Bioecology of coral reef in Panjang Island of Central Java Indonesia

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Abstract

Coral reefs currently are suffered from natural factors along with increasing anthropogenic activity. Panjang Island, a small reef island located in Jepara Regency, may also be experiencing such conditions. Therefore, this work was aimed to observe the condition of the coral cover of Panjang Island. Line intercept transect was applied to survey the coral cover and mortality index from fourteen stations. Insitu data consisted of the bottom substrate composition of the reefs and the physical parameters of the sea. The secondary data, i.e. coral reef area maps from 2001 to 2019 were taken from Landsat Image 7 and 8, data of wind were obtained from www.ogimet.com, while tidal data were collected from BMKG. The bathymetry was determined from the Geospatial Information Agency data, salinity global analysis forecast Phy 001.024 (CMEMS). Sea surface temperature (SST), and chlorophyll-a distribution were analyzed using ENVI software. The result showed that Panjang Island has a poor to the moderate condition of hard coral. Two out of six categories of abiotic and dead coral were found to be high. The mortality index of coral was in the high category (average 0.52). During research periods the sea waters were characterized by high sea surface temperature (29.34-30.94 °C), chlorophyll-a was also tended to be high (0-2.65 mg.m^{-3}), and an average of salinity was high 32 ‰. The weak currents came to all sides of the island, therefore the coral reef was not exposed to extreme currents. The waves came from the east, then the energy decreases after being blocked by coral reefs on the eastern side of the island, so that coral reefs in the northeast and south sides were safer to be exposed. The results suggest that hydrodynamic ecology directly or indirectly affected the percentage of coral cover and mortality index at the reefs of Panjang Island.

Keywords: *Physical parameters, Anthropogenic, Insitu, Line Intercept Transect, Manta Tow, Abiotic*

Introduction

Coral reefs are one of the oldest reef systems on earth (Pandolfi,2011). Hidaka (2016) stated that coral reefs comprise a symbiotic system that coexists among coral algae, ecosystems, landforms, and humans at various levels. As a marine ecosystem, coral reefs are very vulnerable to degradation (Pratchett *et al*., 2013; Vo *et al*., 2013). The degradation has resulted from a combination of natural and human activities (anthropogenic) factors. Pratchett *et al*. (2014) and Wisha *et al.* (2019) stated that coral reefs have a long history of degradation due to human activities. Research has been conducted on several factors that cause degradation of coral reefs, such as climate change (Baker *et al.,* 2008; Munday *et al.,* 2009; Ateweberhan *et al.,* 2013), pollution (Burke *et al*., 2011; Riegl and Purkis 2012), sedimentation (Wolanski *et al.,* 2004; Fabricius, 2005; Wooldridge, 2009), destructive fishing (Jackson *et al.,* 2001; Chabanet *et al*., 2016; Fox *et al.,* 2005; Hughes *et al.,* 2007; Caras and Pasternak, 2009), coral mining (Caras and Pasternak, 2009), marine tourism, and development coastal area (Yusuf, 2007; Mimura, 2008; Vo *et al*., 2013). Research on the ecological conditions of coral reef ecosystems has been carried out in several previous studies. Perera-Valderrama *et al*. (2016) conducted an assessment of the condition of coral reef ecosystems in two marine conservation areas using indicators of ecology, mortality, and disease. Chabanet *et al*. (2016) monitored the condition of coral reefs with time-series data in water areas that are free of pressure from fishery activities. Korpinen and Andersen (2017), Crain *et al. (*2008); and Magris *et al*. (2018) conducted studies on the pressure and

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cumulative impacts of human activities on coral reef ecosystems. Borja *et al*. (2012) conducted a study on the integration of the impact of human pressure and environmental parameters in a time series. Fabinyi (2008) conducted a study of diving tourism and fisheries in conservation areas.

Bioecology is the study of the interaction of the living organism with its environment (Rifa'i, 2004). Bioecological factors are complex and do not act individually but are a unity that interacts and works together simultaneously. They are also dynamic because they change over time (Tjitrosomo *et al*., 2010). Tjahyo *et al*. (2000) stated that bioecology concerns biological and ecological aspects. Bioecological research in many areas has been carried out by several previous researchers. Suharti *et al. (*2018) have examined the Chaetodontidae species composition, distribution, and their bioecology in Togean Islands National Park, Central Sulawesi. Muhammad *et al. (*2013) have examined the bio-ecological application of macrobenthos as an indicator of pond fertility levels. Ardli *et al. (*2015) examined changes in mangrove bioecology in mangrove restoration in Segara Anakan, Cilacap.

