

# Biodiversity of Coral Reefs and Reef Fishes in Pasir Putih Situbondo

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**Abstract.** Biodiversity index assessment is an analytical method to determine the stability of an ecosystem. Coral reefs are the primary productivity for fish resources and other supporting organisms. Along with the increasing threats and needs for utilization, it has resulted in a decrease in cover followed by a decrease in reef fish biota. Therefore, it is necessary to identify and monitor the condition of coral reef biodiversity and reef fish. The purpose of this study was to analyze the condition of coral reef biodiversity and reef fish in Pasir Putih Situbondo. The results showed poor (22.06%) to good (59.16%) status coral cover conditions, the main constituents of 3 families namely Poritidae, Acroporidae and Fungiidae. Poritidae family dominated by *Porites rus* (CS), Acroporidae dominated by *Acropora muricata* (ACB) and Fungiidae dominated by *Fungia* (CMR). The average value of H' was 2.39; E was 0.80 and D was 0.15. The main fish category is dominated by the family Pomacentridae species *Pomacentrus brachialis* at 539 ind/m<sup>2</sup>, family Caesionidae species *Pterocaesio tessellata* at 1,179 ind/m<sup>2</sup> and family Chaetodontidae species *Chaetodon octofasciatus* at 45 ind/m<sup>2</sup>. The average value of H' index was 2.74; E was 0.69 and D was 0.13.

**Keywords:** Coral reef, Reef fish, Biodiversity index, Pasir Putih Situbondo

## 1. Introduction

Coral reefs are one of the coastal ecosystems that have high biodiversity and primary productivity. Coral reefs are limestone structures that provide food, shelter, and habitat for more than 4,000 species of fish<sup>[1]</sup>. Coral reefs are said to be healthy if they are able to maintain their structure and function, can recover naturally from disturbances, and can maintain their

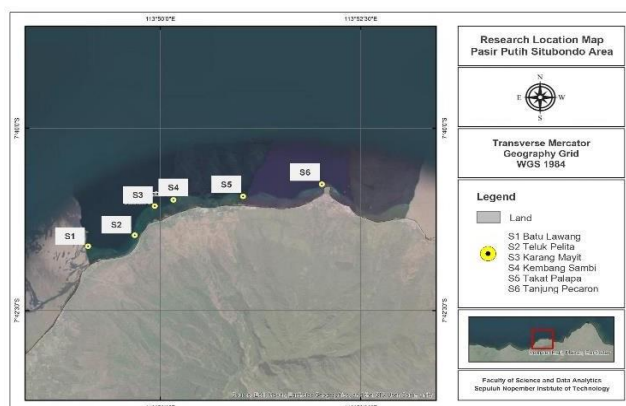
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natural connectivity with other ecosystems<sup>[2]</sup>. Coral reefs are very vulnerable to climate change, anthropogenic pressures, natural disasters, increased sea temperatures that cause growth disorders and coral damage<sup>[3]</sup>. The combination of local threats and climate change causes nearly 45% of Indonesia's coral reefs to be under high to very high threat<sup>[4]</sup>. In general, coral cover conditions in Indonesia are in poor condition (36.18%), in the moderate category (34.30%), and the rest are in good and excellent categories, but there is a tendency for a decrease in cover conditions, which is mainly caused by warming sea surface temperatures that cause coral bleaching<sup>[3]</sup>. Mass coral bleaching due to increased sea temperatures (El-Nino phenomenon) in May to June 2010 was reported in several Indonesian waters<sup>[5]</sup>. According to NOAA, the temperature in the region reached its peak at the end of May 2010, when the temperature reached 34°C, which was 4°C higher than that of the previous year<sup>[5]</sup>.

Some areas in the Madura Strait waters such as Situbondo waters show that coral reef damage is dominated by human activities such as fisheries resources, environmentally unfriendly tourism activities, dredging of coastal areas<sup>[6]</sup>. The condition of coral reefs in Pasir Putih Situbondo has been degraded, considering that this area is an object of coral reef tourism, so that the ecological pressure exerted threatens the existence of ecosystems and their associated biota<sup>[7]</sup>. The percentage of cover in Batu Lawang and Karang Pon-Pon is 32.48% and 27.47% respectively in the moderate category, Teluk Pelita and Karang Mayit is 23.30% in the poor category<sup>[8]</sup>. The coral genus in Batu Lawang is dominated by *Acropora*, while Karang Pon-Pon, Teluk Pelita and Karang Mayit are dominated by *Acropora* and *Porites*. Karang Mayit location has the highest cover of *Acropora* tabulate and *Acropora* submassive species at 22% and Batu Lawang has the highest *Acropora* tabulate species at 31%<sup>[7]</sup>. Batu Lawang, Karang Mayit, Teluk Pelita and Karang Pon-Pon locations have the highest cover types of Coral massive, *Acropora* branching, *Acropora* tabulate, *Acropora* submassive and Coral mushroom with a percentage of 4% - 41% in the category of poor damage - moderate damage<sup>[9]</sup>. Therefore, it is necessary to identify and monitor the condition of coral reef biodiversity and reef fish in degraded areas, namely in Pasir Putih Situbondo.

