The condition of the coral reef ecosystem in Natuna Island

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Abstract. Three groups of marine biotas in the coral reef ecosystem were analyzed to determine the overall condition coral reef ecosystem in Natuna Island (coral, reef fish, and megabenthos). Nineteen sampling sites are distributed completely in Natuna Island, including Natuna Besar Island, Tiga Island, and Sedanau Island. The coral reef monitoring refers to the Underwater Photo Transect (UPT), and data processing used the Coral Point Count for excel (CPCe). The reef fish observation using the Underwater Visual Census (UVC) and megabenthos observations using the Benthos Belt Transect (BBT). The percentage of the benthic cover was analyzed for several benthic categories. The analysis for reef fish consisted of diversity and abundance for the three fish groups, including the corallivore, herbivore, and carnivore. The megabenthos community's analysis consisted of diversity and density from eight groups, including giant clams, lobster, Drupella sp., Linckia laevigata, sea urchin, sea cucumber, trochus, and Acanthaster planci. The Coral Reef Health Index (CRHI) analysis was used to determines the coral reef condition in Natuna. Nine sites were categorized as the fair condition of live coral cover with 26.53–36.87%. The largest composition of coral reef fish groups from herbivorous groups and the highest density megabenthos was sea urchins.

Keywords: coral; diversity; megabenthos; Outer Island; reef fishes
1. Introduction
Natuna Island is a part of Riau Islands Province and potentially have various coastal and marine resources. Natuna has an area of 141,901 km² and mostly consists of waters covering an area of 138,666 km², and the mainland area consists of small islands covering an area of 3,235.2 km². Natuna consists of many island clusters, includes the Natuna Islands cluster (Sedanau, Bunguran, Midai, Laut Island) and Serasan Islands cluster (Subi Besar and Subi Kecil) [1]. Natuna Regency has various coastal ecosystems, particularly coral reefs, mangrove forests, and seagrass beds.

Coral reefs are typical ecosystems found in tropical areas [2, 3]. This ecosystem has very high organic productivity [4-6], likewise with the diversity of biota in it [4, 7-10]. The essential biota component on a coral reef consists of reef fishes and megabenthos communities [11]. The coral reef ecosystem is an ecosystem that lives on the shallow seabed in tropical and subtropical areas [12], which is formed from the biological activity of the anthozoa corals [13]. The coral reef ecosystem is one of the most complex and unique ecosystems and has high productivity and diversity [14]. However, coral reefs’ current condition is very vulnerable to disturbances from changes in the aquatic environment. Changes in water quality will affect the condition of the surrounding coral reefs [3, 15].

Hadi et al. [16] suggests that fish in coral reef ecosystems are a group of fish taxa associated with coral reef ecosystem environments. Allen and Adrim [17] stated that as many as 113 fish families are coral inhabitants, most of them belong to Perciformes. The ten prominent families of these reef fish are Gobiidae, Labridae, Pomacentridae, Apogonidae, Bleniidae, Serranidae, Murraenidae, Syngnathidae, Chaetodontidae, and Lutjanidae [17]. Based on their utilization function and ecological aspects, reef fish can be classified into target fishes, indicator fishes, and major fishes [18]. Target fish are groups of reef fishes species that can be consumed and had high economic value. Indicator fish is a reef fishes species with a strong association in coral habitats [19-22]. Major fish are the group of reef fish that are frequently found in the coral reef ecosystem. Megabenthos is another species of marine organism that lives very close to stony corals. The megabenthos group consists of sea cucumbers, holothurian, giant clams, lobster, lola (Trochus sp. and Tectus sp.), Acanthaster planci, Drupella spp. snails, sea urchins, and Linckia laevigata (blue starfish). Several reef fish and megabenthos species are known to be used as indicators to assess the health of the coral reefs ecosystem (ecological value) [11, 21]. Several species are identified as targets of fishermen’s catch. The ecological value is the most important basis for determining reef fish and megabenthos as coral reef association biota. The ecological value is intended to determine the condition of the coral reef association biota that has a direct role in changing coral reef ecosystems [22], e.g., the coral reef fish species that feed coral polyps, or indirectly to determine the health condition of coral reefs by observing changes in key species in the coral reef ecosystem. Meanwhile, the economic value is not only for the biota targeted for fishing also for ornamental biota and another endangered biota.

Based on previous research by Hadi et al. [16], the condition of the coral reef ecosystem in Natuna was dominated by DCA. Information obtained from the community and local government shows that destructive fishing activities are still occurring in several locations of the coral reef ecosystem in Natuna, especially in the Kelarik area, which is in the western part of Natuna. The other previous research conducted by Putra et al. [23] showed that the coral reef ecosystem in Natuna experienced bleaching due to rising sea surface temperatures in 2019. This study aims to determine the current condition of the coral reef ecosystem in Natuna by looking at the coral reef index value, which consists of coral reef cover, coral fish composition, and the presence of megabenthos in Natuna seawaters.