Coral is very sensitive to changes in environmental factors, especially Sea Surface Temperature (SST) (Corvianawatie and Abrar, 2018). Water quality conditions that can not be tolerated by corals are thought to be able to inhibit the rate of growth and the process of resilience (Osborne *et al.*, 2011; Corvianawatie and Abrar, 2018). Giyanto *et al. (*2017) stated that in the ideal ecology of coral reef, SST is in the range of 27-29°C which is ideal for the growth and development of the corals, and the relationship with chlorophyll-a concentration. Nybakken (1992) said that chlorophyll-a is one indicator to determine the level of seawater quality. Current and wave are hydrophysical ecology factors that interact and control coral growth (Dollar, 1982; Halid *et al*., 2016). Understanding the biology of corals and different sources of disturbance were needed to understand coral reefs resilience (Osborne *et al.*, 2011). Panjang Island is a small island surrounded by coral reefs (Munasik *et al*., 2020). Preliminary identification of bioecology of coral reef in Panjang Island has been conducted by Suryono *et al. (*2017), and reported that the biology aspect of corals in terms of coral cover was in the medium category, and suspected that due to many stressors that caused degradation of coral reefs. The study was conducted to determine the coral reef condition according to the percentage of live coral cover, mortality index (MI), and its relation to hydrodynamic ecological factors which is important information for the conservation of the reefs.

Material and Methods

The study was conducted in the waters of Panjang Island, Java Sea, about 1,5 nautical miles or 2,8 Km from the mainland of Jepara (Suraji *et al.*, 2015; Munasik *et al.*, 2020). Panjang Island is located on the north coast of Central Java in the position of 110°37'30"-110°38'0" East Longitude and 6°34'15"-6°34'45" South Latitude. The island is highly influenced by the Northeast Monsoon from November to February, which brings heavy rainfall and storms (Wong 1993). During that time, ecological pressures are increased. The study used a survey research method (Nazir, 2005). Samples were taken from fourteen (14) sampling stations. Coral reefs ecosystem was monitored using the line intercept transect (LIT) method (English *et al*., 1997). The percent cover of the benthic lifeform was analyzed using a lifeform-based software program with UNEP standards that were applied in ASEAN-Australia (Rahmat *et al.*, 2001). The coral mortality was calculated using the formula from Gomez *et al*. (1994). Mortality Index (MI) is divided into four categories, namely: MI value ranges from 0–0.249= low; 0.25–0.499= medium; 0.50–0.749= high; and 0.75–1= very high category.

The secondary data, *i.e.* coral reef area maps from 2001 to 2019 were taken from Landsat Image 7 and 8, data of wind were obtained from *www.ogimet.com*, while tidal data were collected from BMKG. The bathymetry was determined from the Geospatial Information Agency data, salinity global analysis forecast Phy 001.024 (CMEMS). Sea surface temperature (SST), and chlorophyll-a distribution were analyzed using ENVI software. The change of coral reef area was built and overlayed based on basic data of Landsat 7 and 8 satellite imagery of 2001, 2005, 2010, 2015, and 2019. The GIS method is employed to finalized the changes map of the coral reef area from 2001 to 2019 and was done according to the method developed by Green *et al*. (2000), Arsjad *et al.* (2005), and Siregar (2010).

Ground checks were carried out using the manta tow method to measure the distribution of coral reefs (Kenchington, 1978; Moran *et al.*, 1990; English *et al*., 1997). Furthermore, the map of the area of coral reefs in the year of observation was overlaid according to Adininggar *et al. (*2016), and Titi and Zainuddin (2017) to determine the changes in coral reefs areas. Waves were measured using the Acoustic Doppler Current Profiler (ADCP) instrument and the values were analyzed using the mathematical calculation method (Apuke, 2017). High significant wave (Hs) and significant period (Ts) obtained from wind data conversion to Hs value and Ts with DNS method (Sugianto *et al*.,2017). Currents were obtained by using ACDP equipment (Yuningsih and

Achmad, 2011), then analyzed by quantitative method (Amirullah *et al*., 2014). The results of current and wave modeling were then generating, inputted by processing data using excel, entered into ArcGIS together with the results map of the change coral reef area 2001-2019, to obtain a map of the change coral reef area concerning the direction and velocity of the current, also the direction and wave height.

