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Research Article

Relationship between Percentage of Live Coral Cover and Chaetodontidae Reef Fish in the Tejakula Waters of Buleleng Regency, Bali

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ABSTRACT
Tejakula District is one of the tourism development areas in Buleleng Regency, Bali, based on the condition of the waters, which are classified as good. The increasing population in this location has caused increased exploitation of coastal and beach areas, especially in coral reef areas. The coral covers in the Tejakula utilisation area has been damaged due to natural and human factors. This study aims to obtain information on the percentage of living coral reefs, the abundance of Chaetodontidae fish, and their relationships. The Underwater Photo Transect (UPT) method was used for coral reef data collection, and Chaetodontidae fish data were collected using the Underwater Visual Census (UVC). The CPCE 4.0 application was used for coral reef data processing. The Chaetodontidae fish data were calculated based on the number of individuals, and then identified the type of genus. The relationship between the percentage of coral cover and the abundance of Chaetodontidae fish was analysed using the Pearson correlation. Almost all stations in Tejakula Waters had weak category coral cover. The results on the abundance of Chaetodontidae fish found five genera: *Chaetodon*, *Parachaetodon*, *Heniochus*, *Forcipiger* and *Hemitaurtys*. The relationship between the percentage of cover and fish in Tejakula Waters was in the weak category with r = 0.091. Supervision, monitoring, and attention to activities around Tejakula Waters are needed to ensure the coral reef ecosystem remains well maintained.

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INTRODUCTION

Indonesia is a country with several regions capable of developing in the tourism sector, one of which is the island of Bali, which is known as Indonesia's main tourist destination. Currently, tourism development in Bali is mostly focused on the southern regions such as Denpasar, Nusa Penida and Kuta (Jubaedah & Anas 2019). This is rarely carried out in the northern part, such as Tejakula District in Buleleng Regency. Astronomically, Tejakula sub-district is located at 8˚56'LS - 115˚8'BT with a sub-district area of 97.68 km^2. The entire area of this sub-district is divided into ten villages within Tejakula (Wisnawa 2014). In general, Tejakula waters are relatively healthy and support abundant marine biota in the coral reef area. The coral cover in the Tejakula utilisation area consists of fringing coral reefs and coral clusters or plates that grow around 50 to 100 metres above the tidal line. Coral grows on the bottom of fine black sand and coral fragments at a depth of 4 to 30 metres (Wisnawa 2014).

Coral reefs are ocean floor structures consisting of calcium carbonate ($CaCO_3$) deposits, produced by coral animals in symbiosis with lime-producing algae. Coral reefs have high ecological and economic functions (Falah et al. 2020). Coral reef ecosystems exhibit high biological productivity and provide sources of food, medicine, and construction materials. Ecologically, coral reefs serve as habitats, spawning grounds, nurseries, shelters for marine biota, and natural wave breakers. Recognising the enormous role and function of reefs for marine ecosystems, data and information as well as the condition of coral reefs in an area are very important to know and have for the benefit of sustainable management of coral reefs (Fahmi et al. 2018).

Reef fish are among the most numerous organisms associated with coral reefs and are found in all reef habitats. The lives of reef fishes are very dependent on the condition of coral reefs; if coral reefs are damaged, they lose their habitat (Mujiyanto et al. 2020). Reef fish are one of the leading fisheries commodities (Falah et al. 2020), so it is necessary to monitor them so that fish stocks in nature can be maintained sustainably (Mandolang et al. 2021). Reef fish monitoring aims to track fish populations and their relationship with reef health (Bintoro et al. 2023). Their presence makes coral reef ecosystems the most inhabited by aquatic biota. This high diversity is due to the variation in the main reef types, all of which are inhabited by coral fish species (Rembet et al. 2011; Sudarmaji & Efendy 2021)

Coral mining activities, fishing with toxic materials and explosives, the use of non-selective fishing gear and pollution that occurs in the sea anywhere on land are the main problems causing coral reef degradation (Titaheluw et al. 2015). The influence of changes in environmental quality due to resource exploitation activities in coral reef ecosystems can be identified by looking at physical, chemical and biological indicators (Jubaedah & Anas 2019). Biological indicators of changes in coral reef ecosystems included the presence of Chaetodontidae fish (Bintoro et al. 2023). Damage to coral reefs directly impacts reef fish, particularly those that depend on coral polyps as food (Rembet et al. 2018). One form of association between fish and coral that can be seen is coral-eating fish (corallivores) such as those from the families Chaetodontidae, Balistidae, and Tetraodontidae (Reese 1981).