2. Materials and methods

2.1. Research location
The research location was conducted in nineteen sampling sites location distributed over the Natuna Islands, including the northern (six sites), southern (five sites), western (two sites), and eastern (six sites) (figure 1). Generally, the coral reef ecosystem on Natuna Island was quite diverse, from dense coral cover to the condition of the coral reef had rubble form due to destructive fishing practice. Several
locations on Natuna Island have 500 m long reef flats. The beach substrate consists of rocks, dead coral, and sand covered with coastal vegetation. Generally, the corals found were dominated by *Porites* sp. Live coral growth is still found up to a depth of 10 m. The form of coral growth was dominated by coral massive (CM) and coral encrusting (CE). The southern part of Natuna Island is a volcanic rock wall with a relatively moderate slope. Coral grows in patch form and is also dominated by coral massive (CM) and coral encrusting (CE). *Porites lutea*, *Porites cylindrica*, and *Porites rus* were also found in this location. The eastern part of Natuna Island generally consists of steep slopes condition with mostly sandy beds. The coral growth form was dominated by coral encrusting (CE), coral massive (CM), Acropora tabulate (ACT), and Acropora branching (ACB). The following is a map of the distribution of 19 research sampling sites located on Natuna Island presented in figure 1.

![map of Natuna Island](image)

Figure 1. The Sampling sites location of the coral reef ecosystem in the Natuna Islands.

2.2. *The benthic community structures*

The coral reef's collecting data starts with the visual observation from the coast to the transect location to obtain an overview of the research sites. At each research site's location, a meter tape (roll meter) is distributed along 50 meters as a transect line placed parallel to the coastline on the reef slope with a depth of about 4–7 meters. During laying transects lines, the mainland is placed to the left of the transect. The method used is UPT (Underwater Photo Transect) [24]. The image is taken along the transect line with the guidance of a 44 x 58 cm rectangular frame. The shooting photo images from UPT begin from the 1st meter to the 50th meter with a distance of 1 meter between photo shoots. The photo shots of UPT are considered at each distance of 1st meter (Frame 1), 3rd meters (Frame 3), and the next odd frame was taken to the left of the transect line (the part closer to the mainland). For the even frame (Frame 2nd, Frame 4th, and next even frame number), taken to the right of the transect line (the part away from land).
The benthic community data collection at each site's location was carried out using SCUBA diving equipment and an underwater camera with an area of 2,552 cm$^2$ per frame using the underwater camera at a distance of 60 cm from the object without using zoom.

2.3. Coral reef fishes' assemblages
The underwater visual census method developed by English et al. [25] is a rapid, accurate, effective, and environmentally friendly method [26-30]. The resulting data is relevant to coral fisheries management's objectives in particular, and the management of coral reef ecosystems. Most reef fish are diurnal and active during the day; only a small proportion of reef fishes are active at night [31-34]. Therefore, the ideal visual census time approach is carried out in the morning to evening period (between 09.00–16.00). The time approach additionally requires to consider tidal conditions. Low tide conditions often cause high currents and high turbidity. The ideal time for collecting data on reef fishes is when the water increases where the fish come out to feed. The data collected from reef fishes were the number of species, length of fish, and individuals. Coral reef fish data were collected by diving on belt transects with a census area of 70 x 5 m. Fish species and their estimated numbers are recorded on a waterproof datasheet. Identification of fish species using pictorial manuals by Allen et al. [35]. The approach used in estimating the fish's length in the water is the "stick" method [36], which attempts to estimate the total length of the fish from the tip of the fish's mouth to the tip of the caudal fin. Furthermore, the number of census fish grouped into approximate length (cm): 6–10; 11–15; 16–20; 21–25; 26–30; 31–35 etc. in multiples of five cm.

