The coral reef health at surrounding blue swimming crab fishery sites in Mandangin Island, East Java, Indonesia

I Ardiansah1,3*, S A Hidayat1,3, D F Mutmainah1,3, D M C B Siahaan1,3, M R Firdaus2,3, B Subhan1 and H Madduppa1,4

1 Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University, Dramaga, Bogor 16680, West Java, Indonesia
2 Department of Aquaculture, Faculty of Fisheries and Marine Science, IPB University 16680, Indonesia
3 Fisheries Diving Club, Faculty of Fisheries and Marine Science, IPB University 16680, Indonesia
4 Indonesia Blue Swimming Crab Management Association, Dukuh Kupang Timur XI 60225, Surabaya, Indonesia

*E-mail: irsyal_itk@apps.ipb.ac.id

Abstract. Blue swimming crab fishery activities very often do not put into account the environmental condition. Coral reef, as one of the blue swimming crab habitats, can be affected by these activities. This study aims to determine the effect of blue swimming crab fisheries on coral health in Mandangin Island, East Java, Indonesia. Data collection points are determined based on the results of interviews by participatory mapping. Water quality data includes visibility, temperature, salinity, pH, DO, current velocity. Collecting coral reef data were using Line Intercept Transect (LIT), while for reef fish Underwater Visual Census (UVC) were used. The coral health index was determined based on the relevance between benthic components and fish components. The average of Mandangin Island's water quality is in accordance with the quality standards of the Indonesian Minister of Environment Decree No.51 of 2004. Hard coral cover and fish biomass are classified as low, but the value of resilience is high. The coral reef health index value on Mandangin Island is 3.

Keywords: Blue swimming crab, Coral reef health, fishery activities, Mandangin Island, spatial distribution

1. Introduction

Coral reefs are a component of marine ecosystems that have high diversity and productivity [1]. Good and correct coral reef management must know the health condition of coral reefs and the condition of natural resources that can be utilized [2]. High productivity in coral reef ecosystems is a form of healthy ecosystems. Coral reef ecosystems have an important role, including as living places, spawning, and foraging for the biota of coral reef ecosystems [3]. The diversity of associated biota on the coast is one of the important resources used as a source of income for coastal communities, one of which is blue swimming crab [4].

The blue swimming crab (Portunus pelagicus) is a marine crab commonly found in Indonesian waters [5]. The blue swimming crabs that fishermen target are adult crabs that can be found in the spawning season, which lasts 3-4 months through the dry season [6]. The high price of blue swimming crab makes this marine commodity more focused on the export market so that it contributes to
Indonesia's economic growth [7]. The use of blue swimming crab as a commodity for coastal communities sometimes does not employ environmentally friendly fishing techniques. According to [8], the pressure to use fisheries resources to meet economic needs, consumption, and human activities in coastal areas can cause environmental degradation.

Mandangin Island is located close to the Madura Strait and is included in the Sampang Regency. It has a large coral reefs ecosystem that potential to be exploited by its inhabitants [9]. The people on this island mostly work as fishermen. They do not only catch fish as a fishery commodity but also take advantage of the abundance of blue swimming crab in the area. Fishery activities can cause changes in aquatic ecosystems and damage habitats [10]. The good potential of blue swimming crab on this island must be supported by the management of fishing techniques and monitoring of the waters to maintain the health of coral reefs. Therefore it is necessary to study the health of coral reefs by utilizing geospatial information. This study aims to determine the condition of water quality, coral health index and find out whether there is an impact of blue swimming crab fisheries on coral reef health.

2. Methodology

2.1. Study site and period

The study was conducted in Mandangin Island, Sampang Regency, East Java, which is included in the WPPNRI 721 (State Fisheries Management Area of the Republic of Indonesia) for the Java Sea (Figure 1). This research is divided into three stages. The first stage is to create a grid map of the research area. The grid map of the research area was carried out to determine the blue swimming crab fishing area through interviews with 40 fisherman respondents so that the observation points of coral reef health could be determined. The second stage is to conduct a field survey which was done on 13-15 November 2020. The third stage is to process and analyze survey data at the Faculty of Fisheries and Marine Sciences, IPB University.

![Figure 1. Grid map of the research area in the waters of Mandangin Island, East Java.](image-url)
2.2. **Survey methods**

Data of catchment areas were obtained from interviews with 40 respondents of blue swimming crab fishermen. The sample selection in this observation was using the purposive random sampling method. Interviews were conducted to point out where the blue swimming crabs were caught on the map that had been prepared previously and queried the most abundant season for blue swimming crab based on their experience. Then the data were analyzed and visualized through a geographic information system [11].