Chaetodontidae, or butterflyfishes, characterised by colourful, lined body patterns and are a common coral reef family consisting of 120 species, typically found in pairs or small groups. Butterflyfishes are active during the day and hide in shelters close to the coral surface at night. Butterflyfishes are divided into 10 genera; 78 % feed on coral polyps, while others feed on small invertebrates, algae, or plankton (Mujiyanto et al. 2020). Butterflyfishes are indicator species, which reflect the health of coral reef ecosystems (Riansyah et al. 2018). Coral reefs greatly influence butterflyfish life by providing both shelter from predators and a food source. Reese (1981) stated that butterfly-

fishes can be used as indicators of the health of coral reef ecosystems because they like certain types of substrate which can describe the condition of coral reefs.

According to Citra and Purwanto (2022), although activities in the north of Bali are not as dense as in the south, Tejakula is a marine fisheries sector with a livelihood as fishermen and a tourism sector because its people depend on the potential of the coastal area supported by data from fishermen in Buleleng Regency, the most common were found in Tejakula District, as many as 1590 people in 2019. The population increase in coastal areas, particularly in Tejakula Waters, has led to greater exploitation and utilisation of resources, especially aquatic products such as coral reefs (Citra & Purwanto 2022). Resource exploitation is often conducted in environmentally unfriendly ways, placing pressure on coral reef resources. Some activities that are destructive to these resources come from destructive tourism, cultivation and fishing activities (destructive fishing) using cyanide poison. Water pollution from domestic and industrial waste also contributes (Moira et al. 2020). Some of the coral reefs in Tejakula Waters have degraded, leading to coral reefs destruction and decreased live coral cover. This directly impacts fish resources by reducing available space, shelter, and food, thereby affecting fish species closely associated with coral reefs. Therefore, this research aims to determine the relationship between the percentage of live coral cover and the abundance of fish in the Chaetodontidae in Tejakula Waters, Buleleng, Bali, using the Underwater Visual Census (UVC) method.

MATERIALS AND METHODS

Research Station

This research was conducted in December 2022 in Tejakula Waters, Buleleng, Bali, at six locations using the purposive sampling. Sampling is based on considerations or criteria required when collecting data. The determined locations were six stations: Bondalem 1, Bondalem 2, Tejakula, Tembok, Penutukan and Pacung (Figure 1).

Data Collection

Benthic Survey

Benthic cover data collection in this study were collected using the Underwater Photo Transect (UPT). Data collection used a 100-metre roll metre laid at a depth of 6–8 metres and conducted at each of the six predetermined station points. A rectangular frame measuring 44 × 58 cm was placed at each metre along the coordinate point. Photographs were taken using an underwater camera along the transect line, the photos were taken perpendicularly with a distance of 60 cm from the top of the frame starting from the 1st to the 100th metre with an interval of 1-metre between photos. Photographs with odd numbers were taken on the left side of the transect line and even numbers were on the right side of the transect (Figure 2) (Daud et al. 2021). The following illustration shows how to collect data in Figure 2.

Butterflyfishes Survey

The Underwater Visual Census (UVC) method was used to collect butterflyfishes data (English et al. 1997). Fish data were collected by drawing a 100 m transect line parallel to the edge of the coastline, then reef fish data were recorded by diving following the transect line that had been installed around the coral parallel to the coastline. Starting at one end of the transect, then dive and observe on the side of the transect 2.5 m to the right and 2.5 m to the left and 5 m above the transect until the next 5 m. Butterflyfishes were identified to genus level and recorded around coral reefs. Observations were repeated once to minimise data collection error (Figure 3) (Utomo et al. 2013). Data

