Principal Component Analysis (PCA) in Figure 5.

Relationship between Spatial Distribution and Hydro-Oceanographic Conditions

The relationship between coral variables as biological variables or living things and physical and chemical variables of waters as environmental variables or habitats where they grow is very important to observe. Based on the results of research at the three stations, it shows that the highest percentage of hard coral cover in Toloa waters with the highest oceanographic variable is temperature. However, all the observed oceanographic variables still show good and optimum conditions for coral life.

The results of the principal component analysis at the three research locations showed that the genera *Acropora*, *Monitpora*, *Galaxea*, and *Echinopora* had significant correlations with the variables pH, temperature, and water brightness. While porties, soft coral, and sponge had significant correlations with dissolved oxygen.

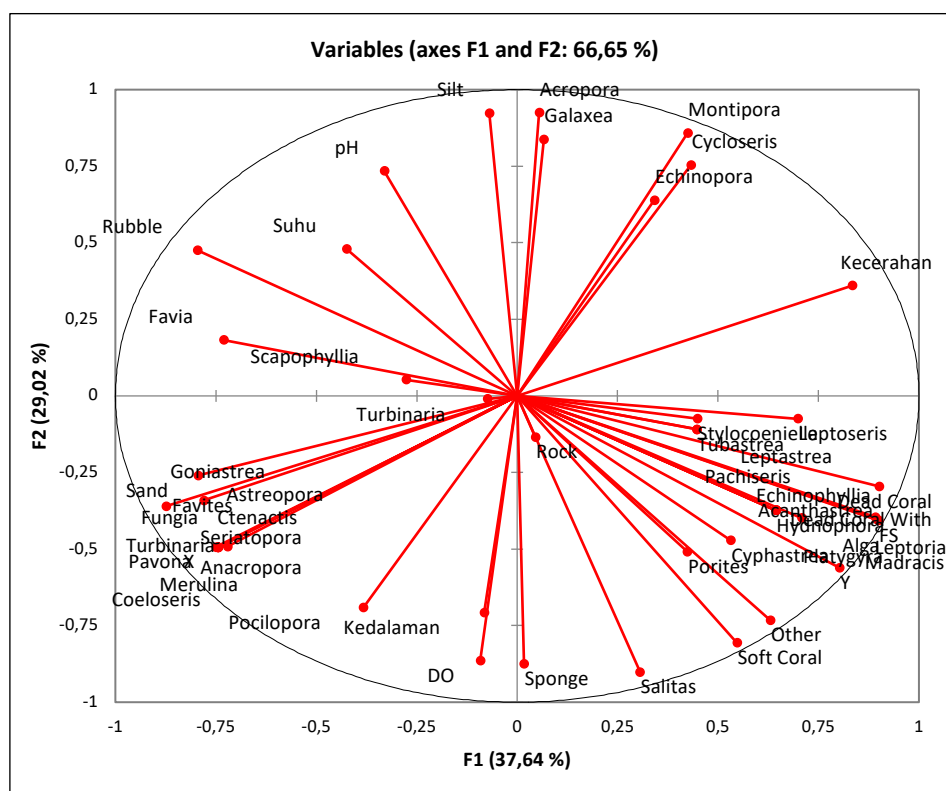


Figure 5. Principal Component Analysis Result

Discussion

Different bottom topography will contribute to the potential for differences in the spatial distribution of coral in waters. Branching corals are predominantly found in waters with flat topography (reef flats), while massive corals and encrusting corals are predominantly found on reef slopes (Angkotasari et al., 2023).

Differences in depth also affect the distribution pattern of corals in waters. Corals are distributed in shallow to mesophotic waters between depths of 5 m and 100 m. Coral taxa show heterogeneity in size structure, with significant differences between depths, morphological growth forms, and species. Branching and corymbose corals are more common in shallow waters, while encrusting and laminar forms cover most of the mesophotic corals (Kremer et al., 2020).

Differences in slope gradient indicate different forms of coral growth, where on a slope gradient of 90° the most common form of coral growth is encrusting, while on slope gradients of 55° and 43° it is generally dominated by massive growth forms (Reskawati et al., 2022).