2.4. Megabenthos community structure
Observation of megabenthos was using the Benthos Belt Transect method develop by Loya [37]. Observations were performed using SCUBA equipment. The Transects location is synchronized with coral and fish transect. This method is performed by laying a roll meter tape parallel to the coastline on a transect length of 70 meters. The coastline is always to the left of transects tape. After the transect was placed, the observer will record the megabenthos group (table 1). The observation of megabenthos performed from 0 meters to 70$^{th}$ meters with an observation width of 1 meter to the left and 1 meter to the right of the transect and the observation area was 140 m$^2$. Following the Megabenthos target categories based on Giyanto et al. [24] presented in table 1.

| No | Megabenthos target |
|----|---------------------|
| 1  | Sea urchin/Diadema spp. |
| 2  | Coral eating snails/Drupella cornus and Drupella rugosa |
| 3  | Giant clams |
| 4  | Trochus spp. and Tectus spp. |
| 5  | Sea Cucumbers, Holothurians |
| 6  | Panulirus spp. |
| 7  | Blue starfish, Linckia laevigata |
| 8  | Crown-f-torn starfish, Acanthaster planci |

2.5. Data analysis
Image data processing of benthic community structures uses data processing applications Coral Point Count for Excel extension (CPCe) with 50 random points on each photo data [38]. A total of 30 random point samples was selected for each data. The photo analysis technique uses 30 random point samples from each frame, and each point is coded according to the code for each biota group and substrate (table 2).
Table 2. Code of each coral reef benthic community group.

| Code | Information |
|------|-------------|
| HC   | Hard Coral = AC + NA |
| -AC  | Acropora = Stony coral from Acropora family: ACB (Acropora branching), ACD (Acropora digitate), ACE (Acropora encrusting), ACS (Acropora submassive), ACT (Acropora tabulate) |
| -NA  | Non-Acropora = Stony Coral other than Acropora family: CB (Coral branching), CE (Coral encrusting), CS (Coral submassive), CF (Coral foliose), CHL (Heliopora), CM (Coral massive), CME (Millepora), CMR (Coral mushroom) |
| DC   | Dead Coral |
| DCA  | Dead Coral with Algae |
| SC   | Soft Coral |
| SP   | Sponge |
| FS   | Fleshy seaweed: from algae group: MA (Macroalgae) + AA (Algae assemblages) |
| OT   | Other fauna: CA (Coraline Algae) + HA (Halimede) + ZO (Zoanthid) + OT |
| R    | Rubble |
| S    | Sand |
| SI   | Silt |
| RK   | Rock |

Furthermore, to see the proportion of cover of each category of biota and substrate for each photo frame using the formula from Giyanto et al. [24]:

\[
\text{percentage of benthic category cover} = \frac{\text{the number of points in the category}}{\text{number of random points}} \times 100\% \tag{1}
\]

Analysis of reef fish consists of diversity analysis (the number of reef fish species observed during research at a coral reef ecosystem location), density analysis (the number of individuals from each species of reef fish per family per area), and biomass analysis (weight of individual herbivores and carnivorous fish per observation area). There were eight families of reef fish (Chaetodontidae, Acanthuridae, Scaridae, Siganidae, Haemulidae, Lethrinidae, Lutjandiae, and Serranidae) as the research object based on Giyanto et al. [24]. The coral reef fishes also from 3 categories, including corallivorous fish, herbivorous fish, and carnivorous fish. The group of coral reef fishes presented in Table 3.

Table 3. Coral reef fishes' data recorded categories (Corallivore, Herbivore, and Carnivore) based on Giyanto et al. [24].

| Categories | Family | Data Recorded |
|------------|--------|---------------|
| Corallivorous | Chaetodontidae | 1. Number of species |
|             | Scaridae | 2. The density of Individual of each species |
| Herbivorous | Siganidae | 1. Number of species |
|             | Acanthuridae | 2. The density of individual of each species |
|             | Haemulidae | 3. The estimate of Total Length each reef fishes |
| Carnivorous | Lethrinidae | 1. Number of species |
|             | Lutjandiae | 2. The density of individual of each species |
|             | Serranidae | 3. The estimate of Total Length each reef fishes |
The following formulas determine the density and biomass of reef fish:

\[
\text{Density} = \frac{\text{the number of individual reef fishes in each family}}{\text{area (350) m}^2} \times \frac{\text{individual weight}}{\text{m}^2}
\]  

(2)

Coral reef fish biomass obtains from a weight-length relationship equation [39-41]. The equation used where the individual weight of herbivorous fish or carnivorous fish (W: grams) equals the species-specific index (a) multiplied by the estimated total length (L: cm) in the power of the species-specific index (b). Species-specific indexes a and b [42].

\[
\text{Biomass} = \frac{\text{total weight each reef fishes families (gram)}}{\text{area (350) m}^2}
\]  

(3)

Megabenthos analysis is only performed for density using the following formula

\[
\text{Density} = \frac{\text{the number of individual megabenthos target}}{\text{area (140) m}^2}
\]  

(4)

The coral reef health index (CRHI) value is a combination of the current condition of live coral cover, the level of coral reef resilience, and the biomass of coral fish. The three components are then grouped (high, low, and medium) based on previously collected data, and the index value obtained represents the condition of the coral reef ecosystem completely. The determination of CRHI value follows Giyanto et al. [24, 43] presented in table 4 below.

