3 MATERIALS AND METHODS

3.1 Time and Location

The research was conducted in Pulau Tiga Subdistrict waters, Natuna District of Riau Kepulauan Province. This location is deliberately chosen with consideration that these areas have coral reef ecosystem and reef fish based on previous baseline study data (CRITC-LIPI 2004).

Sampling site was divided into two locations based on the differences in the characteristics of coral reef ecosystem conditions, representing the relatively disturbed and undisturbed area. Each site was divided into two different depth ranges, i.e. at a depth of 1 to 5 meters and 5 to 10 meters, making a total 4 sites (Fig. 2).

Site 1 and site 2 are as representation of relatively disturbed areas (each measured at 4 meters and 7 meters depth), and site 3 and site 4 are as
representation of relatively undisturbed areas (each measured at 5 meters and 7 meters depth) (Figure 2).

Positions of site were determined directly in the field and aided by using GPS (Global Positioning System) device.

Time of research implementation was carried out during five months from April to August 2009. This research includes: (1) preparation, survey and determining of study site; (2) primary data collection; (3) secondary data collection; (4) data analysis and report writing.

3.2 Material and Tools

Water quality measurements were conducted directly in the field (in-situ) to record temperature, salinity, water clearance, currents, and pH. These parameters were measured by using, subsequently, Hg thermometer, hand refractometers, secchi-disc, floating-droudge and pH-meter digital pen (AZ-8680). While for fish data acquisition and coral observations, I have involved the equipments as follows: global positioning system (GPS Garmin type map 76CS), SCUBA divers, roll-meter, large concrete nail, nylon string (monofilament) with 2 mm of diameter, hammer, buoys marking, boat, under water stationery (a slate and pencil) and A4 size paper (water resistant), laminating sheets of fish and coral identification, or a underwater camera or video (Hertex AQ836, shock + waterproof 10 m), squares transect (1 x 1) m² and ruler.

3.3 Data Collection

Data collection method that used in the research is survey method for collecting primary data, and desk study for secondary data, includes:

3.3.1 Primary Data
a) Physical-Chemical Parameters of Water

Measurement and taking of water sampling was done once during research at each locations and observation site. The variables was measured directly (in-situ) in field consist of surface temperature (°C), salinity (‰), depth (m), transparency (m), current velocity (cm/second) and degree of acidity (pH) using a
measuring instrument, respectively thermometer, hand refractometer, deep meter console, secchi-disc, floating-droudge and pH-tester.

b) Coral Reef

Coral reefs data were obtained from observation sites which have been determined by the repetition of three times.

The method used for determining coral reefs condition was Quadrat Method with quotation of observation area width of 10 m x 10 m. Transect made by the installation of nails, buoys and nylon rope in each corners to form square plot (rectangle). In each site, a plot created above and parallel to the stretch of line transect at 0-10 m, 30-40 m and 60-70 m as a part of recurrence of thrice (Figure 3). And then, at the plot was placed the square tool 1 m x 1 m parallel with observation area width. Observation was supported by taking underwater photos in accordance with the size of specified square. Results obtained of this method are relative percent coverage, diversity, evenness and dominance of genus and species of coral (English et al. 1994).

![Figure 3 Scheme of square transect plot placement in line intercept transect (English et al. 1994).](image)

c) Juvenile Coral Growth

Observation of corals were also measured to determine growth rate of new coral (recruitment) with calculating the spread of new coral colonies from species of Acropora spp. (diameters ranged from 1 to 30 cm) that measured directly, assisted with a ruler. Measurement of colony diameter was conducted by measuring length between the longest edge of the colony or the outer. Then, the relative percent coral coverage of juvenile coral colony was calculated.
d) Algae (DCA) Percent Cover

Algae coverage rate was determined by using the Quadrat Method (10 m x 10 m) that equal with determination of coral reef condition and conducted in line with coral reef observation in the same transect plot at each sites.

