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Analysis of the Relationship Between Percentage Coral Cover and Water Quality Effects in Penuktukan, Bali

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Abstract*—The coral reef ecosystem is a diverse ecosystem that provides coastal protection, food sources, and raw materials for medicine, among other ecosystem services. Coral reef research in Penuktukan, Bali, is fundamental given its urgency in preserving the biodiversity and health of existing marine ecosystems. However, the condition of coral reefs in Penuktukan has yet to be widely studied. Hence, information on species diversity, health conditions, and the impact of environmental change and human activities on this ecosystem still needs to be explored. This research is aimed at fill these data gaps by evaluate the health status of coral reefs, identifying species present, and assessing the impacts of environmental and anthropogenic factors on coral reefs in Penuktukan. The study was conducted at eight observation stations to represent differences in environmental characteristics in July 2023. Field observations were conducted to measure water parameters, and underwater Photo Transects were used to determine the percentage of live coral cover. The results obtained on average water parameters include a temperature of 26.4 ° C, a salinity of 32.7‰, a pH meter of 7.7, a brightness of 3 meters, a depth of 3 meters, and 7 meters depth of 7 meters. This study identified coral massive (CM), coral encrusted (CE), and coralfoliose (CF), which were the most prevalent life forms in Penuktukan Village. The average percentage of live coral reefs in Penuktukan Village was 30.42 %, which suggests that coral reefs in Penuktukan Village Waters are in a medium condition, which is suitable for supporting coral reef ecosystem resilience and development.

Keywords—Coral cover, Underwater Photo Transect, Water quality

I. INTRODUCTION[1]

Indonesia is one of the archipelagic countries in the coral triangle, covering 53% of coral reefs [1]. The 2017 Indonesian Coral Reef status book explained that the coral reefs' condition was terrible. Coral reef ecosystems can be found in Indonesian waters near Penuktukan Village as a marine park. According to the Bali Marine and Fisheries Service, only 55% of the coral reef area in Bali has good quality, 30% of the area has poor quality and the rest is in poor condition [38]. The coral reef ecosystem is very complex and has a vital role in the environment and the survival of life in the sea; the diversity of coral reefs in this area makes this ecosystem able to provide food sources, spawning grounds, and shelter [2][3]. Corals can be found in all waters in the world, both subtropical and tropical, but tropical areas have the best reef growth rate [4][5].

Geographically, Buleleng Regency is located at 8° 3' 40" - 8° 23' 00" LS and 114° 25' 55" - 115° 27' 28" East, which is positioned in the northern part of Bali Island [43]. The northern region is bordered by the Java Sea and the southern region by the Indian Ocean. The east region is bordered by the Lombok Strait, and the west region by the Bali Strait. [44]. The Bali Strait are an area south of the equator located between Java Island and Bali Island [45]. The utilization of the coast of Bali, among others, is for tourism settlements, capture fisheries, and other purposes. However, the waters of Penuktukan Village, Buleleng Regency, based on previous research, have not provided an overview of the condition of coral reefs there, both from the percentage of cover and health conditions to the influence of water quality on the health quality of live coral cover.

There are natural reasons for coral reef ecosystem problems (not caused by humans), such as rising sea temperatures, large waves, and natural disasters, and human factors (anthropogenic), including the use of environmentally unfriendly fishing gear, taking coral reefs for building materials, overfishing, anchoring ship activities in coral reef areas, vessel grounding in coral reef ecosystems and others [6]. The sea surface temperature in Indonesia, especially the waters of Penuktukan Village in 2018 increased sea level so that the coral reef ecosystem does not survive. Therefore, it is necessary to research and fill these data gaps by evaluating the health status of coral reefs, identifying species present, and assessing the impacts of environmental and anthropogenic factors on coral reefs in Penuktukan. The benefits of this study are that it provides information related to coral reef diversity and a source of information for the local community to know the percentage of live coral cover in the waters of Penuktukan Village, Bali.

II. METHOD

A. Time and Place of Research

Determining this location uses techniques that determine sampling points based on the presence of coral reef ecosystems, such as purposive methods. There were eight observation stations with two different depths at odd stations (3 meters deep) and even stations (7 meters deep).

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Figure 1. Research location

This research placed in the waters of Penuktukan Village, Buleleng Regency, Bali, in July 2023, from the morning until noon. The research location can be seen in Figure 1. This study used several tools and materials to support field data collection and measure water quality and data processing. The research tools and materials measuring water quality are used in Table 1.