| No | Benthic component Value | Categories |
|----|-------------------------|------------|
| 1  | Live coral cover (LC)   |            |
|    | LC <19%                 | Low        |
|    | 19≤ LC ≤35%             | Medium     |
|    | LC >35%                 | High       |
|    | FS <3% U (R ≤60 LC >5%) | High       |
|    | FS >3% U (R ≥60 LC >5%) | Low        |
| 2  | Resilience level        |            |
| 3  | High                    | High       |
| 4  | Medium                  | Medium     |
| 5  | Low                     | Low        |
| 6  | High                    | High       |
| 7  | Medium                  | Medium     |
| 8  | Low                     | Low        |
| 9  | High                    | High       |
| 10 | Medium                  | Medium     |
| 11 | Low                     | Low        |
| 12 | High                    | High       |
| 13 | Medium                  | Medium     |
| 14 | Low                     | Low        |
| 15 | High                    | High       |
| 16 | Medium                  | Medium     |
| 17 | Low                     | Low        |
| 18 | High                    | High       |
| 19 | Medium                  | Medium     |
| 20 | Low                     | Low        |

The Coral Reef Health Index value is a combination of the current condition of live coral cover, the level of coral reef resilience, and the biomass of coral fish. The three components were leveling in groups (high, medium, and low) based on previously collected data. Thus the index value obtained can represent the condition of the coral reef ecosystem accurately. The determination of the CRHI value refers to Giyanto et al. [43] presented in table 5 below.

| Live Coral Cover | Resilience Level | Value | Reef Fishes Biomass Value | Total Value | CRHI |
|-----------------|-----------------|-------|---------------------------|-------------|------|
| High            | High            | 6     | High                      | 6           | 12   | 10  |
| High            | High            | 6     | Medium                    | 4           | 10   | 8   |
| High            | High            | 6     | Low                       | 2           | 8    | 6   |
| Medium          | High            | 5     | High                      | 6           | 11   | 9   |
| Medium          | High            | 5     | Medium                    | 4           | 9    | 7   |
| Medium          | High            | 5     | Low                       | 2           | 7    | 5   |
| High            | Low             | 4     | High                      | 6           | 10   | 8   |
| High            | Low             | 4     | Medium                    | 4           | 8    | 6   |
| High            | Low             | 4     | Low                       | 2           | 6    | 4   |
| Low             | High            | 3     | High                      | 6           | 9    | 7   |
| Low             | High            | 3     | Medium                    | 4           | 7    | 5   |
| Low             | Low             | 3     | Low                       | 2           | 5    | 3   |
| Medium          | Low             | 2     | High                      | 6           | 8    | 6   |
Table 5. (Continued).

| Live Coral Cover | Resilience Level | Value | Reef Fishes Biomass | Value | Total Value | CRHI |
|------------------|------------------|-------|--------------------|-------|-------------|------|
| Medium           | Low              | 2     | Medium             | 4     | 6           | 4    |
| Medium           | Low              | 2     | Low                | 2     | 4           | 2    |
| Low              | Low              | 1     | High               | 6     | 7           | 5    |
| Low              | Low              | 1     | Medium             | 4     | 5           | 3    |
| Low              | Low              | 1     | Low                | 2     | 3           | 1    |

3. Result and discussion

3.1. The benthic cover

Generally, the percentage of live coral cover in the Natuna Islands ranges from 10.60–36.87%. The lowest percentage of live coral cover was found on Tiga Islands (NTNC.07), while the highest percentage of live coral cover was found on the mainland of Natuna (NTNC.A). Of the nineteen research site location, nine stations were included in the fairly good coverage category with a range of 26.53–36.87%. Nine research site locations were included in the low coverage category, with a range of 10.60–23.73%. However, the overall average value of the percentage of live coral cover at all research site location stations was 24.53% and included under the low coral cover category criteria. The results of the percentage of benthic cover of coral reefs in Natuna Island were presented in figure 2.

![Figure 2](image_url)

**Figure 2.** The percentage of benthic cover at each research site’s location on Natuna Island. HC: live coral, DC: dead coral, DCA: dead coral overgrown with algae, SC: soft coral, SP: sponge, FS = fleshy seaweed, OT: Other biotas, R: rubble, S: sand, Si: mud and RK: rock.