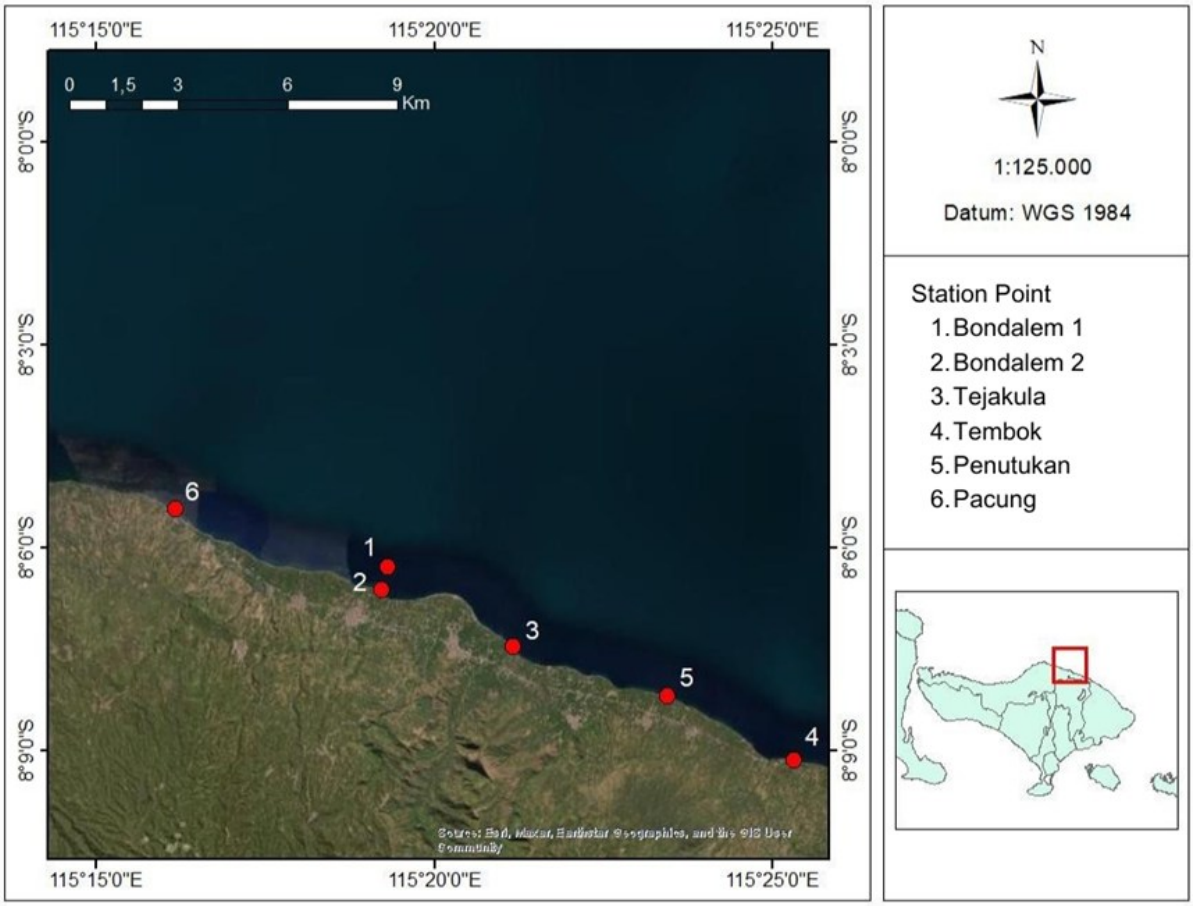

Figure 1. Research Location Map.

Figure 2. Placement frame which is marked with a red box with dimensions of 44 cm x 58 cm on roll meter 100 m long is used for Underwater Photo Transect (UPT) in coral reef ecosystems and Photos of the transects from the right and left sides.

collection was repeated four times, with repetitions every 25 metres along each transect. This repetition was conducted to minimise errors in data collection and to assess the number of fish associated with coral reefs.

Data Analysis

Percentage Analysis of Coral Cover (%)

The percentage of coral reef benthic cover was analysed using the basic category mode in CPCe software with 30 random points. The coral cover data obtained from the above calculation were then categorised according to the Coral Reef Health Index in Indonesia (Table 1).

Table 1. Coral reef condition categories (Giyanto et al. 2023).