2.3. **Water quality measurements**

Water quality data collection is carried out at each observation point by taking six water quality parameters, including the following:

| Parameter     | Tools / methods          | Quality standards | Source |
|---------------|--------------------------|-------------------|--------|
| Visibility    | Secchi disk              | > 5 m             | [19]   |
| Temperature   | Thermometer              | 28 - 30 ℃         | [19]   |
| Current velocity | Floating road, stopwatch, compass aim | -                | -      |
| Salinity      | Refractometer            | 30 - 35           | [19]   |
| pH            | PH paper                 | 7 - 8.5           | [19]   |
| DO            | Winkler Titration        | > 5 mg / l        | [19]   |

The calculation of visibility parameters is carried out using the following formula:

\[
\text{visibility} = \frac{d_1 + d_2}{2}
\]  

Information:
- \(d_1\) = The distance between the water surface until the black and white colour disappears on the Secchi disk
- \(d_2\) = The distance between the water surface and Secchi disk look back (m)

The formula used in calculating dissolved oxygen using the Winkler Titration method is as follows:

\[
\text{Dissolved Oxygen} = \frac{V_p \times N_p \times 8 \times 1000 \times \frac{V_b}{V_s} \times 8}{V_s}
\]

Information:
- \(V_p\) = Titration volume
- \(N_p\) = Normality of titration
- \(V_b\) = The volume of the bottle
- \(V_s\) = Sample volume
- Titran = Sodium thiosulfate

2.4. **Coral reef observation**

Observation of coral reefs was carried out using the line intercept transect (LIT) method [12], which was modified by stretching 20 m transect three times with a gap of 5 m for each repetition at a depth of 3-5 m. The data taken was transitions, lifeforms, and genera of coral.

2.5. **Reef fish observation**

Observation of coral reef fish was carried out using underwater visual census (UVC) method using the same transect for taking coral reef data. The length of the transect used is 20 m long with three repetitions.
and 5 m intervals for each repetition and visibility of 2.5 m to the right and left to form a rectangle called a belt transect [12] at a depth of 3-5 m. Data taken were family, species, and estimation of size and number of fish.

2.6. Data analysis
According to [13], the coral reef health index value consists of two main components, namely the benthic component and the reef fish component. The benthic component consists of the current condition factor, which is calculated based on the live coral cover variable and the resilience level factor calculated based on the fleshy seaweed cover and the rubble cover. The analysis of the percentage of live coral cover is calculated based on the formula [12]:

\[
\text{% Coverage} = \frac{I_i}{L} \times 100\%
\]  

\(I_i\) = length of total reef substrate cover coral (cm)
\(L\) = Total length of the transect (cm)

Information:
\(\%\) Coverage = Percentage of substrate cover
\(I_i\) = length of total reef substrate cover coral (cm)
\(L\) = Total length of the transect (cm)

Table 2. Live coral cover categories.

| Category | Criteria            |
|----------|---------------------|
| Low      | Live coral cover <19%|
| Moderate | 19% ≤ live coral cover ≤ 35% |
| High     | Live coral cover > 35% |

Source: [13]

Meanwhile, the variables used to determine the level of coral reef resilience are based on [13] as follows:
1. Fleshy seaweed, namely macroalgae groups such as Sargassum, Padina, and other macroalgae. The higher the density of the fleshy seaweed cover, the lower the resilience level will be.
2. Rubble. With the increasing number of rubble, the lower the level of resilience is because rubble is not a good substrate for coral larvae to grow and develop.

The categories level of coral reef resilience detail shown in Table 3.

Table 3. Categories of coral reef resilience levels.

| Category | Criteria                                      |
|----------|-----------------------------------------------|
| Low      | Fleshy seaweed cover ≥ 3% Rubble > 60%         |
|          | Live coral cover ≤ 5%                          |
| High     | Fleshy seaweed cover <3% Rubble ≤ 60%          |
|          | Live coral cover > 5%                          |

Source: [13]

The variable used for the reef fish component was the total variable of economically important fish biomass, which included target fish species from 7 families, namely Scaridae, Siganidae, Acanthuridae, Serranidae, Lutjanidae, Lethrinidae, and Haemulidae. Fish biomass is obtained through the use of the weight-length relationship formula by preparing the constants “a” and “b” for each species, and then by substituting the length value in the formula, the weight data will be obtained. The values “a” and “b” can be found on the fishbase.com website [14].