In addition to the percentage of live coral cover, another benthic cover required to be considered is the percentage of dead coral cover covered with algae (DCA) and coral rubble (R). The percentage of DCA cover at each research site's location in the Natuna District ranged from 33.47–74.00%, with an average value of 56.29%. The highest DCA cover was found on the mainland Natuna (NTNC.E), while the lowest DCA cover was found on Sedanau Island (NTNC.D). Furthermore, the percentage of rubble cover (R) at each site's location in Natuna ranged from 0–29.93%, with an average value of 6.77%. The highest percentage of rubble cover (R) was found in Buton Bay (NTNC.G). The low live coral cover,
and high value of dead coral cover covered with algae (DCA) also the higher percentage of coral rubble (R) in Natuna Island, are considered to be the result of destructive fishing in the past. The majority of research sites location found coral rubble and portions of dead coral covered with algae due to cyanide or potassium use. The result was supported by the statement from the coastal community in Natuna. The majority of coastal community state the previous years, the activities of destructive fishing with bomb and poison often happened in Natuna.

The average percentage of another benthic cover as a show was dead coral (DC) 0.79%, soft coral (SC) 3.80%, sponge (SP) 0.22%, fleshy seaweed (FS) 1.84%, other fauna (OT) 0.79%, sand (S) 4.95%, and silt (S) 0.01%. The cover of other biotic components, such as soft corals (SC), sponge (SP), and fleshy seaweed (FS), was higher found in several research sites' location. Soft coral (SC) was considerably dominant at three sites, particularly NTNC.F, NTNC.157, and NTNC.145, with a percentage of cover 14.60%, 14.27%, 13.53%, respectively. The fleshy seaweed (FS) was considered dominant in NTNC.161 with a coverage percentage of 22.80%, with dominant macroalgae species from Sargassum sp.

3.2. Reef fishes' composition

Based on the results of the composition of coral reef fish species from the visual census in Natuna waters, which are divided into three groups of fish species, namely corallivore, which consists of the Chaetodontidae family, herbivores were consisting of Acanthuridae, Scaridae, and Siganidae. Carnivores were consisting of the Haemulidae, Lethrinidae, Lutjanidae, and Serranidae. The highest composition of coral reef fish species shows from the herbivore fish group with a percentage composition of coral reef fish species of 46.67%, followed by the carnivorous fish group with a percentage composition of 36.67%. The lowest species composition from corallivore was 16.67% in NTNC.02. The composition of the herbivorous fish group was high because the Scaridae species were dominant in Natuna Island. The composition of the Scaridae family gave a considerable component value to herbivorous fish in Natuna. Our results showed that herbivorous fish had the most extensive composition in Natuna (figure 3). Several previous studies have shown that herbivorous fish were very fast-growing and had a high density [44, 45]. Herbivorous fish groups have a significant role in coral reef ecosystems and are used as coral reef resilience [46]. The large composition of herbivore fishes in Natuna seawater has a positive impact on the recovery of the coral reef ecosystem in Natuna by supporting to limit, and control the growth of algal communities [47].

The visual census of coral reef fish at 19 stations in Natuna has recorded 90 species included in the seven families of the coral reef fish group. From the result shown, 15 species of Corallivore fish from the Chaetodontidae family. There are 42 species of herbivorous fish belonging to 3 families, nine species of Acanthuridae, 25 species of Scaridae, and eight species of Siganidae. There are 33 groups of carnivorous fish belonging to 4 families, namely four species from the Haemulidae family, eight species of Lethrinidae, ten species of Lutjanidae, and one species Serranidae. The largest number of coral reef fish species from the visual census results are at the NTNC.145 located in the Ranai (figure 3) with a total of 42 species from 3 reef fish groups consisting of 6 species from the Corallivore fish group, 30 species from the Herbivore fish group and six species from the Carnivore fish group. In comparison, the lowest number of species of the three reef fish species was at the NTNC.D located in Sedanau Island, with a total number of species was 12 species. The results showed that herbivorous fish's composition dominated most of the research site's location and indicates that coral reefs in the entire Natuna area were in similar conditions. The presence of herbivorous fish provides information that coral reef ecosystems are under pressure where coral reefs have a strong relationship with herbivores and algae that attach to corals due to pressure on coral reefs [48, 49]. The high presence of herbivorous fish species in Natuna seawaters plays an essential role in preventing the transition from the coral reef phase to algae dominant [50, 51]. Previous research proved that herbivorous fish have an essential role in maintaining a good ecosystem balance to prevent coral mortality [52]. Grazing by herbivores plays a role in maintaining the resilience of coral reefs in Natuna, and their existence is significant for coral reef resilience in Natuna.
Research site located in Sepempang (NTNC.A) and Bunga Island (NTNC.F) has the highest number of density Corallivore fish, with 38 individuals/350 m² (figure 3), followed by NTNC.152 in research sites located in Tanjung Datuk with the number of individuals Corallivore fish of 33 individuals/350 m², NTNC.157 in Ranai and NTNC.D in Sedanau Island (32 individuals/350 m²), NTNC.03 in Tanjung Legung and NTNC.148 in East mainland Natuna Island (31 individuals/350 m²). In comparison, the lowest number of individuals corallivores was found at the NTNC.02 located on Sedanau Island. The NTNC.05 research site's location in Tanjung Datuk had the highest density of herbivorous fish with 273 individuals/ha (figure 4). NTNC.06 on Seluar Island was another higher herbivore density with a fish density of 208 individuals/ha, followed by NTNC.A (Sepempang) of 183 individuals/350m², NTNC.145 (Ranai) of 10 individuals/350 m². In contrast, the lowest density herbivorous fish density was found at the NTNC.D on Sedanau Island with 371 individuals/350m². The NTNC.E research sites located in Pian Tengah have the highest density of carnivorous fish with 45 individuals/350 m² (figure 4), followed by the NTNC.F on Bunga Island density of Carnivore fish of 31 individuals/350 m², NTNC07(Tiga Island) with 29 individuals/350m². In comparison, the lowest density of carnivorous fish was found at the NTNC.D located in Sedanau Island with three individuals/350m². Following are the density of corallivorous, herbivorous, and carnivorous (ind./350 m²) reef fish at each location - Natuna Island is presented in figure 4.