## 2. Materials and Methods

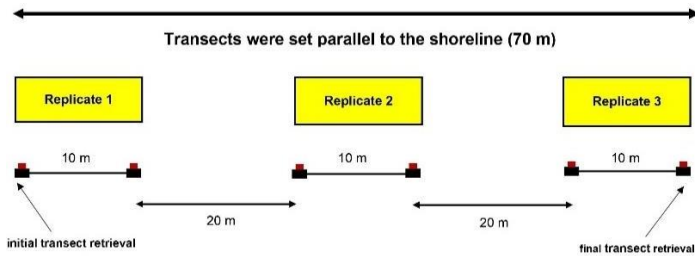
Coral reef and reef fish communities were observed in October 2022 at Pasir Putih Situbondo. St.1 Batu Lawang (7° 41' 37" S and 113° 49' 06" E); St.2 Teluk Pelita (7° 41' 28" S and 113° 49' 41" E); St.3 Karang Mayit (7° 41' 04" S and 113° 49' 56" E); St.4 Kembang Sambi (7° 40' 59" S and 113° 50' 10" E); St.5 Takat Palapa (7° 40' 56" S and 113° 51' 02" E) and St.6 Tanjung Pecaron (7° 40' 46" S and 113° 52' 01" E) (Figure 1).



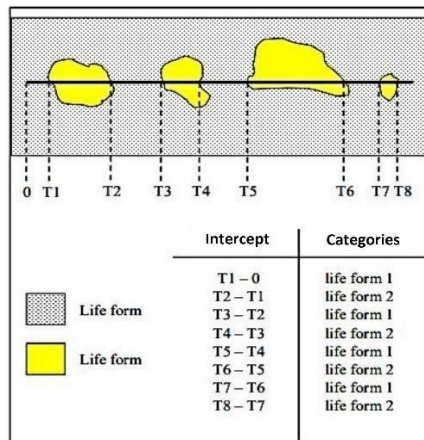
**Figure 1.** Observation locations of coral reef and reef fish ecosystems on the north coast of East Java

## 2.1 Coral Reef Data

Coral reef ecology data were collected using the Line Intercept Transect (LIT) method. Data collection techniques with a transect line length of 70 meters at a depth of 5-10 m that has been determined on the transect line 0 -10 m, 30 - 40 m and 60 - 70 m<sup>[4]</sup> (Figure 2). Coral data recording including cover, lifeform, and species was carried out along the LIT transect line<sup>[4]</sup> shown in (Figure 3).



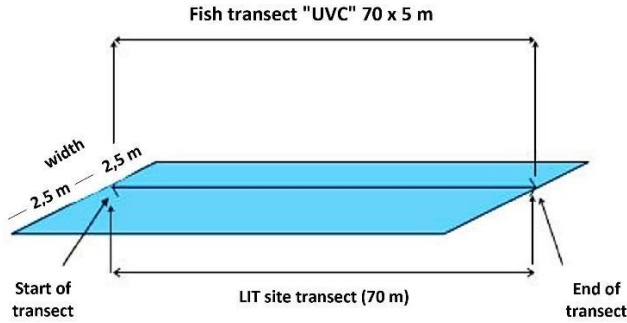
**Figure 2.** Coral data collection technique of LIT method



**Figure 3.** Coral colony data recording technique of LIT method

## 2.2 Reef Fish Data

Reef fish data collection includes abundance and fish species using the Underwater Visual Census (UVC) method<sup>[4]</sup> (Figure 4). Fish species and abundance observed with the UVC method were carried out along the Line Intercept Transect (LIT) transect line 70 m long with a width of 2.5 m left and 2.5 m right of the transect line so that the area of the observation field  $70 \text{ m} \times 5 \text{ m} = 350 \text{ m}^2$  <sup>[4]</sup> (Figure 4). Reef fishes are categorized into three groups based on their role in the ecosystem; Target species, which are economically important fish that are caught for consumption (Serranidae, Lutjanidae, Lethrinidae, Caesionidae, Scaridae, Acanthuridae, and Haemulidae); Major species, which are fish that are found in large numbers on coral reefs and are territorial and used as ornamental fish (Pomacentridae, Labridae, Nemipteridae, Mullidae and Apogonidae); Indicator species, which are fish that always inhabit coral reef ecosystems and are bioindicators of coral reef health (Chaetodontidae)<sup>[10]</sup>.



