



Diversity of coral reef and reef fish in Isau Island, Central Maluku, Indonesia

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Abstract. Coral reef ecosystems are one of the ecosystems found in tropical waters and have an important role in people's lives. Damage that occurs to this type of ecosystem can affect the abundance and diversity of reef fish, which are part of its associated biota. One of the regions with high coral reef ecosystem potential in Indonesia is Maluku Province. One of the islands in Maluku Province, a diving tourism destination with corals and varied reef fish, is Isau Island. Therefore, research on the diversity of coral reefs and reef fish in the waters of Isau Island must be done to determine the condition of the coral reef ecosystem. Hard coral cover is 73.43%, determined from observations using the line intercept transect method at three stations in the waters of Isau Island. In this ecosystem, 108 species of coral and 255 species of reef fish were identified. The condition of coral reefs in the waters of Isau Island was in a good category, with a hard coral cover of more than 70%. In addition, the diversity of coral fish on this island was influenced by the large number of hard corals with branching growth forms, which provide sufficient space for coral fish.

Key Words: coral lifeform, coral reef ecosystem, ecosystem condition.

Introduction. Marine ecotourism is a tourism activity carried out as an effort towards conservation. Marine ecotourism has considerable development potential in Indonesia, especially in coastal areas (Yulius et al 2018). This is the most efficient sector in the marine industry, so the development of nautical tourism/ecotourism needs to be prioritized (Sapanli et al 2020). Small islands are a concern for the development of marine tourism activities. This is because potential assets are supported by the geological structure and characteristics of coastal areas, especially the presence of coral reef ecosystems, especially hard corals.

The coral reef ecosystem is one of the ecosystems found in tropical coastal waters such as Indonesia. The reef results from deposits of Cnidaria secretions in the form of lime (CaCO₃) (Suryatini & Rai 2020). Coral reefs also have an important ecological role in the fisheries sector, apart from having an important role in marine ecotourism. Coral reefs act as habitat, feeding, nurturing, rearing and spawning grounds for various species of fish (Mahi 2016). Even so, the condition of coral reefs in Indonesia in 2019 showed damage reaching 50% (Hadi et al 2020; Armanto et al 2022).

This damage affects the abundance and diversity of reef fish inhabiting coral reef ecosystems (Harvey et al 2018; Rani et al 2019). This condition occurs because reef fish use coral reefs to spawn and protect themselves from predators (Fenner et al 2012; Rondonuwu et al 2019). The high mobility of reef fish also causes the need for coral reefs for their sustainability (Setiawan et al 2017). One of the regions with high coral reef ecosystem potential in Indonesia is Maluku Province, where in 2017 the area reached 439110 ha (Giyanto et al 2017).

This condition is reinforced by the fact that Maluku's position is in the world's Coral Triangle (Sahetapy et al 2021). One of the islands with ecotourism potential from the coral reef ecosystem in Maluku Province is Isau Island in Central Maluku. Isau Island is a diving tourist destination with beautiful corals and varied reef fish. To build sustainable marine ecotourism, this research was conducted to analyze the diversity of coral and reef fish in the coral reef ecosystem around Isau Island, Central Maluku, Papua.

Material and Method

Data collection. This research was conducted on Isau Island, Central Maluku Regency in December-March 2022 at three stations around the island (Figure 1). In each station, water parameters such as temperature, salinity, and current were collected using a thermometer, refractometer, and current meter, respectively, before collecting coral reef and reef fish data. Coral reef data collection was carried out using the Line Intercept Transect (LIT) method, which is a method developed to monitor the condition of live coral and other supporting biota at a coral reef location (Wilson & Green 2009). Data collection was carried out by diving using SCUBA at depths of 3, 6, and 10 m. Each depth was observed at a transect of 50 m along the shore. All coral lifeforms from the transect line were recorded. Observations of coral fish were carried out using the Underwater Visual Census (UVC) method, which recorded fish seen at a viewing distances of 2.5 m on each side of the transect.