Live Coral Cover	Criteria
>35 %	High
19-35 %	Moderate
<19 %	Low

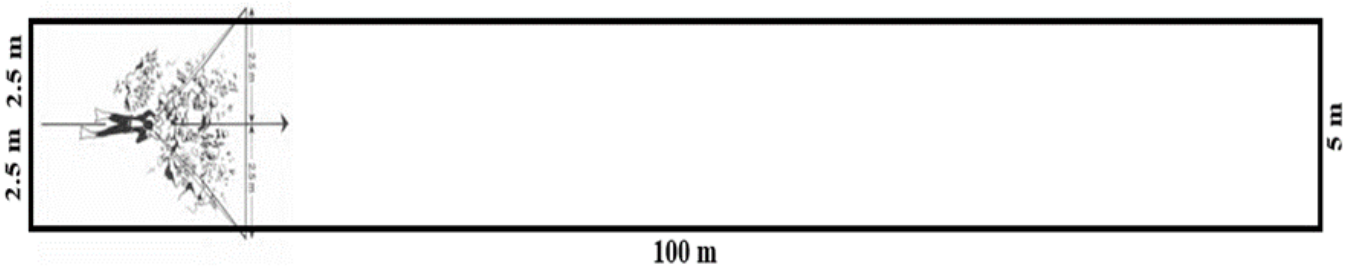

Figure 3. Reef fish data were collected using the Underwater Visual Census (UVC) method by drawing a 100 m transect line then recording the data and observing 2.5 m of the transect side to the right and left at a height of 5 m above (English et al. 1997).

Abundance of Butterflyfishes

The abundance of each type of fish at the research station was described by looking at the composition and abundance of the species. Species abundance was defined as the number of individuals of one species per meter quadrant in each research station. Abundance of butterflyfishes through visual census data collection 100 m long, 5 m wide (100 x 5 = 500 m^2).

Analysis of the Relationship between the Abundance of Butterflyfishes and the Percentage of Live Coral Cover

The relationship between butterflyfish abundance and coral cover percentage was analysed using Pearson correlation. The strength of the relationship between x and y values can be seen from the correlation coefficient (r) value which ranges from (-1) to (+1). The closer to 1 or -1, the stronger the relationship between the two variables (Table 2).

Table 2. Pearson correlation relationship categories.

r	Interpretation
0	No Correlation
0.01-0.20	Very weak correlation
0.21-0.40	Weak
0.41-0.60	Somewhat Weak
0.61-0.80	Sufficient
0.81-0.99	High
1	Very high

RESULTS AND DISCUSSION

Condition of Coral Cover in Tejakula Waters

This research was conducted at six research locations in Tejakula Waters, which had the following benthic cover (Figure 4). It can be seen that the most common benthic cover found in Tejakula Waters is rock, sand, rubble and dead coral.

The characteristics of the water substrate in Tejakula District are in the form of coral reefs, coral fractures, sand dominated by black sand, and muddy (Prasetia et al. 2023). Coral reef health may be directly or indirectly impacted by changes in water quality. At Bondalem 1 and Bondalem 2 stations, more rocks were found than hard corals, which fall into the low category, due to coral damage that resulted in rocks dominance (Figure 4). Rock includes large dead coral heads and solidified coral pieces (Duckworth & Wolff 2011). The damage to the coral is thought to be due to tourism activities in the coastal area and the decline in water quality in Bondalem (Citra & Purwanto 2022). According to Wibawa and Luthfi (2017), pollution from land will subsequently alter the water quality, potentially harming coral reefs.