**Figure 4.** UVC reef fish data collection technique

### 2.3 Biodiversity Index Analysis

To determine the biodiversity value of coral and reef fish species can be known from the value of the diversity index ( $H'$ ), uniformity ( $E$ ), and dominance ( $C$ ) shown (Table 1). The diversity index ( $H'$ ) shows the composition of each individual of a species contained in a community calculated using the Shannon-Wiener equation formula<sup>[11]</sup>, with  $H'$  = diversity index;  $P_i = n_i / N$ ;  $n_i$  = number of individuals of the  $i$ -th species; and  $N$  = total number of individuals of all species.

$$H' = -\sum_{i=1}^n (P_i \ln P_i) \quad (1)$$

Uniformity index ( $E$ ) shows the distribution pattern is evenly distributed or not. The more even the distribution of individuals between species, the more ecosystem balance will increase<sup>[12]</sup>, with  $E$  = uniformity index;  $H'$  = diversity index;  $H'_{max} = \ln S$ ; and  $S$  = number of species observed.

$$E = \frac{H'}{H'_{maks}} \quad (2)$$

Dominance index ( $D$ ) is used to determine the dominance of species in the waters. The smaller the dominance index value, indicating that there is no dominating species, on the contrary, the greater the dominance, indicating that there are certain species<sup>[12]</sup>, with  $D$  = dominance index;  $n_i$  = number of individuals in the  $i$ -th species; and  $N$  = total number of individuals.

$$D = \sum \left( \frac{n_i}{N} \right)^2 \quad (3)$$

**Table 1.** Biodiversity index of corals and reef fishes

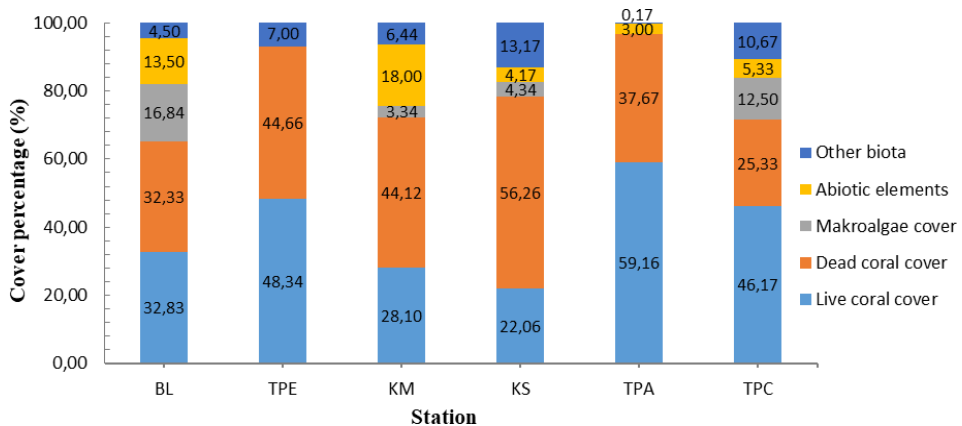
Index			Categories
$H'$	$E$	$D$	
< 1,0	< 0,4	< 0,5	Low
1,0 < 3,0	0,4 < 0,6	0,5 < 0,75	Medium
> 3,0	0,6 < 1	0,75 < 1	High

### 3. Result and Discussion

#### 3.1 Coral Reefs Ecology

##### 3.1.1 Coral reef substrate composition

Based on the results of field data observations in the Pasir Putih Situbondo the percentage of coral reef substrate composition include live coral cover, dead coral, macroalgae, abiotic elements and other biota (Figure 5).



**Figure 5.** Percentage cover of live coral, dead coral, macroalgae, abiotic and other biota

The results showed the highest percentage of live coral cover at Takat palapa at 59.16% good category, where this station is close to the location of aquaculture farm, food hatchery and shrimp farm. Teluk Pelita at 48.34% in the medium category, this station has the most visitors, there are lodging facilities and kios selling souvenirs typical of Pasir Putih beach and boat tourism activities, snorkeling and diving. Tanjung Pecaron at 46.17% medium category, this station is near settlements, aquaculture farms and fish hatcheries. Batu lawang at 32.83% in the moderate category, this station is dominated by hotels, docks, boat tourism activities, snorkeling, mangrove vegetation and shipping activities for research. Karang Mayit at 28.10% in the moderate category and Kembang Sambu at 22.06% in the poor category respectively, where these stations are most dominant fishing activities on the pier and boat tours and there are residential settlements after the conservation monitoring post.