Result and Discussion

Biology of coral reefs

The percentage of live coral cover from 14 stations showed a range between 5-40% (Table 1). Abiotic, dead coral (DC), and hard coral (HC) substrates were three out of six categories found with high percentages. The substrate categories of sponges/others (OT), soft coral (SC), and macroalgae (MA) found in a low percentage. The abiotic substrate was found to dominate in almost every station. The most common type of abiotic substrate in Panjang island is rubble (RB). Overall, the percentage of hard coral (HC) cover was not dominant. However, when compared to the percentage of macroalgae and sponge/other (OT) which are competitors of corals, then the percentage of hard coral (HC) still dominates in coral reefs of the waters of Panjang Island.

The result showed that hard coral (HC) cover was in the medium category indicated that a poor to the moderate condition of hard coral (HC). There was a high percentage of dead coral cover (DC) and abiotic substrate compared to the percentage of hard coral cover (HC). Two factors that may cause damage to coral reefs in Panjang Island are natural and anthropogenic. The dominant factor that occurred is presumed due to human activity impact (anthropogenic) compared to natural factors (Toruan *et al*., 2013; Suryono *et al.*, 2017; Lutfi *et al.,* 2019a; 2019b).

The value of the mortality index (IM) of coral reefs in Panjang Island is shown in Figure 1. The average mortality index is in the high category (0,52). Based on substrate cover percentage and index mortality, it is found that the coral reef in Station 1 is the worst with a mortality Index (MI) is 0.80. The low mortality index of coral reefs was found at Stations 4, 14, and 5 (0.33, 0.40, and 0.42, respectively).

Table 1. Percentage cover of the substrate category of coral reef in Panjang Island of Central Java Indonesia

Station	(%) Hard Coral (HC)	(%) Dead Coral (DC)	(%) Soft Coral (SC)	(%) Abiotic	(%) Macro Algae (MA)	(%) Sponge/ Others (OT)
1	10	40	0	39.95	10	0.05
2	20	20	0	49.9	10	0.10
3	20	20	25	29.27	5	0.73
4	20	10	20	49.47	0	0.53
5	40	30	5	14.8	10	0.20
6	40	40	0	19.27	0	0.73
7	30	20	10	35.0	5	0.36
8	30	30	20	19.55	0	0.45
9	20	20	10	39.75	10	0.25
10	20	30	10	29.7	10	0.30
11	5	10	0	84.78	0	0.22
12	30	40	0	19.34	10	0.66
13	20	30	9.59	30	10	0.41
14	30	20	10	30	9.41	0.59

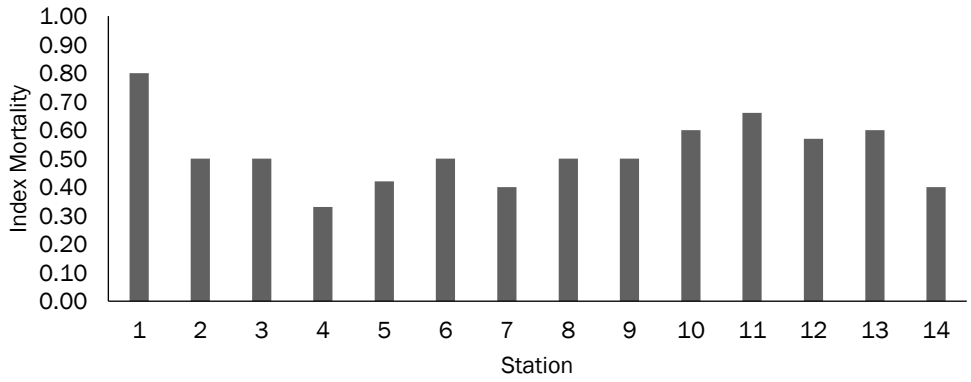

Figure 1. Mortality Index (MI) of coral reef in Panjang Island of Central Java Indonesia

However, when considered the percentage of live coral cover, the coral reef in Station 5 is in better condition compared to other stations. The coral mortality that occurred at all stations was presumed due to pressure that occurs related to IUU (Illegal, Unreported, Unregulated) fishing and destructive fishing activities. The IUU Fishing activity is activity fisheries that are illegal, unreported, and not following the regulations (Arsyad *et al.*, 2014). The waters of Panjang island are one out of three fishing grounds for the fisherman in the Jepara Area (Kunarso *et al.*, 2016).