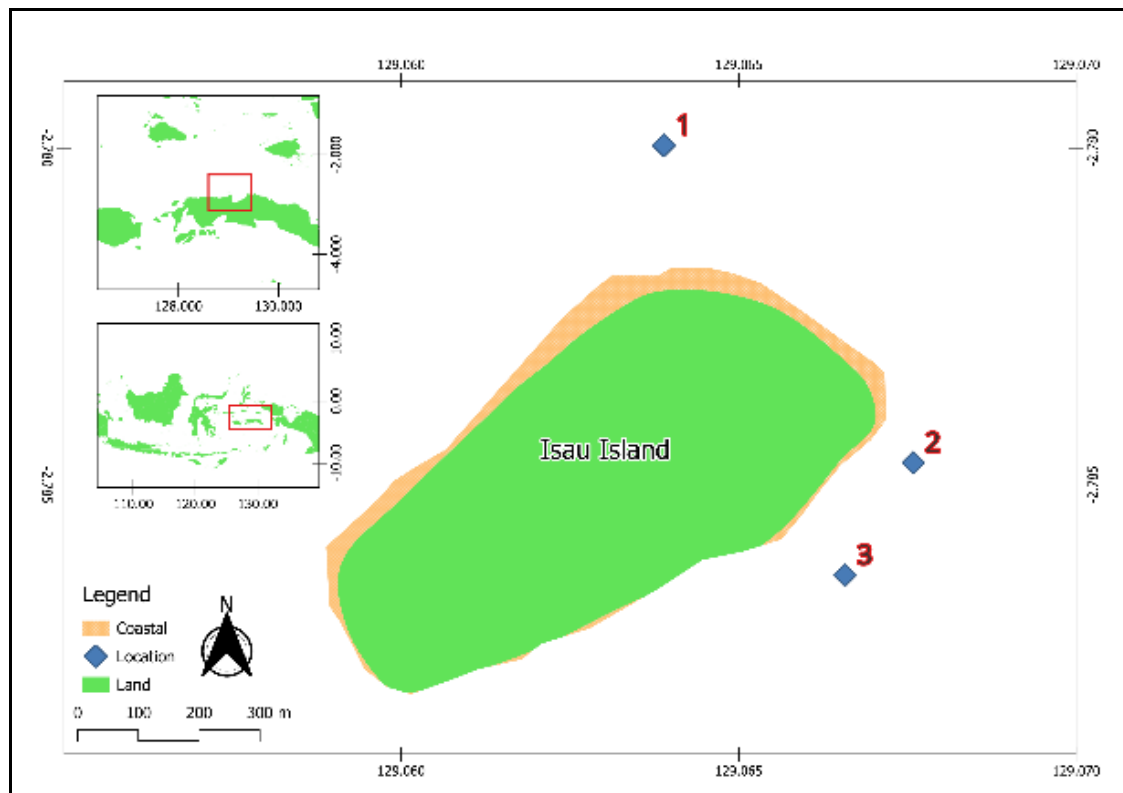


Figure 1. Data collection location.

Data analysis. The data obtained from observations of coral reefs were then subjected to several analyses. The data was analyzed to determine the percentage of coral cover (C) by looking at the length of lifeform cover for each coral (li) and the length of the transect (L) using the formula from English et al (1997):

$$C = (li/L) \times 100$$

The results of this calculation determine the condition of coral reefs by referring to the assessment criteria based on the Decree of the Minister of Environment Number 4 of 2001 (Table 1).