\[
W = a \times L^b
\]
Fish stock in biomass units \((B)\) is the individual weight of target fish \((W)\) per area of the observation area. The detail about categories of total fish biomass is showed in Table 4. The formula for the individual weight of the economically important fish \((W)\) per area of observation \(m^2\).

\[
B = \frac{W_{\text{Total setiap famili}}}{350\ m^2}
\] (5)

**Table 4.** Categories of total fish biomass

| Category | Criteria |
|----------|----------|
| Low      | Total reef fish biomass <970 kg / ha |
| Moderate | 970 kg / ha ≤ Total reef fish biomass ≤ 1940 kg / ha |
| High     | Live coral cover > 1940 kg / ha |

Source: [3]

**Note:**
- Reef fish biomass 970 kg / ha = 33,950gr / 350 m²
- 1940 kg / ha = 67,900 gr / 350 m² of reef fish biomass
- Area per reef fish transect = 350 m²

Analysis of the coral reef health index refers to [13] by combining two main components to produce a coral reef health index value which can be seen in the following table:

**Table 5.** Coral reef health index.

| No. | Live coral cover | Recovery potential | Category reef fish | Coral Reef Health Index Value |
|-----|------------------|--------------------|--------------------|--------------------------------|
| 1.  | High             | High               | High               | 10                             |
| 2.  | Moderate         | High               | High               | 9                              |
| 3.  | High             | High               | Moderate           | 8                              |
| 4.  | High             | Low                | High               | 8                              |
| 5.  | Moderate         | High               | Moderate           | 7                              |
| 6.  | Low              | High               | High               | 7                              |
| 7.  | High             | High               | Low                | 6                              |
| 8.  | High             | Low                | Moderate           | 6                              |
| 9.  | Moderate         | Low                | High               | 6                              |
| 10. | Moderate         | High               | Low                | 5                              |
| 11. | Low              | High               | Moderate           | 5                              |
| 12. | Low              | Low                | High               | 5                              |
| 13. | Low              | Low                | Low                | 4                              |
| 14. | Moderate         | Low                | Moderate           | 4                              |
| 15. | Low              | High               | Low                | 3                              |
| 16. | Low              | Low                | Moderate           | 3                              |
| 17. | Moderate         | Low                | Low                | 2                              |
| 18. | Low              | Low                | Low                | 1                              |

Source: [13]

Further data analysis using linear regression was conducted to describe whether the blue swimming crab catchment area impacts coral reef health. According to [15], bivariate linear analysis can analyze one variable against another. Coral reef percentage and number of blue swimming crab around 2.5 kilometres near the study stations were calculated and tested for significance based on a bivariate linear regression model ANOVA.
3. Result and discussion

3.1. Blue swimming crab catchment area

A questionnaire survey was conducted on 40 blue swimming crab fishermen respondents on Mandangin Island so that the fishing grounds of the blue swimming crab can be identified, which can then be determined to modify the spatial scope of the study area (Figure 2 and Table 6). Blue swimming crab fishermen determine their fishing area based on the time when the most abundant crab can be caught.

The most abundant blue swimming crab population occurs in March – October. They are sailing around Mandangin with the closest radius of 100 meters from the coast, and the coral reef ecosystem yields a high enough crab. However, from November – February, the crab population decrease, therefore the fishermen will have to look for other areas to find crabs.

Figure 2. Study stations and the results of interviews with 40 fishermen respondents for blue swimming crab catchment areas.

| Station | Latitude   | Longitude  |
|---------|------------|------------|
| MDG01   | 7.31143755 | 113.1965451|
| MDG02   | 7.31684839 | 113.2102582|
| MDG03   | 7.31572545 | 113.2294544|
| MDG04   | 7.30946913 | 113.2285052|

The fisherman showed in the map the diverse locality of fishery activities for crab collection. Blue swimming crab fishery activities that are included in the coral reef observation points are found in 4 areas, namely West Mandangin Island (MDG01), East Mandangin Island (MDG02), Southeast Mandangin Island (MDG03), and South Mandangin Island (MDG04). Fishermen on East Mandangin Island tend to look for blue swimming crab by circling the island to a depth of ± 30m, with 27 fishermen
who pick up at that point. Meanwhile, in West Mandangin Island, 20 blue swimming crab fishing activities were pointed, meaning that there were 20 fishermen exploring the area. They also tend to sail around Suramadu, the bride that connects Madura and Java Islands, which is a fishing area outside Mandangin Island. In Southeast Mandangin Island, there are 27 fishermen. In the South Mandangin, there are nine fishermen. Apart from the coral reef observation station, fishermen on Mandangin Island also explore other areas with a total of 17 fishing activity points. Crab fishery activities can indirectly affect the coral reef ecosystem. Indirect effects that occur include oil spills from ships, anthropogenic activities, and the laying of ship anchors that hit coral reefs [16].