Takat Palapa Station has the highest percentage cover, because it is dominated by live coral substrate (*Acropora* and *Non-acropora*) which is higher than other substrate constituents. If a location has a greater percentage of live coral cover (>50%) compared to other substrate constituents, it will be categorized in good condition, because there is a possibility that corals will grow to cover the substrate of the bottom of the water and will enrich the biodiversity of biota in the waters<sup>[13]</sup>.

The percentage of dead coral cover with a relatively high percentage at Kembang Sambu station (56.26%), followed by Teluk Pelita station (44.66%), Karang Mayit (44.12%), Takat Palapa (38.07%), Batu Lawang (32.33%) and Tanjung Pecaron (25.33%), where all stations are dominated by Dead Coral with Algae and Rubble lifeforms shown in (Figure 5). The low percentage of live coral cover at Kembang Sambu is thought to be caused the composition of the constituent substrate at Kembang Sambu is dominated by dead coral cover including lifeform Rubble and Dead Coral with Algae, the other influential constituent substrate is

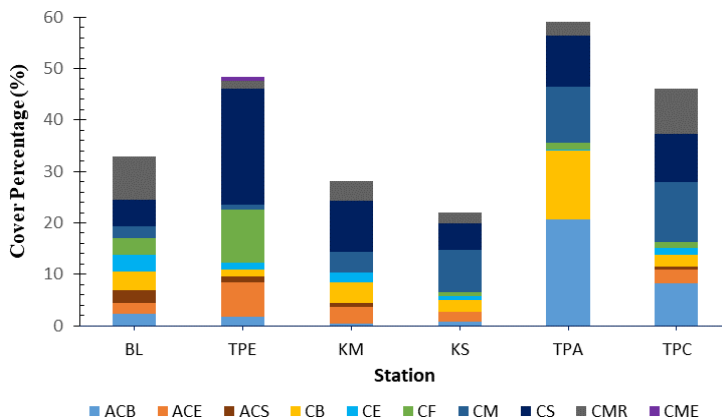
Sand. Hard corals (scleractinia) will be difficult to grow in areas dominated by sand, because if stirred by currents or waves will result in decreased sunlight intensity in the waters that can interfere with the photosynthesis process of algae symbionts that live in corals<sup>[13]</sup>. The high abundance of Sponge biota in Kembang Sambu is also influential, Sponge is identified to carry out bioerosion processes on reefs, namely processing solid calcium carbonate into small fragments and fine particles, so that it can have an effect on reducing sediment production and reducing the strength of the reef structure<sup>[14]</sup>. Anthropogenic factors by environmentally unfriendly lobster and reef fish fishing activities that are still widely carried out by local fishermen who are still using compressors at night around this station, causing coral fractures (rubble) into small fragments due to trampling or nudging and low predation of algae eaters by coral predators, namely herbivorous fish from the Scaridae family<sup>[15]</sup>.

The percentage of macroalgae cover substrate includes Assamblage Algae, Coralline Algae and Macroalgae lifeforms. The highest percentage of cover in Batu Lawang was (16.84%), followed by Tanjung Pecaron (12.50%), Kembang Sambu (4.34%), Karang Mayit (3.34%), while Teluk Pelita and Takat Palapa had no macroalgae cover (Figure 5). This is due to the distribution of algae composition in Teluk Pelita and Takat Palapa stations that only grow in Dead Coral and Rubble areas, while the high macroalgae cover in Batu Lawang station is caused by the high percentage of Macroalgae lifeforms dominated by Turf Algae.

Abiotic substrate constituents include Rock and Sand lifeforms at each station, namely at Batu Lawang station (13.50%), Karang Mayit (18.00%), Kembang Sambu (4.17%), Takat Palapa (3.00%), Tanjung Pecaron (5.33%), and Teluk Pelita no abiotic substrate was found, because at this station the substrate composition is dominated by live and dead coral cover shown in (Figure 5). The composition of other biota constituent substrates includes Soft Coral, Sponge and Zoanthid lifeforms at Batu Lawang station (4.50%), Teluk Pelita (7.00%), Karang Mayit (6.44%), Kembang Sambu (13.17%), Takat Palapa (0.17%) and Tanjung Pecaron (10.67%) shown in (Figure 5), where all stations are dominated by Sponge lifeforms.