Table 1

Coral reef cover category (source: Decree of the Minister of Environment Number 4 of 2001)

<i>Percentage</i>	<i>Category</i>	
0.0-24.9	Bad	Damaged
25.0-49.9	Moderate	
50.0-74.9	Good	Good
75.0-100	Very well	

Data from each reef and coral reef fish census were analyzed to determine the diversity index (H') in order to obtain more detailed information about the reef and coral reef fish communities. The diversity index was calculated using the following equation (Odum 1996):

$$H' = \sum_{i=1}^s (P_i)(\ln P_i)$$

Where: H' - diversity index; P_i - comparison of the number of i^{th} species (n_i) to the total number (N); $P_i = n_i/N$; N - number of species; S - number of taxa.

The range of diversity index values can be interpreted as follows (Brower & Zar 1977): $H' \leq 2$ - low diversity, very strong environmental pressure; $2 \leq H' \leq 3$ - moderate diversity, moderate environmental pressure; $H' > 3$ - high diversity, there is a balance in the ecosystem.

Based on the H' value, we can also obtain the uniformity index value (E) by calculating it with the maximum diversity index value (H'_{max}) obtained from the number of taxa (S) as follows (Odum 1996):

$$E = H'/H'_{\text{max}} = H'/\ln S$$

The E value ranges from 0 to 1, with values closer to 0 indicating a smaller community uniformity, and closer to 1 indicating a more uniform community.

The dominance index (C) analysis was conducted to determine whether there were reef fish species or coral reef lifeforms that dominated the community in the coral reef ecosystem. The C value was obtained using the equation (Odum 1996):

$$C = \sum_{i=1}^s P_i^2$$

The C values can be interpreted as follows: $0 < C < 0.3$ - low dominance; $0.3 < C < 0.6$ - medium dominance; $0.6 < C < 1$ - high dominance.

Results and Discussion. Based on the results of identification and analysis carried out at the three observation stations on Isau Island, 108 species of coral were found from 41 genera and 15 families (Figure 2). Three families dominated the coral reef ecosystem on Isau Island: Acroporidae (31 species), Faviidae (22 species), and Poritidae (12 species). The coral reef ecosystem at stations 2 and 3 had the same number of rock coral species, and higher than at station 1. The number of genera at station 1 was the highest compared to the other two stations. The richness of coral families in station 2 was classified as high, 15 families, compared to the other two stations, which had the same

number of 14 families. At station 1, the Milleporidae family was not found, while at station 3, the Oculinidae family was not found.

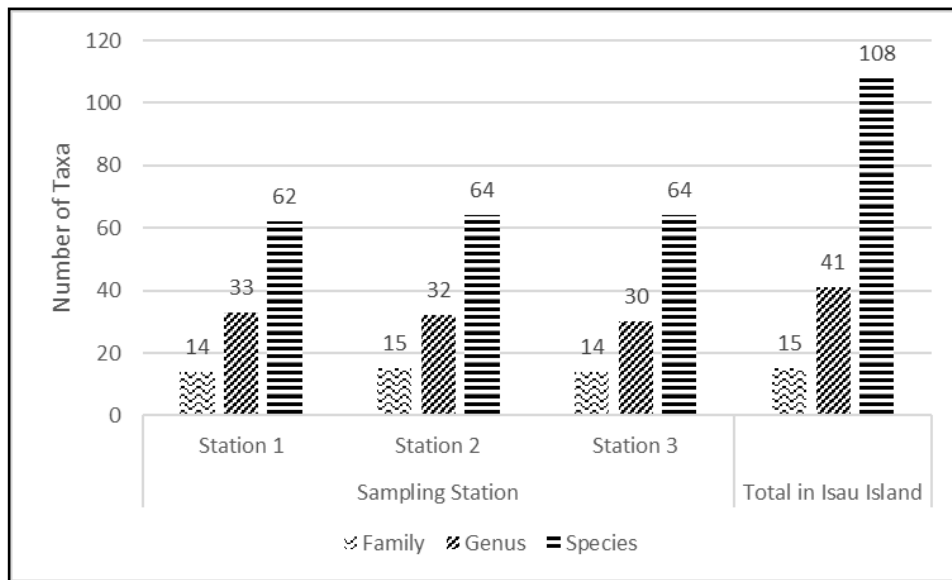


Figure 2. Distribution of coral taxa on Isau Island.