TABLE 1.
RESEARCH TOOLS AND MATERIALS AND WATER QUALITY

Tools and Materials	Function
Self-Contained Underwater Breathing Apparathus (SCUBA)	To diving aids during data collection.
Pencil	To record the results of the data that has been obtained.
Sabak	To record data obtained in the water.
Roll Meter 50m	Measuring the length of transect.
Underwater camera	To help record or take pictures during data collection.
SMB	A sign buoy is on top so that people can see there is activity underwater.
Boat	As transportation in the water.
Transect (58 cm x 44 cm)	As measuring coral reef cover.
GPS	To determine the coordinates of the research station.
Fish and coral identification book	To identify fish and coral reefs.
Laptop	To analyze the data that has been obtained.
Software Excel and XLSTAT	To process data on coral reefs, reef fish, and water quality.
Tissue	Cleaning electronic devices and water quality.
Thermometer	To record the results of the data that has been obtained.
Refractometer	To record data obtained in the water.
pH meter	Measuring the length of transect.
Secchi-disk	To help record or take pictures during data collection.

B. Data Collection Methods

Data collection uses primary data from the field: water parameters and the Percentage of live coral cover. Observation and field data collection can be done directly to obtain primary data. In this observation research, field observation is carried out as an observation method to help to know the conditions in the field.

a. Water quality parameters

Water quality parameters are collected in situ and measured as research support to determine the physical and chemical conditions. Performed with 3x repetition so that the data obtained is an accurate value. The water quality data taken in this study are temperature, salinity, brightness, and pH meter.

b. Percentage of live coral

Percentage of coral cover was determined by the underwater photo transect (UPT) method with a transect line of 50 m. [Each location stretches a roll meter along 50 meters at a depth of 5 meters - 7 meters and parallel to the coastline. Photos of habitat conditions around the

transect line were taken at every 1-meter span along the 50-meter transect line parallel to the coastline from 60 cm above the bottom of the substrate (Figure 2). The first photometer was taken on the left side of the transect line (closer to land), the second one on the right (far from land), and so on until the transect length reached 50 meters. Odd-numbered frames (1, 3, 5, ... 49) were taken left of the transect line, while even-numbered frames (2, 4, 6, ... 50) were taken right of the transect line. Coral Point Count with Excel Extensions (CPCe) software was used to analyze the photographs.

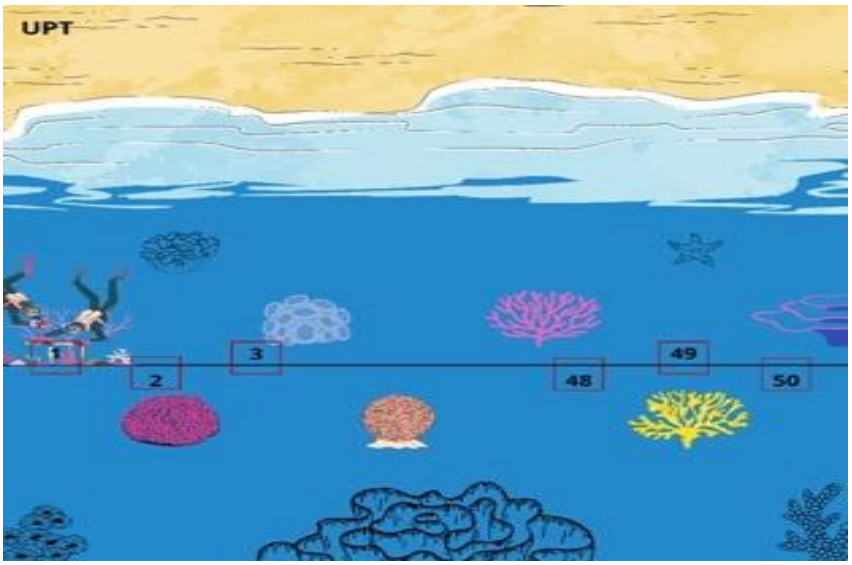


Figure 2. Illustra method Underwater Photo Transect

C. Research Data Analysis

Observers are responsible for data accuracy, documentation, processing, and analysis. All data obtained from the field should be digitized immediately on the same day to avoid forgetfulness and errors in data entry if done after the data has accumulated a lot. Data is documented in an Excel program as a database, then data processing and analysis are carried out, which include:

Water quality

Water quality measurements were taken three times at each research station. The variables measured directly on the spot (field) are the water's temperature, salinity, brightness, and pH. Variables can be calculated using the formula:

