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Research Article

Mortalitas karang dan kelimpahan ikan di Kawasan Suaka Alam Perairan Pesisir Timur Pulau Weh, Sabang, Aceh
[Coral mortality and fish abundance in the Marine Nature Reserve of the Eastern Coast of Weh Island, Sabang, Aceh]

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ABSTRACT | Coral reefs play an important role in marine ecosystems as habitats for various species of fish and other marine organisms, as well as protecting the coast from erosion and storms. However, climate change, pollution, human activities, and bleaching have resulted in declining coral conditions. The purpose of this study was to analyze the level of coral mortality and its effect on the abundance of coral fish. The study was conducted in the coastal nature reserve area of East Weh Island. Data collection was carried out at two depths using the Belt Transect method and the Underwater Visual Census technique. The results showed that the level of coral mortality in the coastal nature reserve area of East Weh Island reached 0.82 ± 0.05% at Reuteuk station. These results show that coral conditions in the protected area have a very high mortality rate. However, the high coral mortality in the area did not affect the abundance of coral fish (p-value > 0.05). This value indicates that coral fish can be found abundantly in damaged coral areas. The average results of coral mortality and abundance of coral fish at depths of 3 meters and 7 meters showed no significant difference. These results illustrate that at shallow or deep depths, coral and coral fish mortality can be found at high/abundant values.

Key words | Abundance, chaetodontidae, mortality

ABSTRAK | Terumbu karang memainkan peranan penting dalam ekosistem laut sebagai habitat bagi berbagai spesies ikan dan organisme laut lainnya, serta sebagai pelindung pantai dari erosi dan badai. Namun, terjadinya perubahan iklim, polusi, aktivitas masyarakat dan juga terjadinya pemutihan mengakibatkan kondisi karang semakin menurun. Tujuan penelitian ini adalah menganalisis tingkat mortalitas karang dan pengaruhnya terhadap kelimpahan ikan karang. Penelitian di lakukan di kawasan suaka alam perairan Pesisir Timur Pulau Weh. Pengumpulan data dilakukan pada dua kedalaman dengan metode *Belt Transect* dan teknik *Underwater Visual Census*. Hasil penelitian menunjukkan tingkat kematian (mortalitas) karang di kawasan Suaka Alam Perairan Pesisir Timur Pulau Weh mencapai 0,82±0,05% yang berada di stasiun Reuteuk. Hasil ini memperlihatkan kondisi karang di kawasan perlindungan memiliki tingkat kematian yang sangat tinggi. Namun, tingginya mortalitas karang di kawasan tersebut tidak mempengaruhi kelimpahan ikan karang (p-value > 0,05). Nilai ini menunjukkan bahwa ikan karang dapat ditemukan melimpah pada kawasan karang yang mengalami kerusakan. Hasil rata-rata mortalitas karang dan kelimpahan ikan karang pada kedalaman 3 meter dan 7 meter menunjukkan tidak terdapat perbedaan yang signifikan, hasil ini menggambarkan bahwa pada kedalaman dangkal ataupun dalam, kematian karang dan ikan karang dapat ditemukan dengan nilai yang tinggi/melimpah.

Kata kunci | Kelimpahan, chaetodontidae, mortalitas

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INTRODUCTION

After the bleaching event in 2016, the condition of Sabang's waters has undergone significant changes. Bleaching caused by the increase in sea temperature due to global warming has resulted in the bleaching and death of many coral reefs (Aldyza *et al.*, 2022a). Research shows that approximately 50% of coral

colonies in some locations in Sabang experienced bleaching, with most corals dying within a few months of the event. The impact of bleaching is not only felt by coral reef ecosystems but also by marine ecosystems as a whole, such as reef fish populations. The decline in live coral cover leads to reduced habitat for various species of fish and other marine organisms. This has an impact on the decline in biodiversity and fish populations in Sabang's waters.