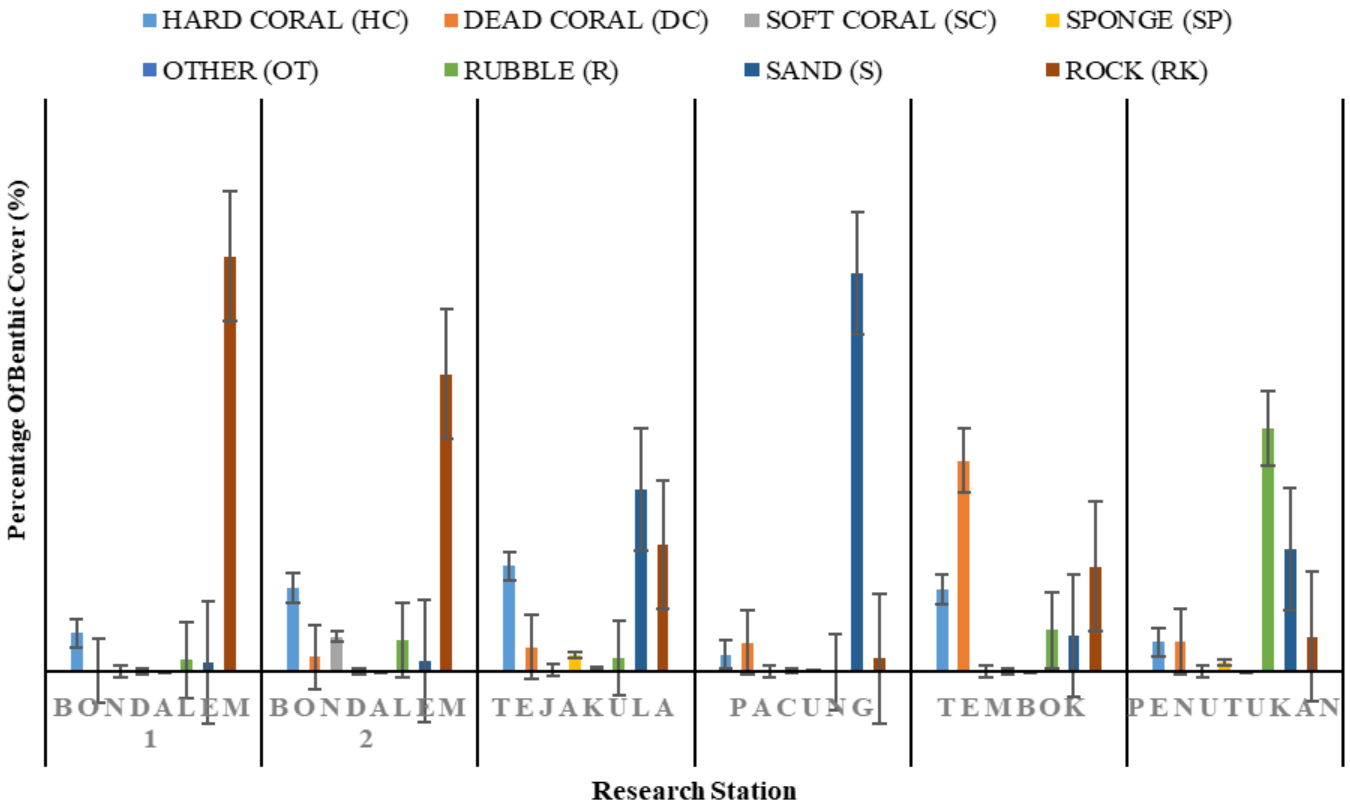

Figure 4. Amount of benthic cover in Tejakula Waters.

Sand at Pacung station was another typical benthic cover. This is due to high sedimentation caused by heavy ship activity, as most local people work as fishermen (Citra & Purwanto 2022). This is in accordance with Maharani et al. (2024), who stated that sedimentation on coral reefs can increase sand accumulation and reduce coral cover. According to Supriyadi et al. (2017), currents have the ability to influence sedimentation by carrying sediment at the water's bottom or on the surface.

There was a lot of rubble at Penutukan station, which is considered to be the result of coral reefs being directly harmed by human activity; the area is frequently passed by fishing boats and has intense community activities. Citra and Purwanto (2022) stated that Penuktukan has fisheries commodities such as fish and squid, while tourism services include enjoying dolphin attractions, fishing, diving and snorkelling which can break the surrounding coral. Human activities such as fishing, gathering ornamental fish, using explosives, non-environmentally friendly gear, and unsustainable harvesting can all directly or indirectly harm coral reefs (Maharani et al. 2024).

Other than that, Tembok station had the most dead coral. Destructive human activities include diving, and the use of potassium for fishing. Coral reef utilisation activities by the Tembok community, such as ornamental fish and coral reef farming by coastal fishermen, are quite high (Citra & Purwanto 2022). If resource the extraction is not environmentally friendly, it can result in the death coral reefs in the waters near the Tembok station. In line with Anwar et al. (2014), there is a significant amount of anthropogenic (caused by human activity) harm and deterioration to coral reef ecosystems. Environmentally harmful resource extraction, such as the use of toxic compounds in fishing, is the cause of this damage.

The results of observations on the condition of live coral cover in Tejakula Waters, Buleleng, Bali are included in the low category with an average of 12.52 % (Figure 5).