Variable = (V1+V2+V3)/3

Percentage of live coral cover

The percentage of coral cover that will be taken with the UPT method is underwater photographs. At least 50 files for each station. The data in the form of photographs must be appropriately handled in advance of analyzing them by immediately transferring them to other storage (internal hard drive or external hard drive) while they are still in the camera memory. With the folder format LLLMMMYYYANA/ORI (location, month, and year, the ANA code is for photo data to be analyzed, while the ORI code is for backup photo data). Then, subfolders with LLLNN format (location and station name) [7]. The calculation of the frame is based on the formula [8][9] based on the percentage value of the category cover of each photo frame, as follow:

$$Category\ cover\ percentage = \frac{Number\ of\ category\ points}{A\ lot\ of\ random\ points}\ x\ 100\%$$

The percentage of live coral cover is calculated according to the standard criteria for coral reef damage (KepmenLH No.4 of 2001), as shown in Table 2.

TABLE 2
THE PERCENTAGE CATEGORY FOR LIVING CORAL COVER

Condition	Category
Bad	0 – 24,9%
Medium	25 – 49,9%
Good	50 – 74,9%
Very good	75 – 100%

D. Analysis of the correlation between coral cover and water quality

Canonical correspondence analysis (CCA) was used to see the relationship between water quality and percent coral cover using XLSTAT software.

III. RESULTS AND DISCUSSION

A. Water Quality Parameters

Several parameters were measured: water temperature, salinity, brightness, and pH of the waters at each research station. The results of parameter measurements of Karimunjawa and Bali Waters with three repetitions were carried out in situ and at a depth of three meters and seven meters. Are presented in Figure 3 as follows:

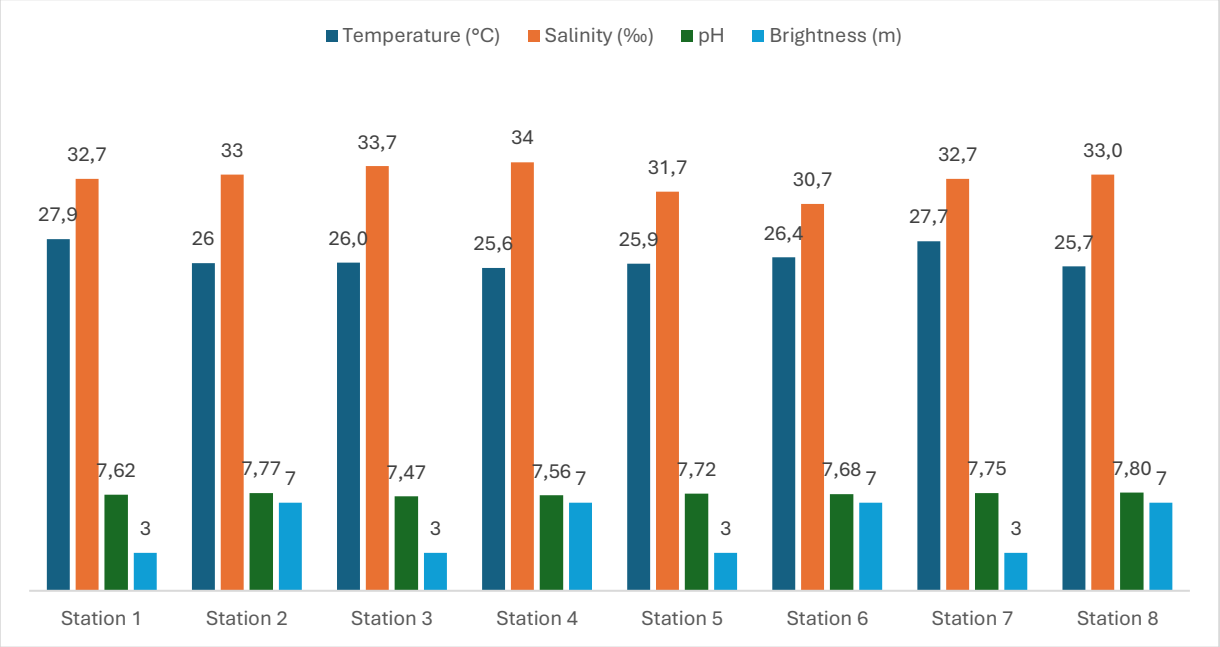


Figure 3. Water quality parameters

Temperature is one of the parameters that can control aquatic life and plays a vital role in marine biota life, especially coral reef ecosystems. The waters are considered suitable for coral reef health at the research location in the range of 26.4 ° C. Coral reefs have an optimum growth or development of 25°C - 30°C. However, some findings show that the general temperature of Indonesian marine waters ranges from 27°C to 32°C [10][11]. Ecologically, temperature changes cause changes in coral reef health conditions. According to several studies, sea surface temperatures that rise by 1°C or 2°C above their average value over an extended period of time can inhibit coral growth and cause coral bleaching [39][16].