The recovery of the Sabang marine ecosystem after the 2016 bleaching involved various initiatives, such as the establishment of conservation. Conservation is one of the efforts to improve and maintain coral reef ecosystems (Afkar & Aldyza, 2018). Coral transplantation programs and management of marine conservation areas have been carried out to improve the quality of coral cover. Although this recovery process takes a long time, there are positive signs that some coral reef areas are starting to show recovery with new coral growth and increased biodiversity. Research on coral ecosystems in Aceh waters and in conservation areas has been conducted by several researchers (Aldyza *et al.*, 2015; Fadli *et al.*, 2014; Munandar *et al.*, 2019; Ulfah *et al.*, 2021). One of the conservation areas that focuses on protecting reef ecosystems is located in the East Coast of Weh Island, Sabang City. Based on KEPMEN-KP Number 57 of 2013, the East Coast of Weh Island (*Pesisir Timur Pulau Weh*, PTPW) has been designated as a Marine Nature Reserve (*Suaka Alam Perairan*, SAP). This area is located in the eastern part of Weh Island with a coastline of approximately 15.8 km and an area of 3207.98 hectares (Siregar *et al.*, 2016). This determination aims to protect and preserve the marine ecosystem in the area.

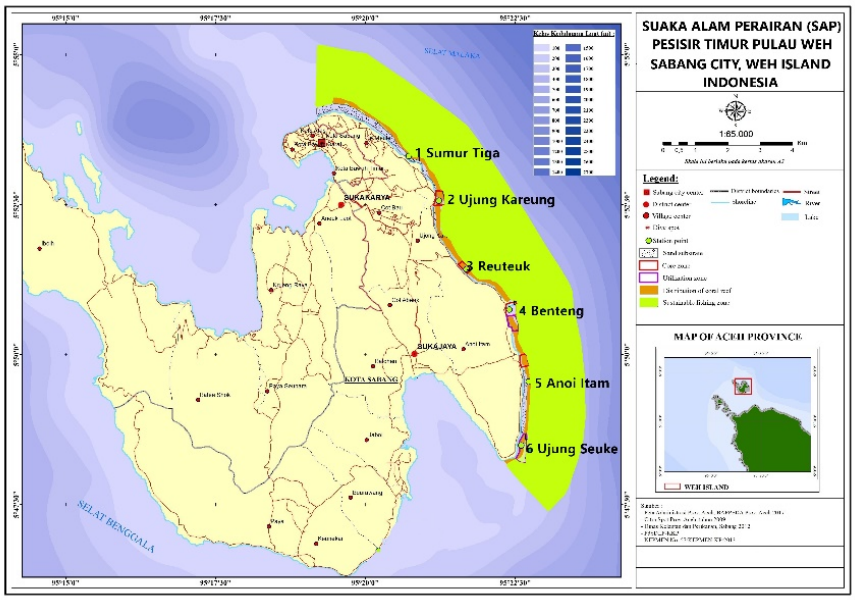

Figure 1. Research station location

SAP-PTPW management is carried out by the customary sea institution in collaboration with the Sabang City Government. This collaboration is an effort to maintain the sustainability of coral reefs in the waters of Weh Island, ensuring that the marine ecosystem is maintained and can be enjoyed by future generations (Aldyza *et al.*, 2022b). The condition of the abundance of coral fish is greatly influenced by the health of the coral reefs. Healthy coral reefs provide an ideal habitat for various species of reef fish, which depend on the complex structure and food sources provided by the coral. When coral reefs experience degradation or death, for example, due to coral bleaching or human activities, the abundance of coral fish tends to decrease. This is due to the loss of habitat and food sources that are essential for reef fish (Akbar *et al.*, 2014; Septiady *et al.*, 2021). Increasing the value of coral mortality can cause significant changes in the coral reef ecosystem. When coral dies, the complex physical structure of the coral will experience a decline in quality (collapse), thereby reducing the capacity of shelter and spawning areas for reef fish. In addition, coral death can also reduce biodiversity in the ecosystem because many species of coral fish are highly dependent on coral for their survival (Muttaqin *et al.*, 2014). The results of preliminary observations that have been carried out at SAP-PTPW show that the condition of the coral at several points

is experiencing degradation, so it is feared that it will continue to decline, which will have an impact on the population of coral fish. Therefore, it is necessary to conduct research on the abundance of coral fish and the level of coral mortality in the SAP-PTPW Sabang area, Aceh Province.

