Analysis of hard coral condition on coral reef ecosystem in Ternate Island

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Abstract. Hard coral is a type of coral building structure in coral reef ecosystems. Hard coral is a coral reef entity that plays an important function in a coral reef ecosystem, especially related to physical and ecological functions in shallow marine waters environment. This study aimed to study percentages of coral cover, species life form, diversity index, dominance index, and distribution clusters of hard corals based on environmental parameters around Ternate Island. Hard coral cover sampling was carried out systematically using the underwater photo transect (UPT) method. The number of sampling stations were 30 location points with 750 photos. The method used for analyzing ecological conditions of hard corals was coral point count with excel extensions (CPCe). Environmental parameters measured included salinity, temperature, pH, brightness level, and dissolved oxygen. The distribution of hard coral clusters was analyzed statistically using the classify-hierarchical cluster. Study results showed that coral cover percentages ranged from 19% to 93% with an average cover of 67%, species diversity range was 7 to 40 species with an average of 19 species, diversity index (H’) with a value of 1.14 to 6.02 with an average of 2.07, dominance index (D) with a value of 0.13 to 0.53 with an average of 0.23. The results of the analysis of the distribution of hard corals consisted of four clusters. The study also found that distribution of hard coral clusters in Ternate Island was related to substrate topography.

1. Introduction

Ternate Island is a small island with an area of 101.6777 km² and a coastline length of 42 km [1]. Coastal waters of Ternate Island has abundant coral reefs which are very important to preserve. The existence of coral reef ecosystems in these waters plays an important role in protecting Ternate Island in its interaction with marine dynamics. Ternate coastal topography and its location that directly facing the Maluku Sea were factors making coral reef ecosystems have important role for Ternate Island. One of critical roles of this ecosystem is as a barrier [2] to protect Ternate Island coast from erosion.

Coral reef ecosystems have a very important function in Ternate Island. The natural functions of coral reefs are (1) habitat and shelter, foraging for food, and breeding grounds for biota that live on coral reefs. (2) as physical protection against destructive currents and waves because coral reefs function as breakwaters. (3) as a biological resource because it produces several products that have important economic values such as various types of reef fish, algae, sea cucumbers, and pearl shells.
(4) as a source of natural beauty because it displays very beautiful scenery and can rarely be matched by other ecosystems, thus bringing in foreign exchange from marine tourism [3][4].

Hard coral is a type of coral ecosystem whose hard structure is formed from limestone and is a very complex and fertile area with very high productivity [5]. Hard coral has abundant types of biota with high economic value. Coral reef ecosystems are composed of a variety of interrelated life-forms. Starting from groups that live permanently at bottom, groups of floating biota, and groups of biota that live as symbionts, commensals, and share predators [6].

Ternate Island is an island that has a very high community activity, both on land and sea. Various kinds of community activities have potentials to cause damage to coral reef ecosystems. These types of activities include waste from household activities, beach reclamation, sedimentation due to sand mining, oil spills from water transportation activities, and other activities that are directly related to the utilization of coral reef ecosystems [7][8].

Continuous availability of coral reef data is the basis for good planning and sustainable management of this ecosystem. High activity on Ternate Island has potentials to cause changes to availability of coral reef ecosystem data. This research was conducted to revise data and availability of up-to-date hard coral data on percentage of coral cover, type of life forms, diversity index and dominance index, and coral distribution clusters based on environmental parameters.

2. Materials and methods

2.1. Study areas
The study was carried out in coastal waters where coral ecosystems were found on Ternate Island, Ternate City (Figure 1). The number of sampling stations was 30 sampling locations.

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*Figure 1. Map of research locations around Ternate Island*
2.2. Data collection and analysis

This study conducted sampling of coral reef cover using the Underwater Photo Transect (UPT) method based on the 2014 Coremap-CTI LIPI Coral Reef Health Monitoring Guide [9][10] with a total of 30 sampling stations. All stations were located at coastal waters of Ternate Island which had coral reef habitat. Coral reef cover measurements was systematically carried out using the quadrant transect method which was made in a block area measuring 30 m x 30 m. In each block area, 5 (five) tracks were placed (Track 1, Track 2, Track 3, Track 4 and Track 5) with a distance of about 6 m which is located parallel to shoreline. Each track was measured its coral reef cover using 1 x 1 m quadrants with a total of 5 quadrants per track with a distance of about 6 m. All quadrants were placed in perpendicular to the shoreline. Total number of 1 x 1 m quadrant placement in each block area was 25 so that the total number of quadrants data sampling obtained for research location was 750 photo-quadrants. Analysis of coral cover percentage, type of life form, diversity index, and dominance index were undertaken with Coral Point Count with Excel extensions (CPCe) [11]. Environmental parameters measured included salinity, temperature, pH, water depth, brightness level, and dissolved oxygen. Cluster analysis in this study used the Classify-Hierarchical Cluster.