At the three observation stations, 15 species of hard coral were identified, which are widely distributed in the coral reef ecosystem of Isau Island. These coral species were: *Acropora aspera*, *Acropora carduus*, *Acropora samoensis*, *Acropora garcilis* and *Montiopora stallata* from the Acroporidae family, *Coeloseris mayeri* from the Agariciidae family, *Turbinaria mesenterina* from the Dendrophyllidae family, *Cyphastrea serailia*, *Platigira pini* from the Faviidae family, *Hydnophora microconos* from the Merulinidae family, *Symphyllia recta* from the Mussidae family, *Oxypora lacera* from the Pectinidae family, *Pocillopra verrucosa*, *Stylophora pistillata* from the Pocilloporidae family and *Heliopora coerulea* from the Helioporidae family.

The number of hard coral species on Isau Island was 18.3% of the total number of 590 hard coral species that inhabit Indonesian waters (Yuanike et al 2019), and 34.6% of the total number of 312 hard coral species found in coastal waters and small islands in Maluku Province (Sahetapy et al 2018). The hard coral family that dominates the waters of Isau Island was Acroporidae, with the genus *Acropora*, with the identification of 31 of the 124 species of *Acropora* throughout the world (Sari et al 2021).

The results of observations of coral lifeforms at the three stations on Isau Island showed high coverage for the hard coral category, exceeding 70%, with a total hard coral cover on Isau Island of 73.43% (Figure 3). The highest hard coral category cover was at station 3, at 77.14%, while the lowest was at station 2, at 70.78%. The cover of dead coral and dead coral with algae on Isau Island reached 1.87% and 2.24%, with no dead corals found. At station 2, there were only dead corals with algae, at 4.94%. Of the three observation stations on Isau Island, the algae cover category was only found at station 1, at 1.72%, which is 0.57% of the total cover on Isau Island. The other fauna category showed a cover of 8.15% on Isau Island, with the largest cover at station 3, at 12%, and the smallest at station 1, at 3.58%. The last cover category was abiotic on Isau Island, at 13.73%, with the highest cover at station 1, at 18.78%, and the lowest at station 3, at 7.02%, dominated by the rock type.

At each observation station, life from hard corals had diversity. Based on Figure 4, the *Acropora* branching (ACB) lifeform had a very high cover value, especially at station 3, which reached 55.92%, while the lowest was at station 1, at 17.28%. However, this result was in contrast to the coral branching (CB) lifeforms at station 1, which had the highest cover reaching 46.52%. Based on all lifeforms found on Isau Island, only station 3 had all lifeforms, excepting submassive corals (CS). At station 1, there was no cover of

Acropora digitate (ACD), *Acropora submassive* (ACS), *Acropora tabulate* (ACT), and *Millepora* coral (CME) lifeforms. In contrast, station 2 had no cover of ACD, coral encrusting (CE), foliose coral (CF), submassive coral (CS), mushroom corals (CMR), and *Heliopora* corals (CHL).