MATERIALS AND METHODS

Location and Time of Research

The research was conducted in the waters of the East Coastal Waters Nature Reserve of Weh Island (SAP-Pesisir Timur Pulau Weh), which consists of six stations, including Sumur Tiga, Ujong Kareung, Reuteuk, Benteng, Anoi Itam, and Ujong Seuke (Figure 1). Data collection was carried out in August–September 2021 using direct observation methods in the field.

Data Collection

In this study, one coral colony is considered as one individual. If the position of one colony of the same genus is separated by one other colony, then each separate part is considered a separate individual. If two or more coral colonies grow between other coral colonies, then each colony is still counted as a separate colony.

Coral mortality data collection was carried out using the Belt Transect method (Aeby *et al.*, 2021) with a transect length of 50 meters and a belt width of 2 meters placed parallel to the coastline, while coral fish abundance data collection used the visual census method (Underwater Visual Census, UVC), which was carried out in line with coral observations; only the width of the left and right belts was 5 meters. After that, the abundance of fish was calculated by the number of individual sigma fish divided by the area of the fish census (Anshari *et al.*, 2020). Each station was placed with six replica transects at two depths, namely a depth of 3 meters and a depth of 7 meters (Novriadi *et al.*, 2023). Identification of coral genera used the guidebook by Suharsono (2008) and Kelley (2009), while identification of fish species used the guidebook by Allen *et al.* (2003).

Data Analysis

The coral data that has been collected is analyzed using the coral mortality index formula (Mutmainah & Clara, 2017), while the calculation of fish abundance uses the abundance formulation calculated at each station based on the area of observation (Tambunan *et al.*, 2020). The category of coral fish abundance found in SAP-PTPW is determined based on Djamali and Darsono (Riskiani *et al.*, 2019) as follows: Very Rare (200-1000 ind/ha), Rare (1000-2000 ind/ha), Less Abundant (2000-4000 ind/ha), Abundant (4000-10000 ind/ha), and Very Abundant (>10000). Statistical analysis using linear regression and an independent T-test with an alpha reference value of 0.05. Statistical data processing using SPSS 23 and Microsoft Excel.

RESULTS

Water Quality

The growth and development of coral ecosystems significantly impact environmental conditions, making water quality a crucial aspect influenced by these factors. In-situ measurements at PTPW revealed the following results (Table 1).

Table 1. Water quality in the SAP-PTPW area

Stations	Depth	Factors				
		Temperature (℃)	pH	Salinity (‰)	Current (m/det)	Visibility (%)
1	3 m	30,67±0,57	7,9±0,06	33,33±1,15	0,15±0,03	300 cm
	7 m	29,67±0,57	7,9±0,06	34±0	0,11±0,02	670 cm
2	3 m	31,33±0,57	8,0±0,06	33,67±0,57	0,17±0,06	300 cm
	7 m	31±0	8,0±0,06	33,33±1,15	0,09±0,01	620 cm
3	3 m	30,67±0,57	8,1±0,06	32,00±1,00	0,07±0,01	300 cm
	7 m	31±0	8,1±0,06	32,33±1,15	0,08±0,03	700 cm
4	3 m	30,00±1,00	7,9±0,06	33,67±0,57	0,11±0,03	300 cm
	7 m	30,33±0,57	8,0±0,06	33,33±1,15	0,13±0,03	600 cm
5	3 m	30,33±0,57	8,1±0	33,00±1,73	0,14±0,01	300 cm
	7 m	31,33±1,15	8,1±0,06	34±0	0,12±0,06	660 cm
6	3 m	30,00±1,00	8,1±0,06	32,67±0,57	0,15±0,04	300 cm
	7 m	30±1	8,2±0	32,67±0,57	0,08±0,02	700 cm

Coral Mortality

Referring to the coral mortality criteria by Mutmainah and Clara (2017), the coral mortality rate at the observation stations in order from highest to

lowest is Reuteuk station 0,82%, Ujong Kareung 0,80%, Ujong Seuke 0,57%, Sumur Tiga 0,50%, Anoi Itam 0,46%, and Benteng 0,39% (Table 2). The results show that Reuteuk and Ujong Kareung Stations have a coral mortality status of 'Very High', Sumur Tiga and Ujong Seuke Stations have a mortality status of 'High', and Benteng and Anoi Itam Stations have a mortality status of 'Medium'.