3. Results and discussion

3.1. Percentage of coral cover

Percentage of coral cover is one of indicators used in determining quality and level of coral damage [12]. This study succeeded in analyzing the percentage of coral cover using CPCe from 750 photo-quadrants from a total 30 sampling stations. The condition of the percentage of coral reef cover at the sampling location ranged from 19% to 93% with an average cover of 67% (Figure 2). In general, coral reef cover was influenced by the condition of coral reef communities to natural disturbances, including coral bleaching, coral disease, Acanthaster planci outbreaks, and storms [13].

Coral cover with the lowest percentage was found at stations 15, 12, and 14 with values of 19%, 20%, and 21%, respectively. Those three stations were located in the eastern part of the island and is a densely populated coastal area with quite high activity. Areas that are densely populated can have an impact on coral sustainability because of the presence of household waste that can cause coral damage [14]. As a densely populated area, this area was found to have several activities that can directly disrupt coral ecosystems [15] such as shipping lanes, boat docks, fishing, swimming, and various other activities.
3.2. Distribution of life form types, hard coral ecological index

Ecological index is a very important indicator in assessing the condition of an ecosystem [16]. Ecological index value is a value that can provide a quantitative picture of objects that can be used as a reference in determining a qualitative assessment. Types of ecological indices that are very important in analysis in a study are diversity index and dominance index. Value of the ecological index is highly dependent on the number of species present in a sample analyzed [17].

In this study, results of analysis of the number of life form coral species found at sampling locations around the coastal waters of Ternate Island ranged from 7 species to 40 species per station. The average life form coral species at each station was classified as medium value with a value of 19 species. Based on environmental parameter data, the difference in the number of species was caused by the varying sea topography conditions over sampling locations.

The diversity index value (H') of life form corals in the study sampling area ranged from 1.14 (found at Station 23) to 6.02 (found at Station 12). The average value of the life form corals at the research station location was 2.07. According to [16], the average value of the life form diversity index was classified as moderate diversity. Coral diversity was classified as low if the value of the Diversity Index (H') was smaller than 1 (H' < 1), classified as moderate if H' = 1 -3, and classified as high if H'> 3.

The value of the dominance index (D) of life form corals in the study sampling area ranged from 0.14 (found at Station 23) to 0.54 (found at Station 12). The average value of the dominance index of life form coral at the research station location was 0.24, the average value was classified as low dominance. According to [18][19], the value of the dominance index with a value of D = 0-0.5 means low dominance, D > 0.5-0.75 for moderate dominance, and if D = 0.75-1 then high dominance.

Table 1. Types of life forms, diversity index, and coral dominance of each cluster on Ternate Island

| Station | Number of Life Form Coral Types (Ni) | Diversity Index (H') | Coral Dominance (D) | Station | Number of Life Form Coral Types (Ni) | Diversity Index (H') | Coral Dominance (D) |
|---------|-------------------------------------|---------------------|-------------------|---------|-------------------------------------|---------------------|-------------------|
| 1       | 13                                  | 1.66                | 0.27              | 16      | 17                                  | 2.01                | 0.21              |
| 2       | 13                                  | 1.40                | 0.34              | 17      | 13                                  | 1.66                | 0.26              |
| 3       | 13                                  | 1.42                | 0.32              | 18      | 40                                  | 2.55                | 0.15              |
| 4       | 14                                  | 2.02                | 0.20              | 19      | 18                                  | 2.20                | 0.14              |
| 5       | 13                                  | 1.42                | 0.32              | 20      | 17                                  | 2.08                | 0.20              |
| 6       | 32                                  | 2.27                | 0.17              | 21      | 33                                  | 2.37                | 0.15              |
| 7       | 19                                  | 2.04                | 0.20              | 22      | 32                                  | 2.39                | 0.19              |
| 8       | 21                                  | 2.07                | 0.20              | 23      | 26                                  | 2.36                | 0.14              |
| 9       | 14                                  | 1.33                | 0.41              | 24      | 18                                  | 2.16                | 0.15              |
| 10      | 23                                  | 2.06                | 0.23              | 25      | 16                                  | 2.10                | 0.16              |
| 11      | 13                                  | 1.77                | 0.21              | 26      | 16                                  | 1.67                | 0.27              |
| 12      | 20                                  | 6.02                | 0.54              | 27      | 20                                  | 1.92                | 0.26              |
| 13      | 12                                  | 1.56                | 0.36              | 28      | 30                                  | 2.06                | 0.20              |
| 14      | 12                                  | 1.82                | 0.21              | 29      | 31                                  | 2.36                | 0.16              |
| 15      | 15                                  | 2.22                | 0.17              | 30      | 7                                   | 1.14                | 0.44              |

The value of the diversity index and dominance index in a population is generally always inversely proportional, meaning that the higher the diversity index value the smaller the dominance index [16][18]. According to [20], the diversity of biota was evidence used to see whether there is
pressure on the environment as a result of exploitation or pollution. Stable ecosystems were usually characterized by high diversity and a well-balanced population.