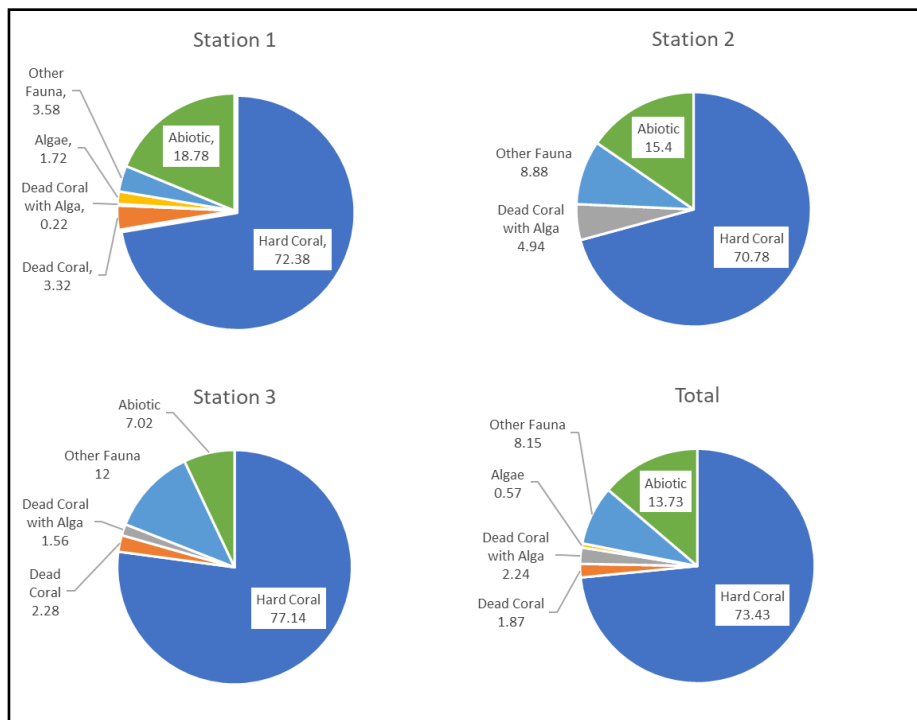


Figure 3. Distribution of lifeforms on Isau Island.

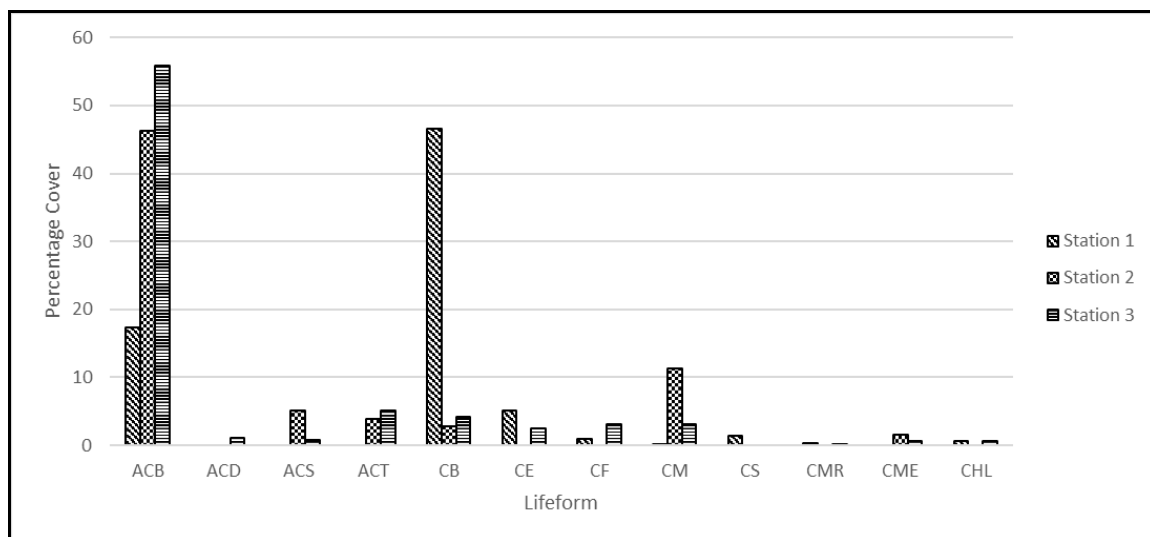


Figure 4. Hard coral lifeforms on Isau Island which had *Acropora* branching (ACB), *Acropora digitate* (ACD), *Acropora submassive* (ACS), *Acropora tabulate* (ACT), branching coral (CB), encrusting coral (CE), foliose coral (CF), massive coral (CM), submassive coral (CS), mushroom coral (CMR), *Millepora* coral (CME), and *Heliopora* coral (CHL).