Algae cover observed is representation of relative percent cover of dead coral with algae (DCA) category as indication of algae domination on the coral substratum which compete with coral community in space.

e) Herbivorous Fish

Data taken of herbivorous fish was the fish from the family of Siganidae, Scaridae, and Acanthuridae, in accordance with Russ (1984). Herbivorous fish sampling was taken by using line intercept transect (LIT) method. With modification of the underwater fish visual census (UVC) method which adopted from English et al. (1994), fish was observed with masker-snorkel equipment over roll meter ribbon that has stretched along 70 meters parallel with coastline in each observation sites which has determined. Observation and withdrawal of fish data are presence and species amount of herbivorous fish carried out visually at 2.5 m radius on the left and right along a line transect. Therefore, observed area per transect was 70 m x 5 m = 350 m² (Figure 4).

Fish data was recorded into table column which has been prepared of A4 paper size (water-resistant) using pencil and slate. Fish data per each observation sites was taken once and assisted by using underwater camera or video.

Figure 4 Scheme of transect and underwater fish visual census of herbivorous fishes (English et al. 1994)
3.3.2 Secondary Data

Secondary data is supporting data obtained from desk study, journal, research report, and available data in government office to notice several affecting aspects of environment condition in study site. Data was taken like demography, fish resource, climate and weather condition, rainfall and summer, and socio-cultural and economic of community obtained from related institution and instance in Pulau Tiga Subdistrict and Natuna District.

3.4 Data Analysis

Survey data of coral reef, juvenile coral colony, algae cover and fish, afterward were analyzed qualitatively and quantitatively. Qualitative analysis carried out to estimate the prospect of coral reef resilience rate indirectly between two main variables in the research into this topic. Quantitative analysis conducted to know ecological condition of herbivorous fish, coral reef and algae base on calculation value or index number as follows:

a) Coral Reef

Data obtained based on quadrat method using underwater camera, and then coral percent cover was analyzed whether genus or species of coral and composition of other benthic substrates within the square transect (using Image-J analysis software program). Working principal of this method is converting the photo from result of underwater captured object with meter unit (as 1 m x 1 m quadrat size) into pixel unit, furthermore, performed digit calculation width of coral species or genus therewith other benthic substrates which is recognized (Appendix 15). Percent coral coverage can be calculated with the formula:

\[
\text{Percent Cover (\%)} = \frac{\text{Sum of intersep width per genus}}{\text{Sum of observation area width}} \times 100\%
\]

Data of coral cover condition obtained from equation above, afterward was categorized based on Gomez and Yap (1988) as presented in Table 1.
Table 1 Criteria of coral reef assessment based on percent coral coverage (Gomez & Yap 1988)

<table>
<thead>
<tr>
<th>Percent Coverage (%)</th>
<th>Assessment Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 – 100 %</td>
<td>Very Good</td>
</tr>
<tr>
<td>50 – 75 %</td>
<td>Good</td>
</tr>
<tr>
<td>25 – 50 %</td>
<td>Medium</td>
</tr>
<tr>
<td>0 – 25 %</td>
<td>Bad</td>
</tr>
</tbody>
</table>

Value of diversity, evenness and dominance indices were calculated according with equal formulation for herbivorous fish, Shannon’s diversity index (H’) (Shannon 1948; Zar 1996), Pielou’s evenness index (J’) (Pielou 1966; Zar 1996) and Simpson’s dominancy index (C) (Simpson 1949).

b) Growth of juvenile coral

Analysis used to assess juvenile coral growth by calculating the percentage of juvenile coral colony width with the formula equal to analysis of percent coral coverage.