Salinity measured at the research site was at an average of 32.7‰. The salinity of 25‰ - 40‰ is still good for coral growth and development. Therefore, the waters are freely associated with the support of sufficient current to support the salinity [12][13]. [14][11] Differences in seawater salinity can be caused by mixing caused by ocean waves or by wind-driven movement of water masses.

The results of measurements of seawater brightness at the research site at odd stations with a depth of 3m have a brightness value of up to 3m, and even stations with a depth of 7m have a brightness value of up to 7m; marine biota can survive when light penetrates the bottom of the waters. Brightness of a body of water is critical to coral reef development, and turbidity disrupts the respiration process and aquatic ecosystem [15]. Coral reef growth can be affected by high brightness levels; brightness directly correlates to light intensity entering the water column. The high brightness will boost photosynthesis and growth of zooxanthellae [40].

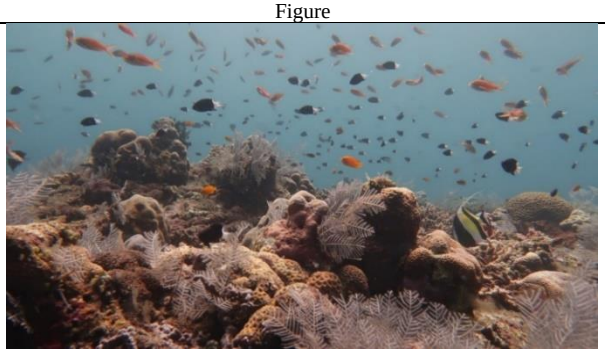
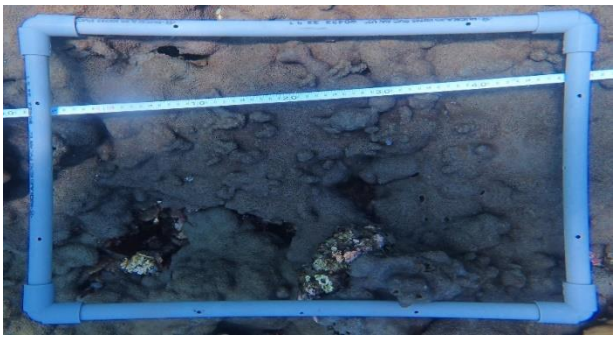
The measurement results show that the pH value of surface seawater at the research site is, on average, 7.67. So, the research location has a difference in pH value, but both waters are suitable for the growth or development of coral reefs. [16] the optimum pH value for coral reef growth ranges from 7.3 - 9.0. Corals are also threatened by acidification of seawater or a decrease in seawater pH since acidification reduces the ability of corals to form skeletons [17][18]. Consequently, increased chemical reactions due to increased ocean acidity can damage seawater chemical reactions and change marine waters' environmental conditions [41][42].

B. Coral Reef Condition

The general conditions at the research site are very supportive of research, as it has a flat seabed contour and dominant corals in non-Acropora corals. The presence of coral reef types reflects environmental conditions, where coral reef types are in the form of coral morphology, which is an adaptation to environmental conditions.

Coral reef growth has different levels of sensitivity to environmental pressures and environmental factors for coral reef growth such as temperature, salinity, depth, current, pH, brightness, and substrate. The dominant types of coral reefs in the research location are Coral Massive (CM), Coral Encrusting (CE), and Coral Foliose (CF) types, which can be seen in Table 3.

TABLE 3
DOMINANT CORAL TYPE

Figure

Coral Massive (CM)

Coral Encrusting (CE)

Coral Foliose (CF)

The presence of coral species in this research location depends on the condition of the aquatic environment, such as temperature, brightness, salinity, current, and substrate. Changes in environmental conditions influence coral growth, growth form, and reproduction abilities [19][20], thus giving effect to the abundance, composition, and diversity of corals [21]. [22] The dominant lifeforms, namely CM, CF, CME, and CA, were dominantly found on reef flat, reef slope, and reef crest forms, and CE and CS were dominant on reef flat and reef slope forms.