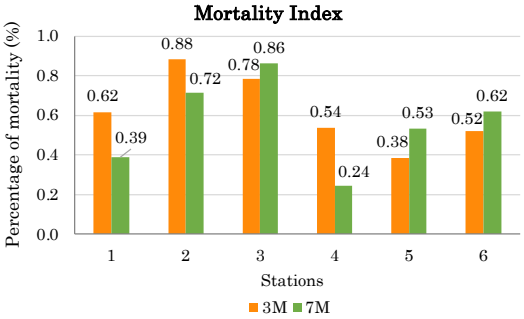

Figure 2. Percentage of coral mortality for each station based on depth. (1: Sumur Tiga, 2: Ujong Kareung, 3: Reuteuk, 4: Benteng, 5: Anoi Itam, 6: Ujong Seuke).

Table 2. Coral mortality index in the SAP-PTPW area.

No.	Stations	MI (%)*	Criteria
1.	Sumur Tiga	0,50±0,16	High
2.	Ujong Kareung	0,80±0,11	Very high
3.	Reuteuk	0,82±0,05	Very high
4.	Benteng	0,39±0,21	Moderate
5.	Anoi Itam	0,46±0,10	Moderate
6.	Ujong Seuke	0,57±0,07	High

**Mortality Index*

Based on the depth level, the observation results show that coral death can occur at a depth of 3 meters or 7 meters (Figure 2). High coral death at a depth of 3 meters occurred at Sumur Tiga, Ujong Kareung, and Benteng Stations, while higher coral death at a depth of 7 meters occurred at Reuteuk, Anoi Itam, and Ujong Seuke Stations. If averaged across all stations, higher coral death occurred at a depth of 3 meters, which was 0.62%, while coral death at 7 meters was 0.56%.

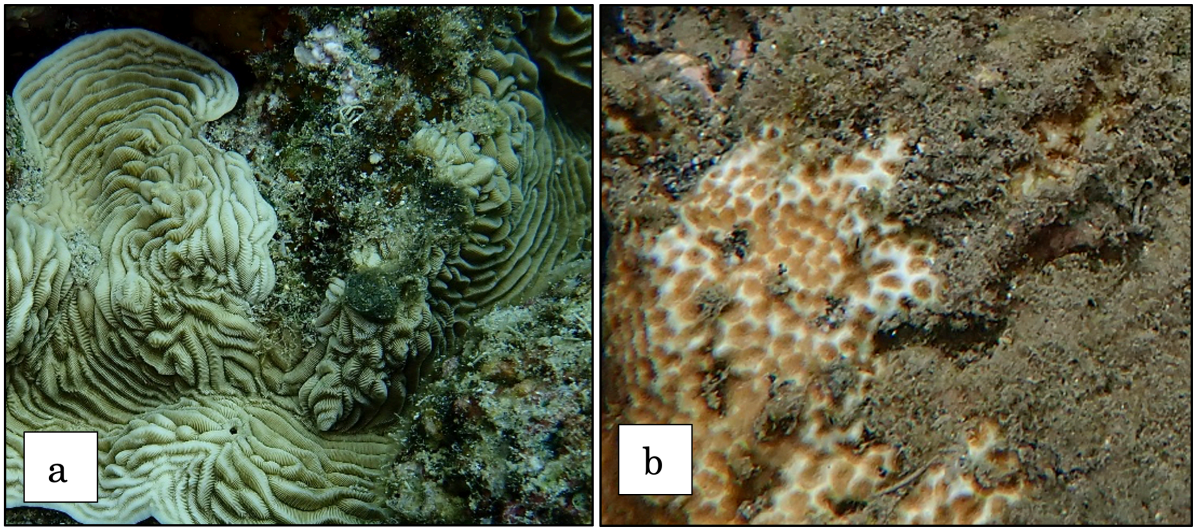

Figure 3. Coral colonies. a) *Pachyseris* sp. and b) *Coeloseris* sp., whose surfaces are partially covered by turf algae and sediment particles.