Differences in depth also affect the distribution pattern of corals in the waters. According to Kremer et al. (2020), corals are distributed in shallow waters to mesophotic waters between 5 m and 100 m depths. Coral taxa show

heterogeneity in size structure, with significant differences between depths, morphological growth forms, and species. Branching and corymbose corals are more common in shallow waters, while encrusting and laminar forms cover most of the mesophotic corals.

Corals of the genus *Acropora* are found distributed in shallow waters in the waters of Pahat Island. The distribution of *Acropora* corals is found in waters with a gentle bottom topography (Arafat et al., 2020). The types of corals found in the outermost location are dominated by crustal corals, while in the deepest location they are dominated by branching corals, namely *Acropora*, *Pocillopora*, and *Montipora* (Siringoringo et al., 2019). Recently, new species of hard corals (Order Scleractinia) were recorded in Indonesia. Genus *Acropora* has been identified as having about 114 species in the world, of which 91 species in Indonesia (Yafie et al., 2022).

The direct effects of the light environment are often cited as the primary factor influencing growth patterns of *Acropora* corals. Light intensity or changes in spectral profile play a significant role in larval settlement under most environmentally realistic settings but may under more extreme or artificial settings (Richard et al., 2021). *Echinopora* corals have a strong relationship with variable light intensity and the primary colony gradient. Having leaf plates acts as a solar light trap, which also adjusts

its primary gradient to optimize light capture (Iwase et al., 2008).

Conclusion

The results of this study produced four conclusions. First, the coral genus *Proites* has the highest percentage of coral cover in the waters of Tidore Island at the three research stations. Second, the coral genus is spatially distributed on different bottom topographies. The genera *Porites* and *Acropora* are predominantly found on reef flats, while the coral genus from the coral encrusting life form is predominantly found on reef slopes. Third, the environmental conditions of the waters, namely temperature and salinity, in the three research locations were higher in July (the southeast season) than in January (the northwest season). Fourth, the variables of temperature and salinity are the main characteristics in the waters of Tidore Island. Temperature has a significant positive effect on the coral genus *Acropora* and *porites*, while current has a significant effect on coral encrusting.

Acknowledgments

We would like to thank the government and people of Maitara Island for their support during the research, as well as Faculty of Fisheries and Marine Science, Khairun University for giving us research grants.