3.2. Water quality conditions

The results of measurements of six water quality parameters (temperature, current velocity, visibility, salinity, pH, and dissolved oxygen) are presented in table 10.

| Location          | Temperature (°C) | Current Velocity (m/s) | Visibility | Salinity (ppt) | pH | DO |
|-------------------|------------------|------------------------|------------|----------------|----|----|
| MDG01             | 29               | 0.158                  | 100%       | 34             | 8  | 5  |
| MDG02             | 30               | 0.031                  | 100%       | 33             | 7  | 5  |
| MDG03             | 30               | 0.033                  | 100%       | 33             | 7  | 6  |
| MDG04             | 29               | 0.115                  | 100%       | 32             | 8  | 7  |
| KepMen LH No. 51 of 2004 | 28-30       | > 5 m                  | 33-34      | 7-8.5          | > 5 | |

The temperature values at the four observation stations ranged from 29-30°C. The temperature that is suitable for the growth of blue swimming crab is ranged from 25 to 32°C [17]. The current velocity values ranged from 0.033-0.158 m/s. The depth of the waters on Mandangin Island ranges from 3-5 m with a visibility value of 100% because when the Secchi disk has reached the bottom, it is still clearly visible. The salinity values at the four observation stations ranged from 32-34 ppt, which is compatible to support marine life, more specifically blue swimming crab [18]. The pH and the dissolved oxygen (DO) values ranged from 7-8 and 5-7, respectively. Referring to [19], the value of water quality in the four observation stations of Mandangin Island can still support marine life.

3.3. Substrate cover of the bottom waters

The percentage of bottom substrate cover in Mandangin Island waters is presented in Figure 3. There are 6 (six) categories of basic substrate cover found, including Abiotic, Algae, Dead Coral with Algae, Hard Coral, Other Fauna and Soft. Coral.
In the waters of Mandangin Island, 12 genera of hard corals were found, namely Acropora, Coeloseris, Cyphastrea, Favites, Galaxea, Goniopora, Leptastrea, Montipora, Pavona, Pocillopora, Porites, and Turbinaria. The average substrate cover is dominated by abiotic, which includes sand and rubble, followed by Dead Coral with Algae (DCA). The highest percentage of abiotic was found at MDG01 station with a value of 71.87%. Meanwhile, the highest percentage of DCA was found at the MDG03 station of 43.95%. At the MDG02 station, the percentage of algae and coral reefs was almost the same, 13.87% and 14.30%, respectively, which indicates that the potential for spatial competition between algae and hard corals is high [20].

3.4. Fish composition
At four observation stations there were eight families of reef fish found in Mandangin Island waters (Figure 4). They were Caesionidae, Centriscidae, Chaetodontidae, Labridae, Mulidae, Nemipteridae, Pomacentridae, Scaridae, and Serranidae.

The coral fish families found in the waters of Mandangin Island are sequentially from the highest number, Labridae 355 individuals, Pomacentridae 304 individuals, Nemipteridae 121 individuals,
Chaetodontidae 21 individuals, Scaridae 10 individuals, Caesionidae 6 individuals, Centriscidae 6 individuals, Mulidae 5 individuals, and Serranidae 2 individuals. The Labridae and Pomacentridae families are included in the dominating family [21], which are often encountered in a coral reef ecosystem [22]. The Labridae and Pomacentridae families can be used for the assessment of coral conditions.

Analysis of reef fish biomass showed that among the eight families found, two were target fish. According to [13], fish families included in the target or economically important fish are Achanturidae, Haemulidae, Lutjanidae, Lethrinidae, Scaridae, Serranidae, and Siganidae. The highest target fish biomass was at the MDG04 station of 76,392 kg/ha. They were followed by the MDG03 station with the amount of 16,557 kg/ha. At MDG01 station and MDG02 station, the target fish biomass value is 0 kg/ha, and this is due to the absence of any target fish species.

3.5. Coral reef health components

The health of coral reefs in Indonesia is largely determined by two main components, namely the benthic and the reef fish components [13]. The benthic component is affected by the current condition of live coral cover and the level of resilience. Resilience is the ability to return to its original state after being disturbed or stressed [14]. Coral fish components also affect the health of coral reefs, as indicated by the high biomass of target fish. Target fish are economically important fish that can have a direct and significant effect on the resilience of coral reefs because of their function in the food web [13]. Target fish are also reef fish that have the highest biomass and abundance found in schooling [14].