Based on the six stations, Tejakula station has moderate coral cover conditions (22.14 %), while the others have low conditions (3.7-17.65 %)

(Figure 5). Although Tejakula is the most optimal location for utilizing coastal resources compared to other stations, the people of this village care about protecting their marine areas because it can affect the community's economy and regional development (Citra & Purwanto 2022). Tejakula station has unique potentials and appeal for domestic and international tourists. The planting of coral reefs in the Tejakula area has an important role in maintaining the marine ecosystem. This awareness can maintain the condition of coral reefs compared to other stations. Jubaedah and Anas (2019) attest to the fact that Bali's coral reef ecosystem is currently being conserved and managed as best it can by the local community, which helps the ecosystem grow.

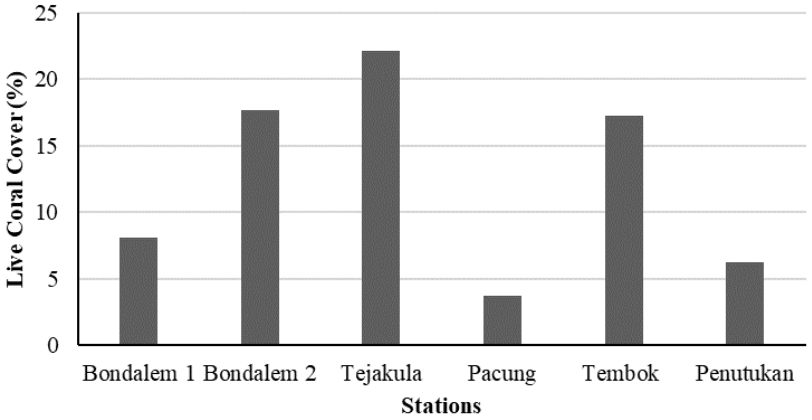

Figure 5. Percentage of live coral cover in Tejakula Waters, Buleleng Bali.

Abundance of Butterflyfishes

Based on the results of observations of butterflyfishes at six stations in Tejakula Waters, the abundance values at all stations were relatively low (Table 3). There were five genera, including *Chaetodon*, *Forcipiger*, *Heniochus*, *Parachaetodon* and *Hemitaurichthys*. The average distribution of Butterflyfishes species in Tejakula waters is 0.092 (ind m^{-2}), found at each station can be seen in Figure 6.

Despite being present at every research station, the *Chaetodon* genus was most abundant at Tembok Station (0.136 ind m^{-2}) and Penutukan (0.134 ind m^{-2}). Even though the coral conditions at these locations ware relatively poor, *Chaetodon* could still be found. The genus *Chaetodon*, known as the largest genus in Chaetodontidae, is a type of butterflyfish commonly found on coral and rocky reefs in tropical and subtropical ocean regions (Rondonuwu et al. 2017). In addition, some special species of *Chaetodon* can be found in damaged coral reef ecosystems. The presence of this genus can indicate dependence on the health of coral reefs (Devanya et al. 2022).

Additionally, this results in varying abundance at each station, which may correspond to the amount of live coral cover (Riansyah et al. 2018). The abundance of reef fish is not only influenced by the percentage of coral cover. Different reef contours, such as caves or walls, can support greater reef fish

Table 3. Abudance of Butterflyfishes.

Research Stations	Abundance (ind m^{-2})				
	Chaetodon	*Forcipiger*	*Heniochus*	*Parachaetodon*	*Hemitaurtys*
Bondalem 1	0.030			0.006	
Bondalem 2	0.052		0.004	0.002	
Tejakula	0.072		0.004		
Pacung	0.038	0.004	0.002		
Tembok	0.136	0.014	0.028		0.004
Penutukan	0.134		0.020		

diversity. The abundance of reef fish is also influenced by biotic and abiotic factors. Biotic factors that can influence this include competition, predation, and the distribution of reef fish. Meanwhile, abiotic factors that influence such as current, depth and brightness. The complexity of coral reef ecosystems also influences fish abundance, including substrate variables, biodiversity, and oceanographic factors (Erdana et al. 2022).