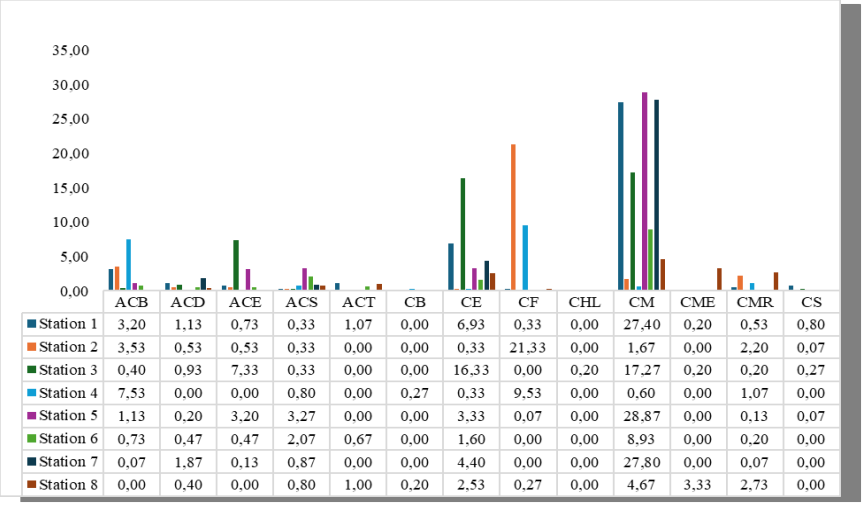
Massive and encrusting morphological forms have a good grip to withstand strong currents [23][24]. [25] Other factors at the Sumberkima Village research site have a hard substrate, sandy and not muddy, which is thought to be rock coral larvae that can easily attach and develop on the substrate. [26][27] There is a possibility of foliose coral (CF) conditions because corals with foliose or branching growth forms often grow at a faster rate than other coral types.

C. Percentage of Live Coral Cover

Coral reef cover, a vital indicator of a sea's coral reef health, was collected with great care at three and seven meters. Based on meticulous observations, the data revealed percentage of live coral cover average of 30.42% in the medium category. This level, resulting from our thorough data collection process, is suitable for coral reef health. Following is a graph illustrating coral reef coverage in the research area:

Coral Cover (%)

Figure 4. Percentage of Live Coral Cover



	ACB	ACD	ACE	ACS	ACT	CB	CE	CF	CHL	CM	CME	CMR	CS
Station 1	3,20	1,13	0,73	0,33	1,07	0,00	6,93	0,33	0,00	27,40	0,20	0,53	0,80
Station 2	3,53	0,53	0,53	0,33	0,00	0,00	0,33	21,33	0,00	1,67	0,00	2,20	0,07
Station 3	0,40	0,93	7,33	0,33	0,00	0,00	16,33	0,00	0,20	17,27	0,20	0,20	0,27
Station 4	7,53	0,00	0,00	0,80	0,00	0,27	0,33	9,53	0,00	0,60	0,00	1,07	0,00
Station 5	1,13	0,20	3,20	3,27	0,00	0,00	3,33	0,07	0,00	28,87	0,00	0,13	0,07
Station 6	0,73	0,47	0,47	2,07	0,67	0,00	1,60	0,00	0,00	8,93	0,00	0,20	0,00
Station 7	0,07	1,87	0,13	0,87	0,00	0,00	4,40	0,00	0,00	27,80	0,00	0,07	0,00
Station 8	0,00	0,40	0,00	0,80	1,00	0,20	2,53	0,27	0,00	4,67	3,33	2,73	0,00

The percentage of live coral cover in the waters of Penuktukan Village at a depth of 3 meters at station 1 is 42.67%, station 3 is 43.47%, station 5 is 40.27%, and station 7 is 35.20% the depth of 3 meters can be said to be in the medium category and suitable for coral reef health, While the depth of 7 meters at station 2 is 30.53%, station 4 is 20.13%, station 6 is 15.13% and station 8 is 15.93% the depth of 7 meters can be categorized as poor and moderate, only station 2 has a percentage value of 30.53% in the moderate category and suitable for coral reef health. Moderate conditions affect coral reef health, and more diverse and richer biota live on the reef [28][29]. Generally, the presence and condition of coral reefs significantly affect the richness and diversity of reef fish [30]. The percentage of live corals in poor condition, there are negative factors from human activities and natural factors in the waters of Penuktukan Village.