The results of calculating the percentage of coral cover on Isau Island (Figure 3) showed that the average percentage value of hard coral cover reached 73%. This value showed that coral reefs on Isau Island are in a good category in accordance with the Decree of the Minister of Environment Number 4 of 2001. Only station 3 had a very good coral reef category, with a cover value of 77%. The coral reef lifeforms that dominate the waters of

Isau Island were ACB at stations 2 and 3, and CB at station 1 (Figure 4). The form of branching growth showed that the water conditions of Isau Island have areas protected from waves (Wicaksono et al 2019).

Based on Table 2, the H' value of the 3 Isau Island coral reef observation stations ranged from 2.03 to 2.34, with an average of 2.16, which was included in the medium diversity category. According to the C value, hard coral cover in the communities at the 3 stations was in the low category, with values ranging from 0.12 to 0.2, with an average value of 0.17. Meanwhile, the coral E values ranged from 0.75 to 0.89, indicating that evenness is classified as high. This condition showed an abundance of populations of certain genera, with an increase in space competition, thereby preventing other corals from expanding their populations (Pratiwi et al 2022). The population was also uniform, within a stable ecosystem, with an even distribution and number of individuals for each species.

Table 2

Coral reef ecological index values

<i>Stations</i>	<i>Diversity index(H')</i>	<i>Homogeneity index (E)</i>	<i>Dominance index (C)</i>
1	2.34	0.89	0.12
2	2.03	0.75	0.20
3	2.11	0.80	0.18
Total	2.16	0.81	0.17

The results of the reef fish census conducted at the three observation stations showed that there were 255 species of reef fish from 103 families (Figure 5). The highest number of species found was at station 3, with 221 species, and the lowest at station 1, with 154 species. Reef fish identified from the census results can be placed in three categories, namely: indicator fish, target fish, and major fish. Based on the categories, fish species in the 'indicator' and 'target' fish categories at station 1 were the lowest, but the lowest in the 'major' fish category were at station 2. Station 3 was where the three categories were most often found on Isau Island. Indicator fish are fish that show the health condition of reef fish, target fish are fish that fishermen catch, and major fish are fish that play an important role in the food chain (Tony et al 2020). More major fish are identified, because this category of fish is active during the day (Harsindhi et al 2020). Most reef fish species found on Isau Island are in the major fish category, reaching 56.8% or 127 of the 255 species.

There are eight families found out of 103 families of reef fish in the Isau Island area (Figure 6). The largest family was Pomacentridae (25%), followed by Labridae (23%) and Chaetodontidae (14%). Of the 8 families, Pomacanthidae, Lutjanidae, and Acanthuridae were the least numerous, with a value of 5-7% of the eight families. Species from the families Pomacentridae and Labridae were the major fish that dominated the waters of Isau Island (Figure 6). These two families were often found in coral reef ecosystems, because their entire life cycle occurs in coral reefs (Harsindhi et al 2020; Mujiyanto et al 2021). The Pomacentridae family is a family widely distributed in Indo-Pacific waters (Aguilar-Medrano et al 2015; Tony et al 2020; Mujiyanto et al 2021). Pomacentridae is a family of herbivorous fish that eat algae and plankton (Mahmudin et al 2020). Members of the Labridae family feed on algae and coral mucus (Sarhan et al 2019). This is supported by the presence of algae cover and dead coral with algae, which was their main food (Figure 3).

The ecological index values for fish are presented in Table 3. The H' value showed a medium diversity category, with a value between 2.67–2.74, and an average of 2.7. The E value was different between stations 1 and 2 and station 3. Stations 1 and 2 had a value of 0.82, which shows high uniformity, while station 3 had a value of 0.79, which shows moderate uniformity. The average E value was 0.81, in the high category. The C value showed a low dominance category in the value range of 0.09–0.1, with an average value of 0.1. Thus, reef fish on Isau Island have a uniformity that falls into the moderate category with stable environmental pressure. A high E value results in low dominance,

which shows that reef fish have an even population distribution with stable ecosystem conditions.