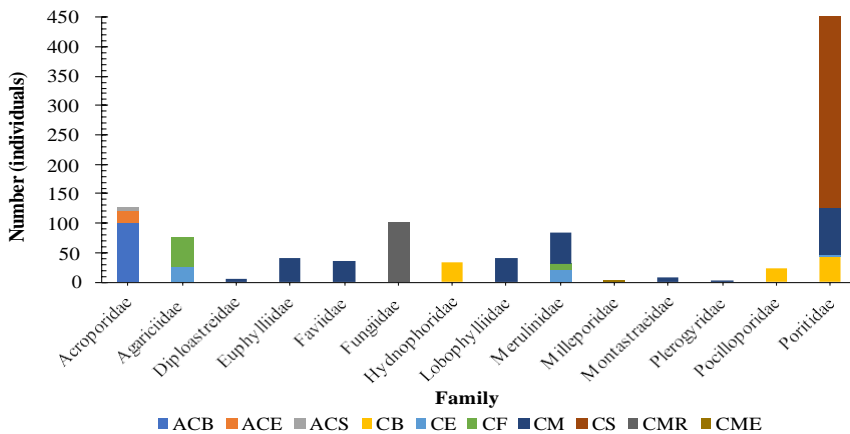
### 3.1.2 Percentage cover of hard coral lifeforms

There are 10 types of hard coral lifeforms found, namely *Acropora branching* (ACB), *Acropora encrusting* (ACE), *Acropora submassive* (ACS), *Coral branching* (CB), *Coral encrusting* (CE), *Coral foliose* (CF), *Coral massive* (CM), *Coral submassive* (CS), *Coral mushroom* (CMR) dan *Coral millepora* (CME) (Figure 6).



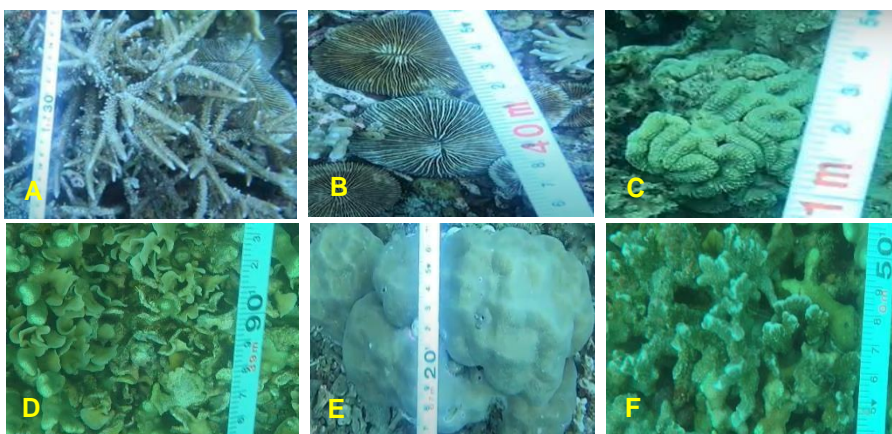
**Figure 6.** Percentage composition of live coral lifeforms

The main constituents of the coral reef ecosystem at the research site consisted of 3 families namely Poritidae, Acroporidae and Fungiidae shown in (Figure 6-7). Batu Lawang station consists of 9 Acropora and Non-acropora coral lifeforms dominated by *Coral mushroom* (CMR) lifeform at 8.33% and *Coral submassive* (CS) at 5.17%. Teluk Pelita consists of 10 lifeforms dominated by *Coral submassive* (CS) by 22.50% and *Coral foliose* (CF) by 10.17%. Karang Mayit consists of 8 lifeforms dominated by *Coral submassive* (CS) by 9.83%, *Coral branching* (CB) and *Coral massive* (CM) by 4.17%. Kembang Sambu consists of 8 lifeforms dominated by *Coral massive* (CM) by 8.33% and *Coral submassive* (CS) by 5.10%. Takat Palapa consists of 7 lifeforms dominated by *Acropora branching* (ACB) by 20.67%, *Coral branching* (CB) by 13.33% and *Coral massive* (CM) by 10.83% and Tanjung Pecaron consists of 9 lifeforms dominated by *Coral massive* (CM) by 11.83%, *Coral submassive* (CS) by 9.33%, and *Acropora branching* (ACB) by 8.17% (Figure 6).



**Figure 7.** Family composition by lifeform

Batu Lawang Station is dominated by *Porites rus* and *Fungia* species. Teluk Pelita is dominated by *Porites rus* and *Pavona cactus* species. Karang Mayit and Tanjung Pecaron are dominated by *Porites rus*, *Porites* and *Fungia* species. Kembang Sambu is dominated by *Porites rus*, *Porites* and *Lobophyllia* species. Takat Palapa is dominated by *Porites rus* and *Acropora muricata* species (Figure 8).