Several natural and human factors will influence coral reefs' high and low conditions. Coral reefs can be damaged by natural factors (predators, changes in water quality, global climate change) as well as by anthropogenic activities in water areas, such as marine transportation activities and fishing [6][31][32]. The factors [33][34] affecting coral reefs condition in near coasts include anthropogenic factors, the influence of other biotic activities around coral reef habitats, abiotic parameters, and the possibility of predator and prey. [35][36] Corals are vulnerable to environmental changes. The impacts on vulnerability to coral reefs are light, current, temperature, substrate, salinity, and brightness.

Negative impact factors from human activities include fishing rods that throw anchors on coral reef areas to break corals, fishing gear that is not environmentally friendly, snorkeling tourists, and human activities carried out on land also have an impact on the condition of aquatic organisms, such as dumping garbage directly into marine waters and pond waste. [37] Other damaging factors are waste disposal, environmentally friendly fishing activities, and tourist activities that step on corals intentionally or unintentionally.

The existence of coral reefs is the main factor that attracts biota to come, grow, develop, and be associated with coral reefs. Such as fish that interact directly by utilizing coral structures as a place to housing, find food, and breeding [46]. [47] [48] The presence of coral reefs positively impacts indicator fish species in finding food and coral reef cavities.

D. Coral reef percent cover and water quality relationship

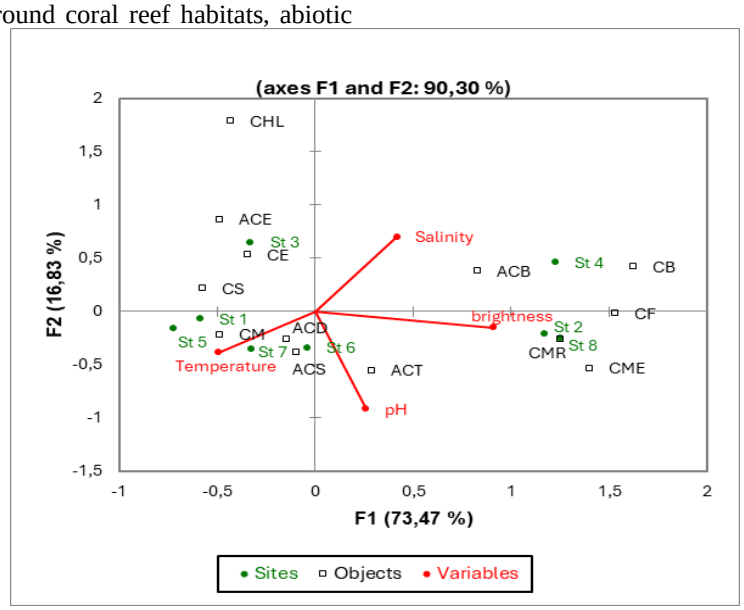


Figure 5. Coral reef percent cover and water quality relationship

Stations 1, 5, 6, and 7 are described with warm temperatures. Stations 2, 4, and 8 are characterized by high water brightness. However, only station 3 is not characterized by a more dominant parameter. As can be seen from the eigenvalue of 90%, the percentage of coral cover is strongly correlated with water quality parameters, which shows that the results of this study are presentative to explain the relationship between the two variables. The results obtained by CM, ACD, and ACS have a strong relationship with water temperature and pH. ACT is only strongly related to pH, while CS only has a close relationship with temperature. CME, CF, and ACB preferred sunnier water conditions. ACE and CE tend to prefer waters with more normal parameter values. Meanwhile, BC and CHL are not described as having a close relationship with water quality parameters because the value of the contribution made to coral percent cover could be more manageable, making it quite challenging to see their relationship with water quality parameters.

CONCLUSION

The results showed that the water parameters in Penuktukan waters, such as an average temperature of 26.4°C, salinity of 32.7‰, pH 7.7, brightness of 3 meters, and depth of 3 to 7 meters, coral reefs at this study site have unique characteristics that influence their condition and diversity. The types of life forms found, such as Acropora and non-acropora, are typical of this region, indicating the importance of this site as a unique habitat for various coral species. The most dominant life forms at depths of 3 and 7 meters, namely Coral Massive, Coral Encrusting, and Coral Foliose, play an essential role in maintaining ecosystem balance and show the specific dynamics of the coral reef ecosystem in Penuktukan waters. According to the average percentage of coral reef cover of 30.42 percent, coral reef ecosystems are in medium condition. This indicates that ecosystems in this region are capable of recovering and developing. Overall, this study indicates that Penuktukan coral reef ecosystems must be managed and conserved properly to ensure their sustainability.

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