The most dominant natural factor that influences the degradation of coral reefs in Panjang Island was sedimentation, sea surface temperature (SST), and salinity. The two most influential anthropogenic factors were destructive fishing (Ministry of Marine Affairs and Fisheries, 2006) and the increase in tourism activities (Badan Pusat Statistik, 2017). Fishing activities are carried out in destructive ways, for example by using toxic cyanide, electricity, and non-environmentally friendly fishing gear such as a net or local name *i.e. Cantrang* net that is still found operated in Panjang Island (Personal inspection). In addition, fishing activities by stepping on coral reefs are still happen (trampling and gleaning) (Suryono *et al*., 2017). Coral mining by coastal community for building materials is found to have accelerated the process of coral reef degradation in Panjang Island (Bappeda Kabupaten Jepara, 2003; Badan Lingkungan Hidup dan Energi Kabupaten Jepara, 2007). The mining of corals causes increasing water turbidity and will inhibit coral growth, even the death of coral reefs (Ariani, 2006). If activities of coral mining are continued, it is not only threatening the existence of the coral reef ecosystem but also inhibits the natural recovery process (Edrus *et al.,* 2010). The damage of the coral reefs ecosystem is a threat to the survival of marine life and it takes a very long time to recover (Nugraha, 2019).

Ecology of coral reefs

The results of sea surface temperature (SST) and chlorophyll-a data are presented in Table 2, and the distribution of salinity can be seen in Figure 2. During the research period, seawater was characterized by high SST, high chlorophyll-a production. and high salinity (32 ‰)

Table 2. Distribution of sea surface temperature (SST) and chlorophyll-*a* of coral reef in Panjang Island of Central Java Indonesia In 2020

No	Month	Sea surface temperature (SST) (°C)	Chlorophyll-*a* (mg.m^{-3})
1	January	30.81	1.82
2	February	30.94	0.54
3	March	29.91	0.73
4	April	30.77	0.68
5	May	31.07	1.44
6	June	30.35	1.64
7	July	29,69	2.01
8	August	29.34	1.29
9	September	30.03	2.66
10	October	30.71	0.56
11	November	30.81	0
12	December	31.52	0.95
	Average	30.19	1.65

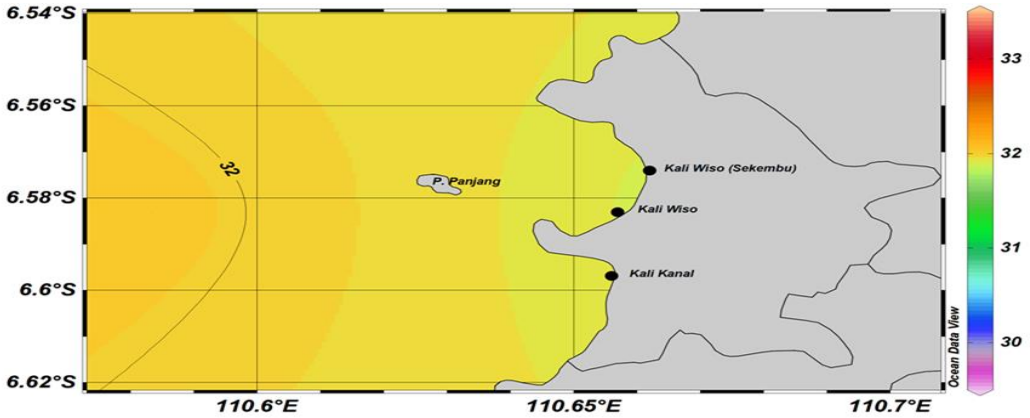

Figure 2. Distribution of salinity of coral reef in Panjang Island of Central Java Indonesia In 2020