Abundance of Coral Fish

The results of the study showed that the abundance of coral fish at six observation stations had the criteria of 'abundant' and 'very abundant' (Table 3). The types of reef fish found consisted of 63 species of fish from 23 families spread across all observation stations. The families found included *Acanthuridae, Aulostomidae, Balistidae, Caesionidae, Chaetodontidae, Cirrhitidae, Fistularidae, Holocentridae, Labridae, Lethrinidae, Mullidae, Muraenidae, Nemipteridae, Ostraciidae, Pinguipedidae, Pomacentridae, Pomachantidae, Scaridae, Scorpaenidae, Serranidae, Siganidae, Tetraodontidae*, and the *Zaclindae* family. Some of the abundant species in the observation transects included *Chromis dimidiata, Odonus niger, Acanthurus leucosternon*, and several other species.

Table 3. The level of abundance of coral fish in the SAP-PTPW area.

No.	Stations	Abundance (Ind/ha)	Criteria
1.	Sumur Tiga	16906,67±8937,82	Very abundant
2.	Ujong Kareung	12720±564,83	Very abundant
3.	Reuteuk	8773,33±3148,97	Abundant
4.	Benteng	4353,33±1008,8	Abundant
5.	Anoi Itam	2040±2847,27	Less abundant
6.	Ujong Seuke	8426,67±3318,68	Abundant

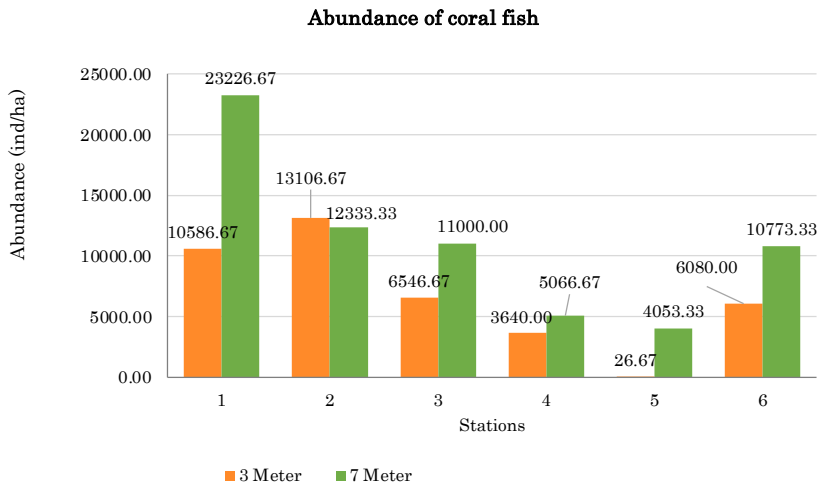

Figure 4. Abundance of coral fish at each station based on depth. (1: Sumur Tiga, 2: Ujong Kareung, 3: Reuteuk, 4: Benteng, 5: Anoi Itam, 6: Ujong Seuke)

The graph above shows that Sumur Tiga Station has an abundance of reef fish of 10586.67 ind/ha at a depth of 3 meters and 23226.67 ind/ha at a depth of 7 meters. Ujong Kareung Station with an abundance of 13106.67 ind/ha (3 meters) and 12333.33 ind/ha, Reuteuk Station with an abundance of 6546.67 ind/ha (3 meters) and 11000 ind/ha (7 meters), Benteng Station with an abundance value of 3640 id/ha (3 meters) and 5066.67 ind/ha (7 meters), then Anoi Itam Station with an abundance value of 26.67 ind/ha (3 meters) and 4053.33 ind/ha (7 meters), and Ujong Seuke Station 6080 ind/ha (3 meters) and 10773.33 ind/ha (7 meters). These data show that the abundance of coral fish is higher at a depth of 7 meters than 3 meters, except at Ujong Kareung Station.