References

- Angkotasan, A.M., D.G. Bengen, I.W. Nurjaya, N.P. Zamani, N.M. Natih, F.Novico. 2022. Geomorphology of small islands and its seafloor profiles in the Eastern And Western Halmahera waters. *Bulletin Marine. Geology.* 37 (2). DOI <https://doi.org/10.32693/bomg.37.2.2022.774>.
- Angkotasan, A.M., D.G. Bengen, I.W. Nurjaya, N.P. Zamani, N.M. Natih, and Zulfikar A. 2023. Hard coral cover in the Halmahera waters: Spatial distribution and environmental factors. *Regional Studies in Marine Science* 68 (2023)103234. <https://doi.org/10.1016/j.rsma.2023.103234>
- Avendaño O, Salas-Monrealb D, Anisc A, Salas-de-Leond A.D, Monreal-Gomez A.M, 2019. Monthly surface hydrographical variability in a coral reef system under the influence of river discharge. *Estuarine, Coastal and Shelf Science* 222 (2019) 53–6. <https://doi.org/10.1016/j.ecss.2019.04.012>.
- Bengen G.D, 2004. Sinopsis Teknik Pengambilan Contoh dan Analisa Data Biofisik Sumberdaya Pesisir. PKSPL-IPB. Bogor.
- Bengen G.D, W.S.A. Retraubun, S. Saad. 2012. Menguak Realitas dan Urgensi Pengelolaan Berbasis Eko-Sosio Sistem Pulau-Pulau Kecil. Pusat Pembelajaran dan Pengembangan Pesisir dan Laut (P4L). Bogor.
- Bonelli, A.G.; Martin, P.; Noel, P.; Asner, G.P. Global Chlorophyll Concentration Distribution and Effects on Bottom Reflectance of Coral Reefs. *Oceans* 2024, 5, 210–226. <https://doi.org/10.3390/oceans5020013>
- Creswell K.A, P.D. J.E., Thomson, R.M. Trevenen, 2017. A Function-structural coral model. 22nd International Congress on Modelling and Simulation, Hobart, Tasmania, Australia, 3 to 8 December 2017.
- DeVantier L and Turak E, 2017. Species Richness and Relative Abundance of Reef-Building Corals in the Indo-West Pacific. *Diversity*, 9(3), 25. doi:10.3390/d9030025.
- Giyanto. 2013. Metode Transek Foto Bawah Air Untuk Penilaian Kondisi Terumbu Karang. Oseana, Volume XXXVIII. Nomor 1, Tahun 2013 47-61.
- Giyanto, M. Abrar, W.E.A. Manuputty, M.R. Siringoringo. 2017. Panduan Pemantauan Kesehatan Terumbu Karang (Edisi 2). P2O LIPI. Jakarta.
- Hoegh-Guldberg O, Poloczanska ES, Skirving W and Dove S (2017) Coral Reef Ecosystems under Climate Change and Ocean Acidification. *Front. Mar. Sci.* 4:158. doi: 10.3389/fmars.2017.00158 (Hutcheon, 1970).
- Hutcheson, K, 1970. A Test for Comparing Diversities Based on the Shannon Formula. *Journal of Theoretical Biology*, 29, 151-154. [http://dx.doi.org/10.1016/0022-5193\(70\)90124-4](http://dx.doi.org/10.1016/0022-5193(70)90124-4)
- Iwase A, Sakai K, Suzuki A, and van Woessik R, 2008. Phototropic adjustment of the foliaceous coral *Echinopora lamellosa* in Palau. *Estuarine, Coastal and Shelf Science*, 77 (4) <https://doi.org/10.1016/j.ecss.2007.10.022>.
- Kramer N, Tamir R, Eyal G, Loya Y. 2020. Coral Morphology Portrays the Spatial Distribution and Population Size-Structure Along a 5–100 m Depth Gradient. *Front. Mar. Sci.* 7:doi:10.3389/fmars.2020.00615.
- Kusumoto, Buntarou, Costello, J. Mark, Kubota, Yasuhiro, Shiono, Takayuki, Wei, Chiao, Lin, Yasuhara, Moriaki, Chao, Anne. 2020. *Global distribution of corals diversity: Biodiversity knowledge gradients related to spatial resolution. Ecological Research*, 0, 1440-1703.12096
- Kohler E.K and Gill M.S, 2005. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers & Geosciences* 32 (2006) 1259–1269.
- Li T, Feng J, Zhao L, Wang D, Fan R, 2024. Geographical distribution of coral reefs and their responses to environmental factors in the South China Sea. *Ecological Indicators* 158 (2024) 111485. <https://doi.org/10.1016/j.ecolind.2023.111485>
- Madupa H., P.N. Zamani, 2011. A Standard Criteria for Assessing the Health of Coral Reefs: Implication for Management and Conservation. *Journal of Indonesia Coral Reefs* 1(2) (2011) 137-146.
- Salas-Monreala D, Monreal-Jimenezb R, Contreras-Terezac K.V, Monreal-Gomez A.M, Salas-de-Leond A.D, Riveron-Enzastiga M.L, 2022. Hydrographic variation in a tropical coral reef system: The Veracruz Reef System, Gulf of Mexico. *Oceanologia* 64 (2022) 473—488. <https://doi.org/10.1016/j.oceano.2022.03.002>
- Miller J.M, Wouthuyzen S, Aoyama J, Sugeda Y.H, Watanabe S, Kuroki M, Syahailatua A, Suharti S, Hagihara S, Tantu Y.F, Trianto, Otake T, and Tsukamoto K, 2021. Will the High Biodiversity of Eels in the Coral Triangle be Affected by Climate Change. *IOP Conf. Series: Earth and Environmental Science* 789 (2021) 012011 IOP Publishing. doi:10.1088/1755-1315/789/1/012011.
- Mujiyono and Oktaviani, 2021. Segitiga Terumbu Karang Dunia (The Coral Triangle): Manfaat, Masalah Dan Upaya. *Jurnal Dinamika Global* Vol. 6 No. 1, Juni 2021 P-ISSN 2548-9216. E-ISSN 2684-9399.
- Mutaqin, B.W., M.A. Marfai, D.S. Hadmoko, H.Wijayanti, A. Faral. 2021. Comparison of DEMs Spatial Resolution for Geomorphological Study in a Small Volcanic Island of Tidore, North Maluku, Indonesia. *Odum, E.P. (1971) Fundamental of Ecology. 3rd Edition, W.B. Saunders, Philadelphia.*
- R Core Team, 2021. R core team (2021). R A Lang. *Environ. Stat. Comput. R Found. Stat. Comput.* Vienna, Austria. URL <http://www.R-project.org>.
- Ricardo F, Harper E.C, Negri P.A , Luter M.H, Wahab A.AM and, Jones R.J, 2021. Impacts of water quality on *Acropora* coral settlement: The relative importance of substrate quality and light Gerard. *Science of the Total Environment* 777 (2021) 146079..