3.3. Hard coral distribution cluster
The characteristics of the location of the waters based on the sampling location were grouped using a Hierarchical Cluster with the Euclidean distance method. Based on the results of the Euclidean distance analysis with a similarity distance of 12.5 data characteristics (simplification of 50% Euclidean distance) obtained 4 (four) clusters (Figure 3). The formation of a station cluster as a result of field data measurements in the waters of Ternate Island was caused by the similarity of the characteristics of the variable values measured at the sampling station. The clusters were Cluster I which includes 8 stations namely stations 11, 12, 14, 15, 20, 21, 22 and 23, Cluster II includes 13 stations namely stations 1, 2, 10, 13, 17, 18, 19, 24, 25, 26, 27, 28 and 29, Cluster III includes 6 stations, namely stations 3, 4, 5, 6, 7, 8 and 16, and Cluster IV includes 1 station, namely station 30. This condition was following research conducted by [21] assessment of water quality in coastal areas was a multi-parametric phenomenon. [22] said that the hydrogeochemical characterization affects the spatial behavior of water quality.

![Figure 3](image)

**Figure 3.** Results of cluster analysis of hard coral distribution based on sampling stations on Ternate Island

Table 2 presents the distribution of life form of hard coral species found in each cluster shown in Figure 3. The total types of life form hard coral found at the study site were 53 species. The presence of this type of distribution was found to be different in each cluster. Based on environmental parameter data, this was more due to the different topographic depth conditions at the location of the sampling area. Bathymetric condition is a parameter related to the intensity of light and temperature that enters the bottom of the water as a requirement for corals to grow [23][24].
| Number | Types of Life Form Coral | Type of Life Form Coral for each Cluster |
|--------|--------------------------|----------------------------------------|
| 1      | Acropora cervicornis (AC) | √                                      |
| 2      | Acropora palmata (AP)     | √                                      |
| 3      | Acropora prolifera (APR)  | √                                      |
| 4      | Agaricia agaricites (AA)  | √                                      |
| 5      | Agaricia fragilis (AF)    | √                                      |
| 6      | Agaricia grahamae (AG)    | √                                      |
| 7      | Agaricia lamarckii (AL)   | X                                      |
| 8      | Agaricia tenuifolia (AT)  | √                                      |
| 9      | Agaricia undata (AU)      | √                                      |
| 10     | Colpophyllia breviserisialis (CB) | X                                      |
| 11     | Colpophyllia natans (CN)  | X                                      |
| 12     | Coral (general) (CORAL)   | X                                      |
| 13     | Coral juvenile (CORJU)    | X                                      |
| 14     | Dendrogyra cylindrus (DCY) | X                                      |
| 15     | Dichocoenia stellata (DST)| X                                      |
| 16     | Dichocoenia stokesi (DSO) | X                                      |
| 17     | Diplopora clivosa (DC)    | X                                      |
| 18     | Diplopora labyrinthisformis (DL) | X                                      |
| 19     | Diplopora strigosa (DS)   | X                                      |
| 20     | Eusmilia fastigiata (EF)  | X                                      |
| 21     | Favia fragum (FF)         | X                                      |
| 22     | Isophyllia sinuosa (IS)   | X                                      |
| 23     | Leptoseris cucullata (LC) | X                                      |
| 24     | Madracis decactis (MD)    | X                                      |
| 25     | Madracis mirabilis (MM)   | X                                      |
| 26     | Manicina areolata (MAR)   | X                                      |
| 27     | Meandrina meandrites (MME)| X                                      |
| 28     | Millipora alcicorns (MILA)| X                                      |
| 29     | Millipora complanata (MILC)| X                                      |
| 30     | Millipora squarrosa (MILS)| X                                      |
| 31     | Montastrea annularis (MA) | X                                      |
| 32     | Montastrea cavernosa (MC) | X                                      |
| 33     | Montastrea faveolata (MFAV)| X                                      |
| 34     | Montastrea franki (MFRN)  | X                                      |
| 35     | Mussa angulosa (MAN)      | X                                      |
| 36     | Mycetophyllia aliciae (MAL)| X                                      |
| 37     | Mycetophyllia danaan (MDA)| X                                      |
| 38     | Mycetophyllia ferox (MF)  | X                                      |
| 39     | Mycetophyllia lamarckiana (ML)| X                                      |
| 40     | Oculina diffusa (OD)      | X                                      |
41 Porites astreoides (PA) X √ √ X
42 Porites branneri (PB) X √ √ X
43 Porites divaricata (PD) √ √ √ X
44 Porites furcata (PF) √ √ √ X
45 Porites porites (PP) X √ √ X
46 Scolymia cubensis (SC) √ √ √ X
47 Scolymia lacera (SL) X √ X X
48 Siderastrea radians (SR) √ √ √ X
49 Siderastrea siderea (SS) √ √ √ X
50 Solenastrea bournoni (SB) √ √ √ X
51 Solenastrea hyades (SH) X √ X X
52 Stephanocoenia michelini (SM) √ √ X X
53 Tubastraea aurea (TA) X X √ X