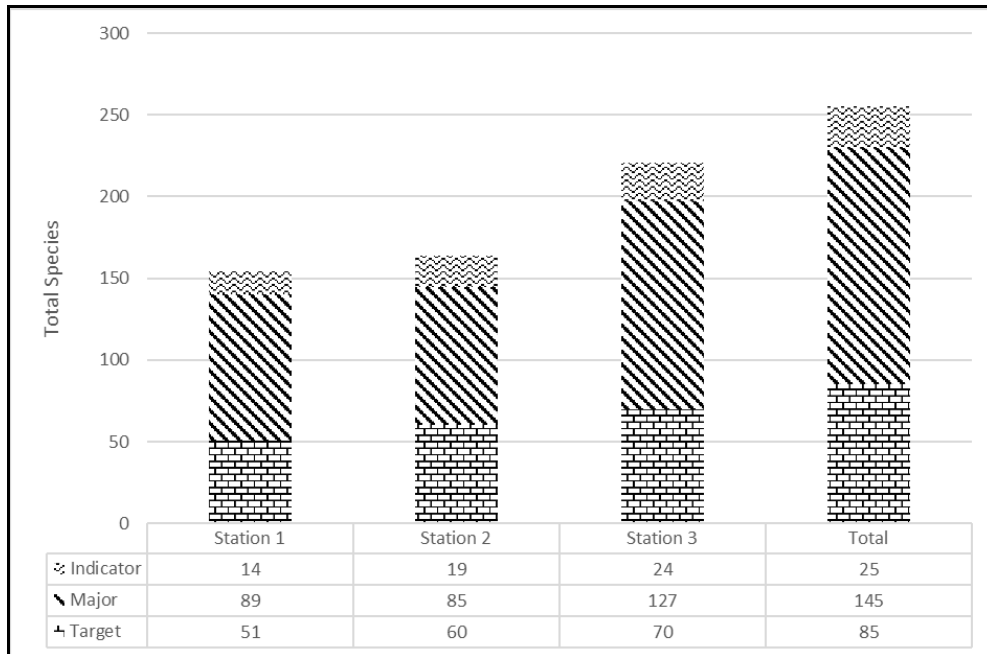


Figure 5. Distribution of fish species by category.