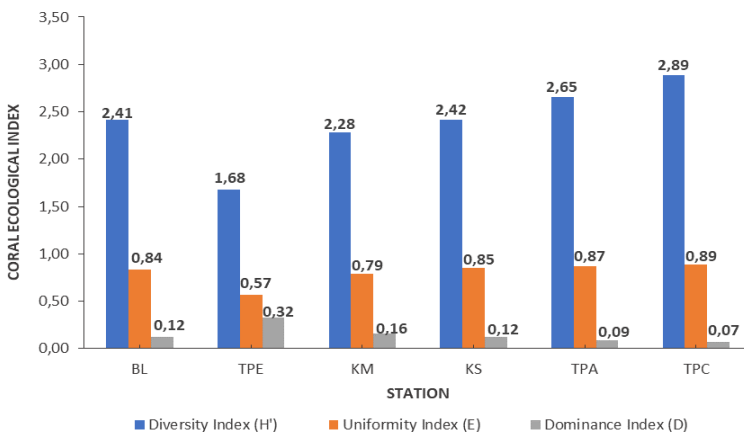
**Figure 8.** Coral species; A. *Acropora muricata*; B. *Fungia*; C. *Lobophyllia*; D. *Pavona cactus*; E. *Porites*; F. *Porites rus*

*Porites*, *Porites rus*, *Fungia* and *Lobophyllia* species belongs to the category of massive and submassive lifeforms, which are able to live in poor waters with high sedimentation, but can also live in sandy, muddy or damaged coral habitats<sup>[18-19]</sup>. *Pavona cactus* and *Acropora muricata* species belong to the category of foliose and acropora branching lifeforms are only able to live in fairly clear water conditions with sedimentation and low hydrodynamic pressure<sup>[18;23]</sup>. The stronger the currents and waves, the coral will grow short, strong, and creeping like digitate, massive and encrusting, while in sheltered areas with strong currents and low waves the coral shape tends to be slimmer and elongated like branching and foliose<sup>[23]</sup>. Corals that live in areas protected from waves (leeward zones) have slender and elongated branching forms, in contrast to open areas with strong waves (windward zones) tend to branch short, strong, creeping or submassive<sup>[24]</sup>.

Colonies characteristic of *Porites*, *Porites rus*, *Fungia* and *Lobophyllia* species are found in shallow water habitat zones on reef slopes, upper reef slope and lagoons<sup>[19]</sup>. *Pavona cactus* species are usually found in lagoon and on the upper reef slope, especially on fringing reefs, and tolerate turbid waters and protection from waves<sup>[19-20]</sup>. *Acropora muricata* species are common in the reef slope and lagoon<sup>[20-21]</sup>. This is in accordance with the reef cover classes at the research point located on a Sheltered reef slope, is reef slope (submerged sloping area extending into Deep Water) more protected from strong directional prevailing wind or current, either by land or by opposing reef structures<sup>[22]</sup>.

### 3.1.3 Coral reef ecological index

The average value of diversity index ( $H'$ ) is 2.39 *medium* category, uniformity index ( $E$ ) is 0.80 *high* category and dominance index ( $D$ ) is 0.15 *medium* category (Figure 9). At all research stations, the diversity index ( $H'$ ) shows a moderate category, which indicates conditions of diversity with sufficient productivity, ecosystem conditions are quite balanced and moderate ecological pressure. Batu Lawang, Karang Mayit, Kembang Sambi, Takat Palapa and Tanjung Pecaron stations with a high population uniformity index ( $E$ ), that indicates the pattern of distribution of individuals between species is very evenly distributed, so that the balance of the ecosystem is increasing, while Teluk Pelita uniformity index ( $E$ ) population category is moderate. Batu Lawang, Teluk Pelita, Karang Mayit and Kembang Sambi have a dominance index ( $D$ ) in the medium category, while Takat Palapa and Tanjung Pecaron have a dominance index ( $D$ ) in the low category, indicating that there are no extreme species that dominate at these locations.