The results showed that the Corallivore fish from the Chaetodontida family in the eastern Natuna had a more excellent density value than in the western Natuna (figure 4). The presence of Corallivore fish from the Chaetodontidae family indicates that the condition of coral reefs in the western part of Natuna is experiencing degradation and increasing pressure. The evidenced by the dominant composition of rubber and dead coral algae in the coral reef ecosystem of the western part of Natuna. Chaetodontidae fish is one of the organisms directly related to coral reefs by having an extensive area in the coral reef ecosystem so that this fish group is used as an indicator in the coral reef ecosystem [53]. Among coral reef fish, Corallivore fish from the Chaetodontidae family depends heavily on hard corals [54]. Previous studies have shown a close relationship between butterflyfish and coral prey [21]. Although the abundance of Corallivore fish in Natuna seawaters was lower than the herbivorous fish composition, in terms of fish species composition, the species richness of corallivore fishes in Natuna was more numerous than in other areas close to Natuna, including Bintan and Batam, with only two found two and three species Chaetodontidae fishes respectively [23]. Compared to several eastern Indonesia...
locations, the number of corallivore fish species in Natuna was higher, especially compared to Spermonde with 16 species Chaetodontidae [55], although not as large as in Minahasa with 20 species [56]. Compared with several coral reef locations in western Indonesia, Natuna was included in the higher species richness than other locations, specifically Bangka, with only two species of corralivore fish from the species *C. octofasciatus* and *C. rostratus* [57]. Even if it is compared to the coral reef ecosystem in western Sumatra, such as in Padang with only six species of Chaetodontidae were found [58], Natuna even has three times the number of species. From the research results, the degradation causes the abundance of Chaetodontidae fish in Natuna below, but it does not affect the number of species richness Corralivore fish in Natuna with relatively high for the western part of Indonesia.

| Location | Corallivore | Herbivore | Carnivore |
|----------|-------------|-----------|-----------|
| NTNC.02  | 6           | 88        | 6         |
| NTNC.03  | 31          | 145       | 19        |
| NTNC.05  | 6           | 67        | 5         |
| NTNC.06  | 20          | 208       | 16        |
| NTNC.07  | 24          | 83        | 29        |
| NTNC.144 | 8           | 134       | 9         |
| NTNC.145 | 21          | 162       | 10        |
| NTNC.146 | 23          | 96        | 21        |
| NTNC.148 | 31          | 147       | 19        |
| NTNC.152 | 33          | 118       | 18        |
| NTNC.157 | 32          | 102       | 14        |
| NTNC.159 | 27          | 74        | 5         |
| NTNC.161 | 9           | 16        | 7         |
| NTNC.A   | 38          | 183       | 5         |
| NTNC.B   | 17          | 138       | 5         |
| NTNC.D   | 32          | 13        | 18        |
| NTNC.E   | 12          | 90        | 45        |
| NTNC.F   | 38          | 76        | 31        |
| NTNC.G   | 11          | 273       | 9         |

Coral Reef Fishes Density

**Figure 4.** The density of corallivore, herbivores, and carnivores reef fishes (Ind./350m²) at the location of each site - Natuna Island.