DISCUSSION

Water Quality

Based on the observation results, the environmental parameter conditions at the six stations showed variations that could impact coral conditions. The water temperature ranges from 29.67°C to 31.33°C. Based on the water temperature conditions, even the slightest increase in temperature can trigger coral bleaching. Dao *et al.* (2021) stated that prolonged high temperatures can cause coral bleaching so that corals can release their symbiotic algae (zooxanthellae) due to stress. The pH value ranges from 7.9 to 8.2. The pH value range shows a normal number according to the Decree of the Minister of State for the Environment concerning Sea Water Quality Standards, that a good pH range for the growth of coral ecosystems is in the range of 7 to 8.5. However, small changes can still affect the ability of corals to form skeletons. If the pH changes, it can reduce the calcium carbonate saturation in the water, making it more difficult for corals to form and maintain their skeletons. These small changes can disrupt sensitive biological processes and cause stress to corals, which can ultimately increase the risk of bleaching and coral death if unstable conditions persist in the long term.

Salinity at the observation station ranged from 32 ‰ to 34 ‰. Ding *et al.* (2022) stated that exposure to a salinity level of 34 ‰ can cause a decrease in the rate of photosynthesis and coral respiration, leading to death if exposure occurs for a long time. Current speed ranged from 0.07 m/sec to 0.17 m/sec. The highest current speeds were at Station 2 (0.17 m/sec) and Station 6 (0.15 m/sec), which have the potential to cause physical damage to corals. Then, for visibility ranging from 60 cm to 300 cm, indicating variations in sediment levels that can cover corals and inhibit photosynthesis. These factors can collectively affect the level of coral death and damage at each station.

Coral Mortality

The results of the study showed that the level of coral mortality in the SAP-PTPW conservation area varied from 'Moderate' to 'Very High'. Death can occur due to low coral resistance, such as *Acropora* corals found in broken and crushed conditions. Generally, finger-shaped and branching corals tend to be easily damaged and broken, resulting in death. The speed of ocean currents can cause damage to coral reefs. Currents play a critical role in coral mortality for several reasons. Firstly, they can carry sediment particles that accumulate on the surface of corals, reducing the sunlight necessary for photosynthesis and disrupting the symbiotic relationship between corals and zooxanthellae. Additionally, when currents

are particularly strong, they can lead to abrasion of the coral structure or even breakage.

The other genera that dominate the SAP-PTPW waters come from the non-*Acropora* group of the *Porites* genus (Massive Coral). *Porites* is a coral that has stronger resistance than *Acropora* corals. This is in accordance with the statement of Muttaqin *et al.* (2014) that corals with low resistance come from *Acropora* and *Poccilopora* corals, so that benthic conditions in PTPW are generally dominated by massive corals such as *Porites*.

Research conducted by Gleason & Wellington (1993) in Barus *et al.* (2018) states that massive corals (*Porites* sp.) are relatively resistant to temperature stress and if bleached, tend to recover with little or no increase in mortality. *Acropora* (branching coral) is actually more sensitive to increasing water temperatures so that it experiences bleaching and death in the next 3-6 months. This can be seen from the results of research in SAP-PTPW waters, which have a small number of *Acropora* coral colonies after bleaching. Although *Porites* is included in the coral that can survive the bleaching phenomenon, this type of coral is also susceptible to death. This is in accordance with the statement of Miswar *et al.* (2023) that *Porites* is susceptible to several types of diseases and other health disorders.

The high coral mortality that occurred in the SAP-PTPW area also occurred due to the invasion of turf algae that spread on the surface of the coral, so it is feared that turf algae can spread further and cause coral death. This is in accordance with the statement of Ditzel *et al.* (2022) that the ability of turf algae to grow rapidly can have a negative impact on corals that grow slowly; then the loss or damage of one coral colony can increase macroalgae cover by around 20%. The presence of turf algae that exceeds coral cover is very worrying because turf algae that dominates the substrate can make it difficult for corals to regenerate (Aldyza *et al.*, 2022a). In addition to turf algae, several cases found in the field are known to have also damaged corals due to the accumulation of sediment particles attached to the turf algae (Figure 3). This can make it more difficult for corals to clean themselves, so that over time the corals become pale due to lack of light and nutrient penetration. The thickness of the matrix on the coral surface makes it difficult for corals to carry out photosynthesis, so that corals can potentially lead to coral mortality.