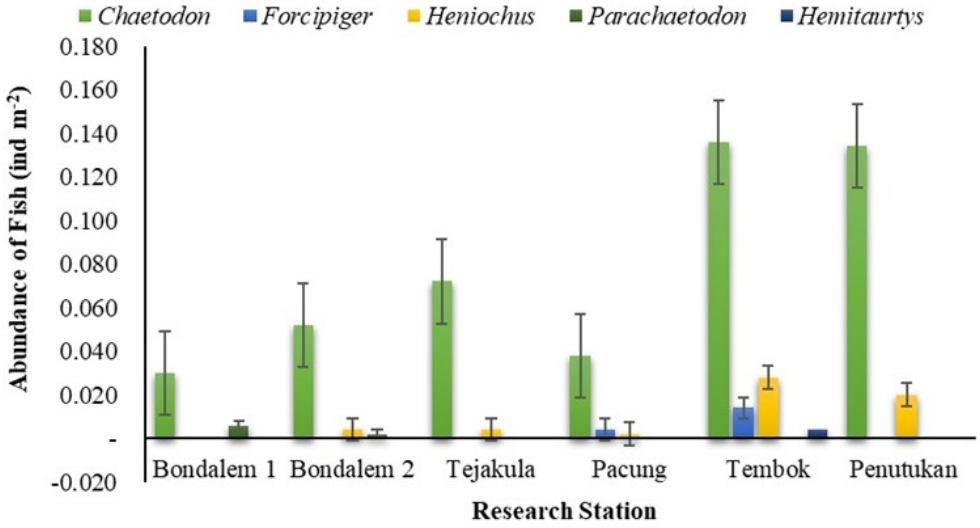

Figure 6. Abundance of butterflyfishes in Tejakula Waters, Buleleng Bali.

Relationship between Percentage of Live Coral Cover and Abundance of Butterflyfishes in Tejakula Waters, Buleleng Regency, Bali

Figure 5 and Figure 6 shows the findings from observations at six different locations in Tejakula Waters regarding butterflyfish abundance and the percentage of live coral cover. Stations with higher coral cover generally reported higher numbers of butterflyfish. Nonetheless, some results were inconsistent, such as Penutukan station, which had high fish abundance despite low coral cover. Invertebrate biota (worms, molluscs, soft corals) and algae, in addition to coral, are considered to be more abundant in this area and can be consumed by butterflyfishes.

Berumen and Pratchett (2008) stated that butterflyfishes generally feed on hydrozoans, sponges, polychaetes, crustaceans, algae, and corals, including *Scleractinia* and *Alcyonacea*. Suharti et al. (2018) stated that the butterflyfishes are more prevalent on coral reefs dominated by *Acropora* corals, a type of long branching colony. *Acropora* corals are home to a variety of fish species, such as *Chaetodon auriga*, *Chaetodon citrinelus*, and *Chaetodon octofasciatus*. The number and variety of butterflyfishes are similar to the types of coral found in the waters. Butterflyfishes typically consume *Acropora* and *Pocillopora* corals (Pratchett 2005). Since *Acropora* is the predominant coral genus in Tejakula Waters, as shown in Figure 7, the quantity of butterflyfishes in Tejakula Waters was comparatively directly correlated with the high level of coral cover.

According to the findings of the Pearson correlation study, there was a very weak association (r = 0.091) between the percentage of coral cover and the number of butterflyfishes (Figure 8). There was a positive association between the amount of coral cover and the number of butterflyfishes. This weak association is believed to be caused by changes in the water characteristics, which are often dynamic and can affect the coral reef ecosystem, which is the habitat for coral and other marine biota in Tejakula Waters, as well as the mobilization of butterflyfishes.

This is consistent with Adrian et al. (2020), who suggest that other factors, such as the hydro-oceanographic characteristics of the waters, may be responsible for the waters' instability due to the minimal presence of indicator fish groups. Suharti et al. (2018) state that butterflyfishes have the strongest

association with coral and are highly sensitive to changes in water conditions and damage to coral reefs. It also has a positive relationship with coral reefs, and a decline in the population of this species is considered a sign of changes in coral reef conditions. Similar findings were made by Adrian et al. (2020) in Pengunjung waters, Bintan Regency, where a minor correlation was also observed (r = 0.276). In the Pulau Koon marine conservation area, research by Erdana et al. (2022) also demonstrated a correlation (r) has a value of 0.0001. There is an extremely weak correlation between the amount of coral cover and fish abundance, as indicated by the Pearson correlation value of 0.001.