c) Algae (DCA) Percent Cover

Analysis used to assess percent cover of algae from DCA category was equal with analysis of percent coral coverage. Analysis result obtained from the process of Image-J software program then was calculated to get the percent cover of algae by using the formula:

\[
\text{Percent Cover algae (\%) = \frac{\text{Sum of intercept width of DCA category}}{\text{Sum of observation area width}} \times 100\%}
\]

d) Herbivorous Fish

1. Presence relative frequency of herbivorous fish species

Presence relative frequency of herbivorous fish species per sites was expressed in percentage and calculated according to the formula:

\[
FRI\% = \frac{f_i}{n} \times 100
\]

Explanation:

\(f_i\) = number of herbivorous fish species of \(i\) presence found in each sites
\(n\) = total number of sites that observed
2. Density of herbivorous fish species or family

Density of herbivorous fish was expressed in the average of fish individual number per hectare according to species or family and calculated by using the formula:

\[ K_j \text{ or } K_s \ (\text{individual number/Ha}) = \left( \frac{\Sigma J_i}{n} \text{ or } \frac{\Sigma S_i}{n} \right) \times \frac{1}{0.035} \]

Explanation:
\[ \Sigma J_i \text{ or } \Sigma S_i = \text{number of individual fish by species } i \text{ or family } i \text{ found per sites (350 m}^2) \]
\[ n = \text{total number of sites that observed} \]

3. Diversity of herbivorous fish species

Condition of herbivorous fish species diversity was expressed in Shannon’s diversity index (Shannon 1948; Zar 1996) which calculated by using the formula:

\[ H' = -\sum_{i=1}^{n} p_i \ln p_i \]

Explanation:
\[ p_i = \frac{n_i}{N} \]
\[ n_i = \text{number of individual presence of species to-} i \]
\[ N = \text{total number of individual presence of all species} \]

4. Evenness of herbivorous fish species

Condition of individual balance in the overall herbivorous fish population was expressed in Pielou’s evenness index (Pielou 1996; Zar 1996) which calculated by the formula:

\[ E = \frac{H'}{H'_{\text{max}}} \]

Explanation:
\[ H'_{\text{max}} = \ln S \]
\[ S = \text{number of species} \]
5. Dominance of herbivorous fish species

Condition of dominance rate of one species to another species was expressed in Simpson’s dominance index (Simpson 1949) that calculated with the formula:

\[ C = \sum_{i=1}^{n} \left( \frac{n_i}{N} \right)^2 \]

Explanation:
- \( C \) = dominance index
- \( n_i \) = number of individual to-\( i \)
- \( N \) = total of individual number

e) Relationship between benthic structure and fish community structure

The results obtained based on analysis of community structure will be adjusted to the analysis of benthic structure of coral reefs to know relationship pattern and habitat grouping formed between the two communities, among others:

1. Benthic structure of coral reef ecosystem

To know the patterns of biota and substrates that form in the study sites, was used multivariate analysis such as principal component analysis (PCA), hierarchical analysis (HA) and multidimensional scale analysis (MDS) using the software program XLSTAT 2009 version of 2.01. Application some of the analysis are to see the grouping patterns formed by the features and similarity of benthic structure of coral reef ecosystems, thus creating information from interactions and associations in more detail.

2. Fish community structure (non-herbivorous and herbivorous reef fishes)

Analysis of fish community structure was conducted to know variations in patterns of distribution and composition of fish that formed at each study sites used the same multivariate analysis performed on the analysis of coral reefs benthic structure, using the software program XLSTAT 2009 version of 2.01.

f) Relationship between herbivorous fish density, coral reef and algae cover (DCA)

Analysis used to see the relationship between variables of herbivorous fish density, algae cover (DCA) and the condition of coral reefs (including the growth of juvenile coral) was a correlation analysis and multivariate analysis (PCA) for some
quantitative analysis results. Some of the analysis will be done by using the software program XLSTAT 2009 version of 2.01.

The results obtained by statistical analysis, furthermore will be represented as a description to estimate the prospects of ecological recovery rate of coral reef ecosystems indirectly by describing a causal relationship between conditions of herbivorous fish density and prospect for resilience of coral reef ecosystem.