- Rogers S.J, Monismith G.S, Koweek A.D, Torres I.W, and Dunbar B.R, 2016. Thermodynamics and hydrodynamics in an atoll reef system and their influence on coral cover. *Limnol. Oceanogr.* 61, 2016, 2191–2206. VC 2016 Association for the Sciences of Limnology and Oceanography doi: 10.1002/lno.10365
- Reskiwati, Ompi M, Rembet J.W.N.U, Kusen D.J, Mantiri E.S.O.R, and Sumilat A.D, 2022. Vertical distribution and effect of the depth on growth form and genus of hard coral on coral reef in Bunaken Island, North Sulawesi, Indonesia. *Aquatic Science & Management*, Vol. 10, No. 1, 1-7 (April 2022) Graduate Program, UNSRAT, Manado, Indonesia. DOI: <https://doi.org/10.35800/jasm.v10i1.35238>
- Suharsono, 2008. Jenis-jenis Karang di Indonesia. Lembaga Ilmu Pengetahuan Indonesia (LIPI), Coremep Program. Jakarta.
- Siringoringo M.R, Hadi A.T, Sari P.W.N, Abrar M, and Munasik, 2019. Distribution and Community Structure of Coral Reefs in The West Coast of Sumatra, Indonesia. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences* March 2019 Vol 24(1):51-60. DOI: 10.14710/ik.ijms.24.1.51-60.
- Susiloningtyas D., T. Handayani, N.A. Amalia. 2018. The Impact of Coral Reefs Destruction and Climate Change in Nusa Dua and Nusa Penida, Bali, Indonesia. *IOP Conf. Series: Earth and Environmental Science* 145 (2018) 012054.
- Tomascik, T., R.Van Woesik, A.J. Mah, 1996. Rapid coral colonization of a recent lava flow following a volcanic eruption, Banda Islands, Indonesia. *Coral Reefs* 15.
- Van T.T, Hieu D.T.N, Huan H.N, and Lien P.N, 2022. Investigating Sea Surface Temperature and Coral Bleaching in the Coastal Area of Khanh Hoa Province. *IOP Conf. Series: Earth and Environmental Science* 964 (2022) 012004 IOP Publishing doi:10.1088/1755-1315/964/1/012004.
- Veron J.E.N., L.M. Devantier, E. G. Turak, A.L. Kininmonth, S.Stafford-Smith, M. Peterson 2009. Delineating the Coral Triangle. *Galax-J. Coral Reef*. 11, 91–100.
- Yafie M, Yusuf S, Haris A, Rani C, and Rasyid A, 2022. Biodiversity of the Genus *Acropora* (Order Scleractinia) in Spermonde Archipelago. *Coral Triangle Indonesia. Jurnal Ilmu Kelautan Kepulauan*, 5 (2) ; 585-597, DESEMBER , 2022. <http://ejournal.unkhair.ac.id/index.php/kelautan>.

How to cite this paper:

Angkotasan, M. A., A. A. Siolimbona, F. Ismail, Salnudin, H. A. Daud, N. M. N. Natih. 2025. The spatial distribution of coral diversity and connection to the oceanography conditions of Tidore Island waters. *Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan*, Special Issue The 5th ICFM: 170–178