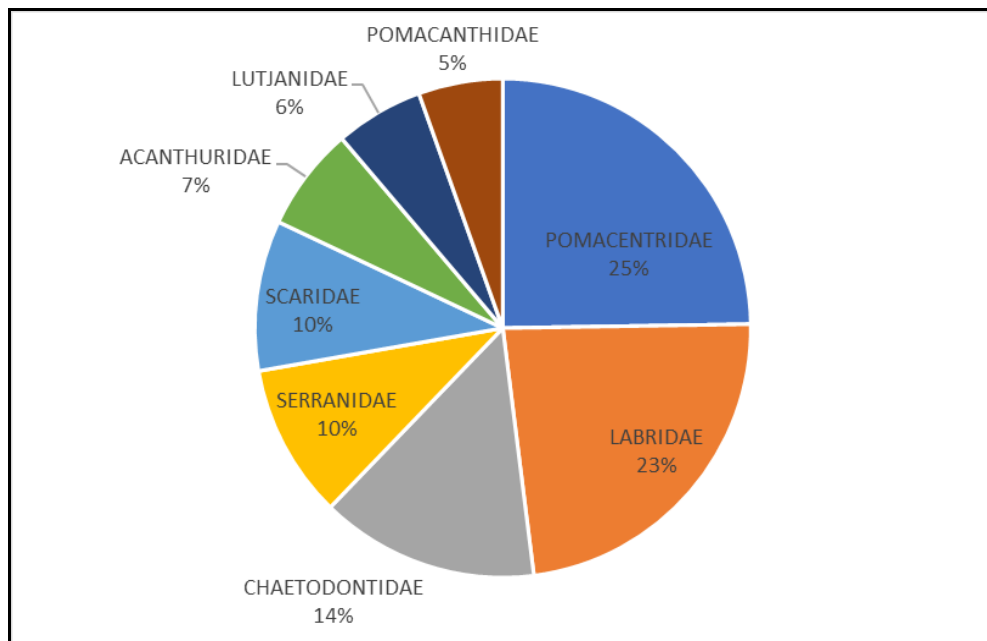


Figure 6. Reef fish families found on Isau Island.

Table 3

Ecological index values for reef fish

Stations	Diversity index (H')	Homogeneity index (E)	Dominance index (C)
1	2.74	0.82	0.09
2	2.7	0.82	0.09
3	2.67	0.79	0.1
Total	2.7	0.81	0.1

The habitat condition of the coral reefs has a big influence on biota, and this condition can be analyzed based on water parameters (Chong-Seng et al 2012). The water parameters observed in situ (Table 4) showed an average temperature of 28.8°C, with the highest value at station 3 (29.2°C). The water temperature conditions on Isau Island are within the quality standards for coral reef water quality set by Minister of Environment Decree No. 51 of 2004 (28-30°C). The temperature has significant influence in coral reef ecosystems (Saptarini et al 2017). The salinity in the waters of Isau Island showed an average value of 34.6‰, with the highest value of 34.8‰ at station 2. The salinity of the waters of Isau Island (34.6‰) was slightly above the quality standard (33-34‰). Even so, coral reefs and their associated biota can tolerate changes in salinity between 25‰-40‰, although this might cause a decrease in growth (Smyth & Elliott 2016). The current speed at station 1 was the highest, reaching 7.4 cm s⁻¹, with an average current speed on Isau Island of 3.1 cm s⁻¹. The current speed on Isau Island had an average of 0.031 cm s⁻¹, with the highest speed at station 1 reaching 0.074 m s⁻¹. This current brings food supply for the coral reef ecosystem in the form of nutrients and plankton (Sekerci & Petrovskii 2015).

Table 4

Water parameter values

Parameter	Stations			Average
	1	2	3	
Temperature (°C)	28.4	29	29.2	28.8
Salinity (‰)	34.7	34.8	34.4	34.6
Current (cm s ⁻¹)	0.074	0.009	0.008	0.031

Station 3, with the highest hard coral cover (77.14%), presented 221 species of reef fish. Station 1, with the lowest hard coral cover (70.78%) presented only 154 species of reef fish. However, the diversity of reef fish cannot be used as an indicator of the health of the coral reef ecosystem because most of them are in the major fish category. The health of the coral reef ecosystem can be seen by looking at the abundance of indicator fish categories, such as the Chaetodontidae family (Harahap et al 2019). In addition, coral lifeforms that mostly cover the waters of Isau Island, namely branching *Acropora* and branching corals, also influence the diversity of associated biota such as reef fish. The branched growth form provides more space for biota to grow, thereby increasing diversity in the coral reef ecosystem (Muniah et al 2017).

Conclusions. The coral reef ecosystem on Isau Island is in good condition, with hard coral cover reaching 73.43%, in the good category. There were 108 species from 41 genera and 15 families of hard coral. The most commonly identified reef fish families on Isau Island were the Pomacentridae and Labridae families, living on coral reefs. The Pomacentridae family was the most frequently observed, because it was in contact with algal cover at each station, which is its main food. The dominance of branching lifeform types (branching *Acropora* and branching corals) on Isau Island gave rise to a high diversity of biota, such as reef fish in the island's coral reef ecosystem.

Conflict of Interest. The authors declare that there is no conflict of interest.

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