3.3. Megabenthos composition

Based on the 19 research site's location, megabenthos target biotas found were six categories (figure 5). In contrast, the other two categories were not found, including sea urchins, clams, *Drupella* spp., *Lola*, sea cucumber, and *Linckia laevigata*. The majority of megabenthos target categories were NTNC.7, NTNC.B, NTNC.E, and NTNC.G site location with five categories (figure 5). There were six categories of megabenthos located in the substrate of live coral, dead coral, and sand, particularly sea urchin, giant clams, *Acanthaster planci*, *Drupella* spp., snails, *Lola*, and sea cucumbers. Sea urchins were found to have two types of color, specifically black and white color. Black sea urchins have longer spines than...
white sea urchins. *Drupella* spp. was common in live corals with a branching form of growth. These snails always in groups and stick between coral branches. Clams are found embedded in massive corals and partly outside of reefs. Lola snails were found attached to dead coral and soft corals. There are three species of sea cucumbers, particularly *Holothyria atra*, *Holothuria edulis*, and *Thelenota anax*. The target megabenthos found were varied in size, especially in the clams. The clams were located at 11 research stations with sizes ranging from 2.1 cm to 47.2 cm. Following are the composition megabenthos community in Natuna Islands is presented in figure 5 below.

![Figure 5. The composition megabenthos community in Natuna Island.](image)

The highest density of clams was found at NTNC.2 with 20 ind./140m², and at this research site location found the largest of clams with the size reached 47.2 cm. The lowest density of clams was only found 1 ind./140m² in several research sites location, including at NTNC.145, NTNC.C, NTNC.152, NTNC.A, NTNC.D, NTNC.E, and NTNC.G. The megabenthos that dominate in Natuna were *Drupella* spp. and sea urchins. The megabenthos group is ecologically important because their presence affects the growth of coral reefs. Of the six categories of megabenthos target was found, the highest percentage value was *Drupella* spp. with 38%. In contrast, the smallest percentage value was found in lola snails and sea cucumbers with 1%. Sea urchins also had high composition with a percentage value was 34%. Based on the result, *Drupella* spp. and sea urchins are very dominant biota in Natuna based on the percentage value of the target megabenthos composition.

Based on the 19 research sites' location, *Drupella* spp. had the largest mean density for megabenthos of 14.37 ind./140 m², followed by sea urchins (12.84 ind./140 m²), *Linkea laevigata* (5.79 ind./140 m²), clams (14.37 ind./140 m²), lola (0.58 ind./140 m²) and sea cucumber (14.37 ind./140 m²). The highest average density value from megabenthos on NTNCD with 750 ind./ha. The majority of high-density value consists of four megabenthos target biota (Sea urchins, *Drupella* spp., Clams, and *Linkea laevigata*). The highest density derived from sea urchins (77 ind./140 m²) was found in NTNC.D, followed by *Drupella* spp. (54 ind./140 m²) found at NTNC 148. The lowest density value was 71 ind./ha, particularly from sea urchins, *Drupella* spp., clams, lola, and sea cucumbers and spread over 12 research site locations. Based on each site's result, the megabenthos target was mostly found in Natuna, was essential ecological value biota, including *Drupella* spp. (34%) and sea urchins (38%). The ecological value possessed by the two biotas is an indicator of coral reefs' health because the presence of both biotas can directly or indirectly affect coral growth. *Drupella* has played an essential role in the destruction of many reef areas around the world due to its predatory nature of coral [59, 60]. *Drupella* spp. can consume live coral tissue so rapidly that it can do more than 50% damage in some outbreaks.
The presence of *Drupella* spp. in Natuna in an extensive area indicates a significant pressure on the coral reef ecosystem in Natuna (figure 6). In different components, Natuna island had a significant abundance of sea urchins. Sea urchins are a significant component of marine communities and their pastoral ability limits algal biomass growth [62]. The existence of sea urchins is essential for the sustainability of the coral reef ecosystem in Natuna with high destructive fishing activity. It causes massive damage to coral reefs and the emergence of algae. Meanwhile, from our result, we found several megabenthos targets have a significant economic value in Natuna, especially in giant clams. On the other hand, giant clams are thought to play various ecological roles in coral reef ecosystems, and giant clams increase the heterogeneity of reef topography and act as a reservoir for *zooxanthellae* [63]. But the presence of giant clams in Natuna was threatened due to the coastal community in Natuna usually consumes the giant clams meat, and the shell is used as decoration.

**Figure 6.** The average density of megabenthos composition (ind./140m²) in Natuna Island.

### 3.4. Coral reef health index

The coral reef health index (CRHI) is a value that reflects the current condition of live coral cover and its recovery potential and associated ecological functions. CRHI condition is more reflective of the actual condition of the reef because it involves several important parameters, including the percentage of live coral cover (LC), potential recovery consisting of percentage values of rubble (R) and fleshy seaweed (FS), and biomass of target reef fish (Herbivore and Carnivore) as an ecological function of the coral reef ecosystem. Apart from having a high live coral cover with high resilience/recovery potential, healthy coral reefs have high biomass of economically important coral reef fish.