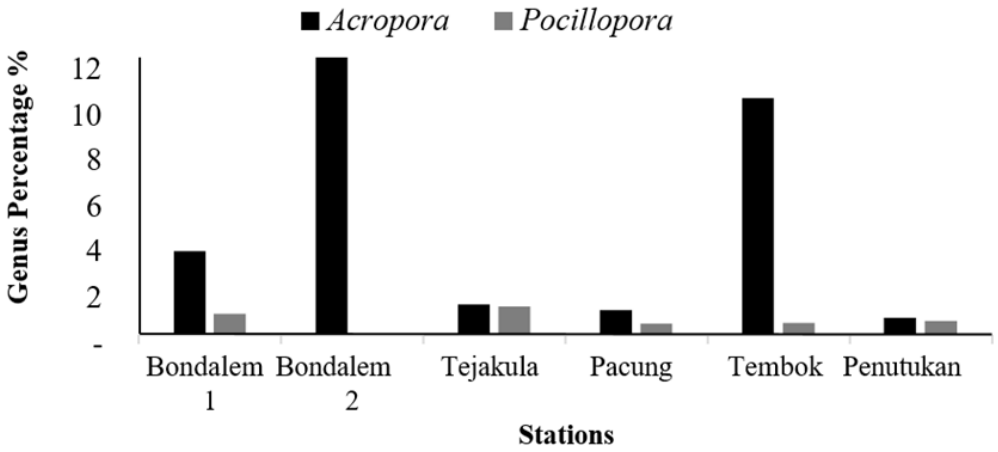

Figure 7. Percentage of coral genus in Tejakula Waters, Bali.

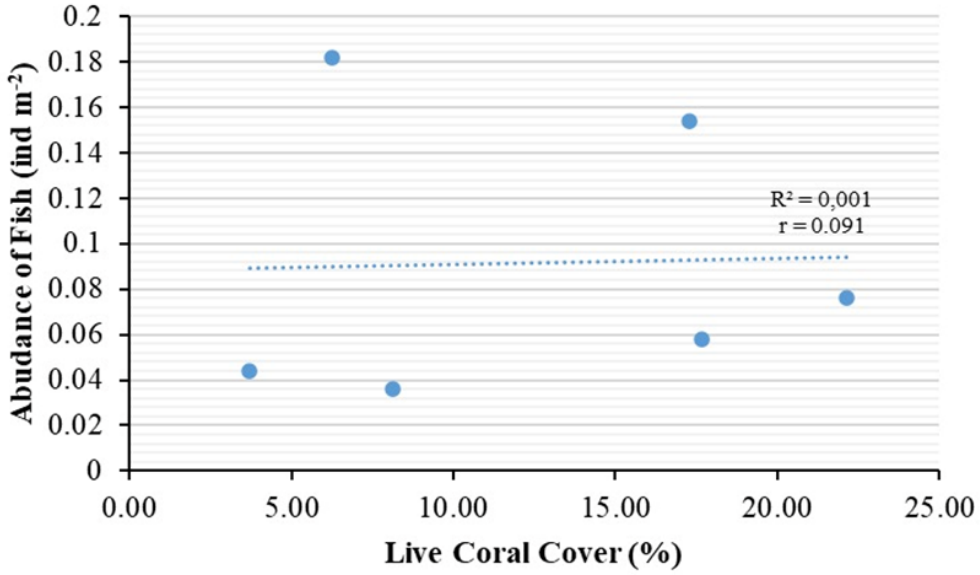

Figure 8. Relationship of butterflyfishes with live coral cover in Tejakula Waters.

CONCLUSIONS

The percentage of live coral cover in the waters of Tejakula, Buleleng, Bali falls into the low category. The average abundance of butterflyfishes was measured at 0.092 (ind m^{-2}). There is relatively weak relationship between Tejakula Waters' coral cover and the number of butterflyfishes. Further research on the relationship between butterflyfish abundance and the percentage of live coral cover in Tejakula Waters, Buleleng, Bali, is recommended.

AUTHOR CONTRIBUTION

N.F.A. contributed to data collection, analysis, and writing the original draft. F.K contributed to wrote manuscript editing, and text proofreading. D.P contributed to main concepts, ideas, research equipment, and script revision. R.

contributed to the main concepts, idea, and script revision.

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CONFLICT OF INTEREST

The authors declare no competing interests regarding the research or the research funding.

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