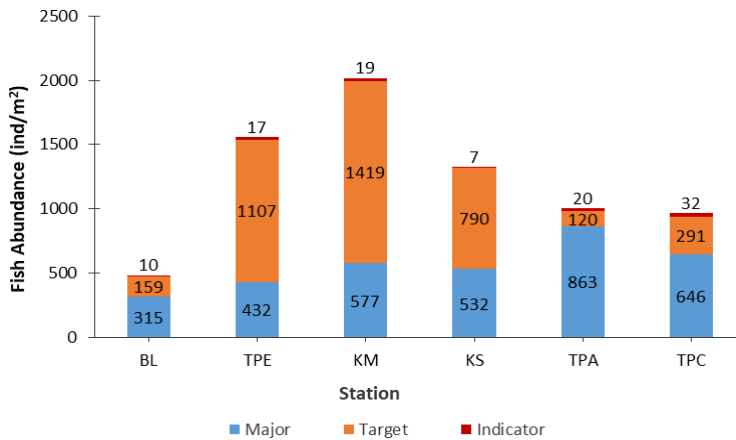


**Figure 9.** Coral reefs ecological index

### 3.2 Reef Fish Ecology

#### 3.2.1 Reef fish abundance by group category

The abundance of individual fish groups at Batu Lawang station amounted to 484 ind/m<sup>2</sup> consisting of fish groups (major 315; target 159; indicator 10). Teluk Pelita at 1.556 ind/m<sup>2</sup> consists of fish groups (target 1.107; major 432; indicator 17). Karang Mayit at 2.015 ind/m<sup>2</sup> (target 1.419; major 577; indicator 19). Kembang Sambu at 1.329 ind/m<sup>2</sup> (target 790; major 532; indicator 7). Takat Palapa at 1.003 ind/m<sup>2</sup> (major 863; target 120; indicator 20) and Tanjung Pecaron at 969 ind/m<sup>2</sup> (major 646; target 291; indicator 32) (Figure 10).

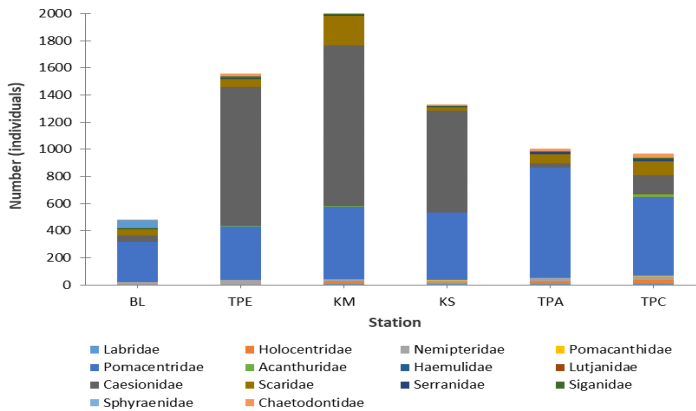


**Figure 10.** The abundance of fish at each station

Based on Figure 10, fish abundance by group category with a total of 7.356 ind/m<sup>2</sup>, consisting of 3.365 major fish ind/m<sup>2</sup>, 3.886 target fish ind/m<sup>2</sup> and 105 indicator fish ind/m<sup>2</sup>. The abundance of target fish group species dominated 52.83% of the total abundance of fish groups, due to variations in suitable habitat such as coral fragment substrates<sup>[16]</sup>. The openness of the area in the coral fragments (simple spatial structure) is the reason that many target fish visit the area and are used as a feeding ground area<sup>[16]</sup>. Major and indicator fish groups amounted to 45.74% and 1.43%. This group of fish is found in a variety of rocky substrate habitats, sand, branching corals, branching dead corals<sup>[16-17]</sup>.

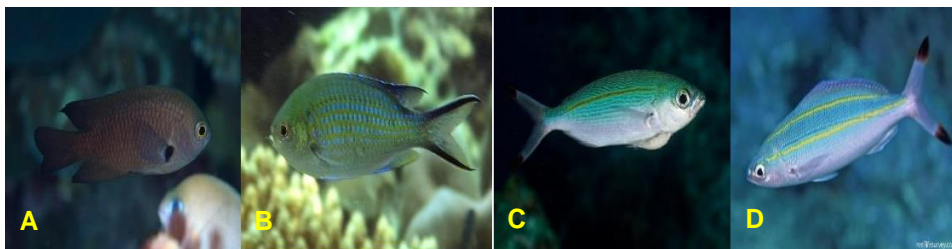
#### 3.2.2 Reef fish family composition

Based on the abundance of individuals, Caesionidae is the family with the largest number of individual species, which amounted to 3.169 ind/m<sup>2</sup> or 43.08% of the total number of individuals found at all stations, followed by the Pomacentridae family with a total of 3.110 ind/m<sup>2</sup> or 42.28%, the Scaridae family with a total number of individuals of 523 ind/m<sup>2</sup> or 7.11%, and 7.53% were found from other families (Figure 11). The abundance of the number of species found, the Pomacentridae family had the highest diversity of species with a total of 36 species or 45.57% of the total number of species found, followed by the Chaetodontidae family with a total of 9 species or 11.39%, the Serranidae family with a total of 7 species or 8.86%, and 34.18% were found from other species (Figure 11).



**Figure 11.** Reef fish composition at each station

Batu Lawang and Tanjung Pecaron are dominated by *Pomacentrus brachialis* from Pomacentridae family, Takat Palapa by *Neopomacentrus anabatoides* species from Pomacentridae family is dominant. Karang Mayit and Kembang Sambu are dominated by *Pterocaesio tesellata* (one-stripe fusilier) from Caesionidae family, while at Teluk Pelita the species *Pterocaesio diagramma* (double-lined fusilier) from Caesionidae family (Figure 12).