Based on assessing the CRHI in Natuna Island had values were 2 to 6 (table 6). The average CRHI value was five with a moderate coral cover condition, high coral recovery rate, and low target fish biomass. The highest CRHI value was at 6, particularly at NTNC.146, NTNC.148, and NTNC.A research sites. The coral cover category has a high value at that site's location is supported by the high recovery category. However, this is not supported by the target fish biomass, which is low biomass, causing the CRHI value to be rated six or moderate.

Furthermore, nine stations have a CRHI value of 5, particularly NTNC.02, NTNC.03, NTNC.06, NTNC.145, NTNC.152, NTNC.159, NTNC.D, NTNC.E, and NTNC.F due to the live coral cover is in the medium category with high recovery rates and low target fish biomass. Furthermore, six stations have a CRHI value of 3, particularly NTNC.05, NTNC.07, NTNC.144, NTNC.157, NTNC.B, and NTNC.G live coral cover is in the low category with a high recovery rate and low target fish biomass. Low coral cover with a high recovery rate has the potential to improve the condition of coral reefs. The
high cover of fleshy seaweed will interfere with coral growth [24, 43]. Overall, the rate of coral recovery in the Natuna is in high condition, supported by the average value of coral Rubble (R) of 6.77 and fleshy seaweed (FS) of 1.84%. The higher condition of coral recovery indicates that if the coral reef ecosystem in Natuna Regency is under pressure from the environment, then the corals will recover well as disturbances disappear (which causes coral stress).

Table 6. The coral reef health index value in Natuna island.

| Location | Sites   | Coral cover class | Fish class | Reef Health Index |
|----------|---------|-------------------|------------|------------------|
| Eastern  | NTNC.144| Low               | Low        | 3                |
| Eastern  | NTNC.145| Medium            | Low        | 5                |
| Eastern  | NTNC.146| High              | Low        | 6                |
| Eastern  | NTNC.148| High              | Low        | 6                |
| Eastern  | NTNC.A  | High              | Low        | 6                |
| Eastern  | NTNC.B  | Low               | Low        | 3                |
| Northern | NTNC.06 | Medium            | Low        | 5                |
| Northern | NTNC.152| Medium            | Low        | 5                |
| Northern | NTNC.157| Low               | Low        | 3                |
| Northern | NTNC.159| Medium            | Low        | 5                |
| Northern | NTNC.F  | Medium            | Low        | 5                |
| Northern | NTNC.G  | Low               | Low        | 3                |
| Southern | NTNC.03 | Medium            | Low        | 5                |
| Southern | NTNC.05 | Low               | Low        | 3                |
| Southern | NTNC.07 | Low               | Low        | 3                |
| Southern | NTNC.161| Medium            | Low        | 2                |
| Southern | NTNC.E  | Medium            | Low        | 5                |
| Western  | NTNC.02 | Medium            | Low        | 5                |
| Western  | NTNC.D  | Medium            | Low        | 5                |

From the results of our research, it shows that the CRHI value in Natuna is in the medium category with a value of 5. The condition was due to the coral reefs in Natuna had more Rubble and DCA condition, which causes low coral cover at several observation sites' location. Previous studies on Natuna Island in 2018 showed the Natuna benthic community shifted over time from Poritidae and sand in 2004 to higher Acroporidae and rubble cover in 2007 and 2010. Then, in 2013, the site composition shifted to greater dominance to dead coral algae (DCA) [16]. Another pressure that causes the condition of the coral reef ecosystem in Natuna is included in the moderate category because in 2016, several coral reefs located in Natuna turned bleach due to rising sea surface temperatures [23]. This is due to the El Nino phenomenon which almost attacks most tropical coral reefs [64]. Two significant problems with the coral reef ecosystem in Natuna, both destructive fishing and rising sea surface temperatures in 2016, were the main impediments to the recovery of coral reefs in Natuna.

4. Conclusion
In general, the percentage of live coral cover in the condition of live coral cover is in the low to a high cover category, with cover values ranging from 10.60–36.87%. The average cover value of 24.53% is included in the medium cover category. The coral reefs’ overall health condition in Natuna shows an increase in live coral cover condition. The largest coral reef fish groups’ composition comes from the Herbivore fish group, consisting of the Acanthuridae, Scaridae, and Siganidae families. The abundance of target megabenthos in Natuna is in a low category. The utilization of the megabenthos biota in Natuna
is because it is included in the important economic biota groups such as clams, sea cucumbers, and even lobsters that are not found in the research station.

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