Information: Cluster I = Station 11, 12, 14, 15, 20, 21, 22 dan 23; Cluster II = Station 1, 2, 10, 13, 17, 18, 19, 24, 25, 26, 27, 28 and 29; Cluster III = Station 3, 4, 5, 6, 7, 8 and 16; Cluster IV = Station 30

3.4. Environmental parameters

Environmental parameters measured in coral reef research were habitat characteristics that affect the survival of coral reefs [25]. Environmental parameters that affect the condition of coral reefs in this study were salinity, temperature, pH, Dissolved Oxygen (DO), brightness, and depth with the number of sampling points carried out at 30 locations over coastal waters of Ternate Island. The results of statistical analysis of environmental parameters showed that Ternate Island coastal waters to have variations in the value of each measured variable but no scientific analysis results with extreme values of significant refractive error. This was indicated by SE Mean which was generally a value less than 0.5. Dissolved oxygen with a value of 0.545 (confidence value slightly greater than 0.5) was caused by the nature of dissolved oxygen in nature which changes very quickly and was susceptible to environmental variable conditions such as quick temperature changes or sea turbulence generated by waves that also related to wind. This condition caused the DO value to change rapidly so that it was not consistent at every measurement sampling station. [26] have studied dissolved oxygen in seawater in the Gulf of Thailand and east coast of Malaysia Peninsula in September 1995 and April-May 1996 and found that the chemical properties of water vary widely.

| Variable         | Mean     | SE Mean | StDev  | Minimum | Median | Maximum | Range   |
|------------------|----------|---------|--------|---------|--------|---------|---------|
| Salinity (ppt)   | 34.89    | 0.39    | 2.14   | 30.00   | 35.93  | 36.68   | 6.68    |
| Temperature (°C) | 27.43    | 0.50    | 2.75   | 25.20   | 25.93  | 34.10   | 8.90    |
| pH               | 7.96     | 0.05    | 0.29   | 7.14    | 8.05   | 8.50    | 1.36    |
| DO (ppm)         | 13.73    | 2.80    | 15.36  | 2.10    | 7.20   | 46.70   | 44.60   |
| Brightness (%)   | 100.00   | 0       | 0      | 100     | 100    | 100     | 0       |
| Depth (m)        | 3.42     | 0.33    | 1.82   | 1.80    | 2.95   | 11.20   | 9.40    |

The study results showed that waters around Ternate Island had environmental parameters that were still suitable to support sustainability of coral reef organisms. Environmental variable data obtained in this study were considered feasible and were under tolerated values of the Indonesian seawater quality standard for biota as regulated by Decree of Indonesian Minister of Environment Number 51 of 2004 concerning Seawater Quality Standards.
Table 4. Average results of water quality measurements around Ternate Island waters according to seawater quality standards for biota

| Number | Variable       | Average Result of Measurement | Quality Standards (Indonesia Environment Minister’s Decision number 51, 2004) |
|--------|----------------|-------------------------------|--------------------------------------------------------------------------------|
| 1      | Salinity       | 34.88                         | coral: 33-34 and tolerate changes in salinity up to < 5% seasonal mean salinity  |
| 2      | Temperature °C | 27.43                         | coral: 28-30 and tolerance changes < 2°C from natural temperature             |
| 3      | Ph             | 7.96                          | 7 - 8.5 and tolerance changes up to < 0.2 pH units                           |
| 4      | Do (mg/l)      | 5.22                          | > 5                                                                           |
| 5      | Brightness (%) | 100                           | coral : > 5 m and changes up to < 10% euphotic depth                           |

4. Conclusion

Conclusions that can be made from this study results are as follows: (1) Percentage of coral cover ranged from 19% to 93% with an average cover of 67%, life form hard coral species (Ni) were found from 7 species to 40 species with an average of 19 species, the diversity index (H’) with a value of 1.1414 to 6.02403 and an average of 2.0713, the dominance index (D) with a value of 0.1363 to 0.5361 with an average of 0.2396, (2) Distribution of hard corals on Ternate Island consisted of four clusters caused by coastal waters topographic variations, while condition of aquatic environmental parameters sampled were relatively stable with relatively uniform values at all stations.

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