Fish Abundance

Reef fish are an important group of active biomes in coral reef ecosystems. Reef fish use this ecosystem as a place for spawning, foraging, and breeding. Wisha *et al.* (2019) stated that the coral ecosystem strongly supports the survival and habitat of reef fish. The results of observations showed that the most commonly found reef fish species were *Odonus niger* with 1592 individuals and *Chromis dimidiata* with 1701 individuals. Based on the high level of coral mortality in the SAP-PTPW area, it turns out that the abundance of reef fish still has a high value. The abundance of reef fish in areas with high mortality rates indicates that the fish inhabiting the area are suspected not to be from the polyp-eating fish group. This is in accordance with the statement of Nasir *et al.* (2017) that the condition of the substrate and the variation of coral in a body of water influence the presence, number, and diversity of reef fish.

For groups of obligate corallivores such as *Chaetodon collare*, *Chaetodon meyeri*, and *Chaetodon trifasciatus*, which are polyp eaters, very few were found. The low number of polyp predatory fish is due to the low coral cover area, such as the *C. trifasciatus* species, which was only found at stations with high coral cover, namely in Sumur Tiga and Ujong Seuke. In addition to fish from the obligate group, there are several facultative coral fish. Facultative fish species from the Chaetodontidae family found at the research location include *C. citrinellus*, *C. falcula*, *C. vagabundus*, *Forcipiger longirostris*, *Forcipiger flavissimus*, and *Hemitaurichthys zoster* (Aldyza *et al.*, 2022b). Therefore, although coral cover in the PTPW area is low due to high mortality, facultative Chaetodontidae fish tend not to experience a population decline because they have alternative food sources such as small crustaceans, polychaeta, and turf algae. Other types of herbivore (algae-eating) groups can also live abundantly in areas with high coral mortality. This is supported by the results of statistical analysis, which showed no significant effect between coral mortality and fish abundance with a Sig. value of 0.479 (p-value > 0.05), so it can be concluded that certain reef fish can be found abundantly in waters with high mortality rates.

In this study, observations were conducted at two depths. When viewed on the graph, stations 1, 2, and 4 have high coral mortality values at a depth of 3 meters. These results are similar to the results of the study by Nirwan *et al.* (2017), which showed that coral

mortality at a depth of 3 meters was higher by 41.47% and at a depth of 7 meters by 38.66%. This is also reinforced by the research of Sakaria (2022), which showed that coral mortality was higher at shallow depths. Shallow waters are areas exposed to more sunlight so that the growth of turf algae also increases. Although there is a difference in mortality rates, the statistical results show no significant difference (Sig. 0.623) between the average coral mortality at 3 meters and 7 meters in SAP-PTPW waters.

The average value of fish abundance tends to be high at a depth of 7 meters, but there is no significant difference between the abundance of coral fish at a depth of 3 meters and 7 meters (0.223> 0.05). This illustrates that both depths have abundant fish from both benthic algae-eating and small invertebrate-eating groups. Reef fish generally require slightly calm waters when they are going to predate, so they tend to be found at a depth of 7 meters. Fahlevi *et al.* (2018) in Marista *et al.* (2023) stated that the abundance of coral fish was higher at a depth of 10 meters than in shallow waters. Similarly, research at PTPW indicates that certain fish species, particularly Odonus niger, thrive on rubble beds at a depth of 7 meters. Pereira *et al.* (2018) also stated that the abundance of coral fish was twice as high in deeper reef ecosystems. Depth is known to affect many factors in coral reef ecosystems for both coral and reef fish communities and can affect the structure of coral reef communities, especially due to light attenuation, changes in water temperature, and resource availability.

CONCLUSION

Coral fish and coral reef ecosystems have a complex relationship. However, coral fish also have good adaptation to their environment. Although the death of coral reefs in SAP-PTPW is of high value, coral fish can still live in abundance by adapting themselves and can also be moved to areas that still have environmental conditions that support their lives. In addition, some species of coral fish are able to survive by utilizing other structures in the sea, especially seaweed or large stony corals that have gaps so that they do not affect the death of coral reefs.

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