**Figure 12.** Reef fishes species; A. *Pomacentrus brachialis*; B. *Neopomacentrus anabatoides*; C. *Pterocaesio tesellata*; D. *Pterocaesio diagramma*

*Pomacentrus brachialis* species are closely associated with coral reefs, do not migrate during spawning, are demersal, feed on zooplankton and benthic algae<sup>[25]</sup>. Adults are found hiding in reef caves and scattered on outer reef slopes and reef flats from depths between 6 - 40 m<sup>[25]</sup>. These species are dispersed individually or clustered in large groups<sup>[26]</sup>. *Neopomacentrus anabatoides* species do not migrate during spawning and are demersal<sup>[25]</sup>. Adults inhabit soft bottoms around coral or rock outcrops, lagoons, harbors and coastal reefs distributed in large groups at depths of 10 - 15 m<sup>[27]</sup>. The species *Pterocaesio tesellata* (one-stripe fusilier) and *Pterocaesio diagramma* (double-lined fusilier) are both closely associated with coral reefs, do not migrate, feed on zooplankton in the water column and inhabit clear beaches until they are distributed in the outer reef slopes habitat zone to a depth of 0-50 m<sup>[25;27]</sup>.

### 3.2.3 Reef fish ecological index

The average value of diversity index ( $H'$ ) is 2.74 *medium* category, uniformity index (E) is 0.69 *high* category and dominance index (D) is 0.13 *medium* category (Figure 13). The diversity index ( $H'$ ) at Batu Lawang and Tanjung Pecaron in the high category, indicating high productivity and balanced ecosystem stability, while in Teluk Pelita, Karang Mayit,

Kembang Sambu and Takat Palapa the diversity index ( $H'$ ) is in the medium category, indicating conditions of diversity with sufficient productivity, balanced ecosystem conditions and moderate ecological pressure. Batu Lawang, Kembang Sambu, Takat Palapa and Tanjung Pecaron with a high population Diversity Index (E), indicating the pattern of distribution of fish individuals between species is very evenly distributed, so that the balance of the ecosystem is increasing, while in Teluk Pelita and Karang Mayit shows a medium population Diversity Index (E), indicating the number of individuals distributed in each type is relatively the same. Teluk Pelita, Karang Mayit and Kembang Sambu show a Dominance Index (D) of medium category, indicating that there are species that dominate at that location, although not too extreme or dominant in their presence. Meanwhile at Batu Lawang, Takat Palapa and Tanjung Pecaron stations show a low category of Dominance Index (D), indicating that there are no extreme species that dominate at that location.

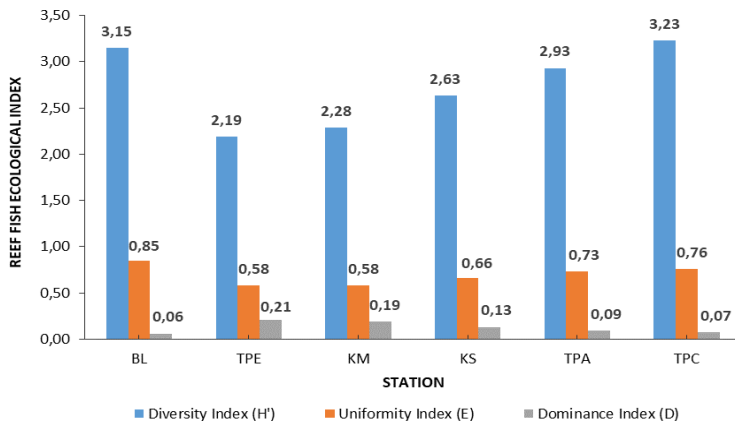


Figure 13. Reef fishes ecological index

## 4. Conclusion

The results of the analysis show the condition of coral cover in poor status (22.06%) to good (59.16%), the main constituent of the ecosystem consists of 3 families namely Poritidae, Acroporidae and Fungiidae. The Poritidae family is dominated by *Porites rus* species with submassive lifeform, Acroporidae dominate by *Acropora muricata* species with acropora branching lifeform and Fungiidae dominated by *Fungia* species with mushroom lifeform. The average value of coral biodiversity index includes  $H'$  is 2.39; E value is 0.80 and D value is 0.15. The major fish category was dominated by the family Pomacentridae species *Pomacentrus brachialis* with 539 ind/m<sup>2</sup>, target fish from the family Caesionidae species *Pterocaesio tessellata* with 1.179 ind/m<sup>2</sup> and indicator fish from the family Chaetodontidae species *Chaetodon octofasciatus* with 45 ind. The average value of the fish biodiversity index includes  $H'$  is 2.74; E value is 0.69 and D value is 0.13.

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