The results of observing the health components of coral reefs at four observation stations are presented in the form of a spatial distribution profile (Figure 5).

![Figure 5. The spatial distribution of coral reef health components in the waters of Mandangin Island, East Java.](image-url)
The highest percentage of live coral cover was located at MDG04 station at 24.47%, followed by MDG02 and MDG03 stations with a value of 14.30% and 15.33%, respectively. The lowest value of live coral cover was at MDG01 station of 3.97%. Based on in-situ data collection, the diversity of coral reefs in the south of the island is the highest among other stations, but the east station of Mandangin Island has the highest percentage of live coral cover. The low live coral cover on Mandangin Island can be caused by the low substrate (base) suitable for the planula larvae to grow. The high presence of rubble and Dead Coral with Algae (DCA) on Mandangin Island means that planula larvae cannot find suitable substrates to grow. Planula larvae are the result of sexual reproduction in corals.

The map of the spatial distribution of reef health components (Figure 5) shows that of the four observation stations, three of them (MDG01, MDG02, and MDG03) have low values of live coral cover and reef fish biomass. Meanwhile, the MDG04 station has low reef fish biomass, but its live coral cover is in the medium category. Despite the low average value of live coral cover and fish biomass, the four stations still have a high level of resilience. According to [13], high resilience values indicate that the condition of coral reefs has a high chance of improving.

The coral reef health component is then analyzed by categorizing the relationship between benthic component values and reef fish component values to be used as an index value that has an ordinal scale so that it is easier to understand (Table 2). The results of the analysis of the coral reef health index value showed the same value at the four observation stations, namely 3 (Figure 5 and Table 8). The benthic category on the index with a value of 3 has a characteristic low coral cover and biomass category but has a high resilience category value [13].

As mentioned earlier, Mandangin Island fishermen catch blue swimming crab in areas of 100 m from the coastline in March – October, using traps and dredge net. Dredging is still commonly used by fishermen from West Mandangin Island to catch blue swimming crab around the Suramadu Bridge (outside the study area), while fishermen from East Mandangin Island only use traps to catch blue swimming crab. The blue swimming crab yields obtained by using dredge net were smaller than that of traps because dredge is a fishing tool that has a low level of selectivity [23].

Table 8. The health of coral reefs.

| Parameter                        | MDG01     | MDG02     | MDG03     | MDG04     |
|----------------------------------|-----------|-----------|-----------|-----------|
| Live coral cover category        | Low       | Low       | Low       | Low       |
| Resilience category              | High      | High      | High      | High      |
| Benthic Component Value          | 3         | 3         | 3         | 3         |
| Benthic Category                 | Low coral cover but has the potential to improve conditions | Low coral cover but has the potential to improve conditions | Low coral cover but has the potential to improve conditions | Low coral cover but has the potential to improve conditions |
| Biomass Category                 | Low       | Low       | Low       | Low       |
| Value of Fish Components         | 2         | 2         | 2         | 2         |
| Total value                      | 5         | 5         | 5         | 5         |
| Coral Reef Health Index Value    | 3         | 3         | 3         | 3         |
Table 9. Bivariate linear regression.

| Model                | Sum of Squares | df | Mean Square | F     | Sig.    |
|----------------------|----------------|----|-------------|-------|---------|
| Regression           | 27.888         | 1  | 27.888      | .305  | .636b   |
| Residual             | 183.122        | 2  | 91.561      |       |         |
| Total                | 211.009        | 3  |             |       |         |

a. Dependent Variable: Coral Reef Percentage  
b. Predictors: (Constant), Number of Blue Swimming Crab Catchment Area

Based on Table 9, The Sig value is higher than 0.05, which means that there was no significant effect from the number of blue swimming crab catchment areas on the percentage cover of coral reefs. High fishing activity can put pressure on coral reefs. Thus, differences in the percentage of coral reef cover at the study site can be affected by other pressures. Coral quality can be reduced not just from fishery activities but also by industrial and destructive tourism activities, natural conditions such as global warming, natural disasters [24], as well as high growth of macroalgae as coral’s competitor [25].

4. Conclusion  
The condition of Mandangin Island's coral reefs as a whole is in poor condition but has a high chance of recovering. The catchment area of the blue swimming crab does not have a significant effect on the health condition of the Mandangin Island coral. Further research on the number of fishing groups that carry out fishing in the area is needed to be able to trace how often fisheries interact with coral reefs.

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