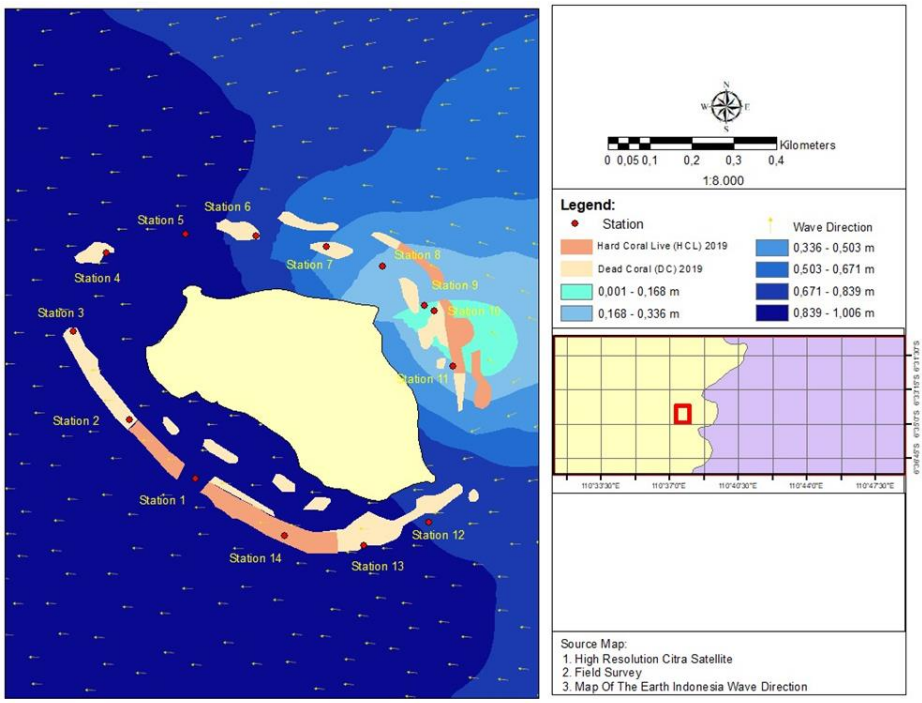

Figure 3. The change of coral reefs area and wave hydrodynamic of coral reef in Panjang Island of Central Java Indonesia In 2019

Overlay results of coral reef area changes from 2001 to 2019 and the hydrodynamics of waves and currents are presented in Figures 3 and 4. The coral reefs in Panjang Island had undergone extensive changes, decreased to 45.742%, with a change rate of 0.302 Ha.y^{-1} from 2001-2019. In 2001, the distribution of live coral reefs was seen on the northeast, east, south, and west sides of Panjang Island, then reduced their area, until they were left on the northeast and south sides of the island in 2019.

The lowest wave height is 0.001-0.168 m, and the highest wave is 0.84-1.01 m. The waves come from the east then the energy decreases after being blocked by coral reefs on the eastern side of the island, so that coral reefs on the south side of the island are safer from wave exposure (Figure 3.). The lowest currents speed ranges were 0.00-0.16 m.s^{-1}, while the highest currents speed ranges were 0.00–1.00 m.s^{-1}.The currents come from all directions of the island so the coral reef of Panjang Island was exposed to currents. Unfortunately, the speed of the currents is weak, so that the coral reefs are not extremely exposed to the currents (Figure 4.).

Nybakken (1992) states that chlorophyll-a is an indicator to determine the level of seawater fertility. Vollenweider *et al*. (1998) stated that the chlorophyll-a concentration ≤5 mg.m^{-3} was categorized as mesotrophic and eutrophic waters. The high distribution of chlorophyll-a concentrations in Panjang Island is due to a large supply of nutrients that came from the run-off of the mainland (Hartuti *et al*., 2004). Chlorophyll-a can also be used as an indication of coral reef health (Limbu and Kyewalyanga, 2015). Chlorophyll-a concentration was above 0.2mg.m^{-3} showed the presence of sufficient planktonic to sustain the fishery commercial (Widodo, 1999).

Sea surface temperature (SST) is another important factor in the distribution of coral reefs. An ideal temperature for the coral reef was in the range of 27-29°C (Siburian and Mega, 2019). Coral reefs grow and develop optimally in waters with an average annual temperature of 23-25°C Giyanto *et al.,* (2017) mentioned that the ideal temperature for coral reef growth is in the range of 27-29 °C, this warm temperature has a relationship with the chlorophyll-a concentration. The average water temperature of coral reefs in the optimum range for stony coral growth is 28-29°C (Supriharyono, 2007).

The salinity of the waters of Panjang Island was lower than the seawater standard for marine biota, which is 33-34‰ (KLH, 2004). Coral reefs can only live in the waters with a normal salinity of 32-35‰ (Swart, 2013). Coral reefs do not live in waters that receive regular freshwater runoff from large rivers, which leads to low salinity (Anonymous, 2019). These factors play an important role in the continuity of the photosynthetic process by zooxanthellae found in

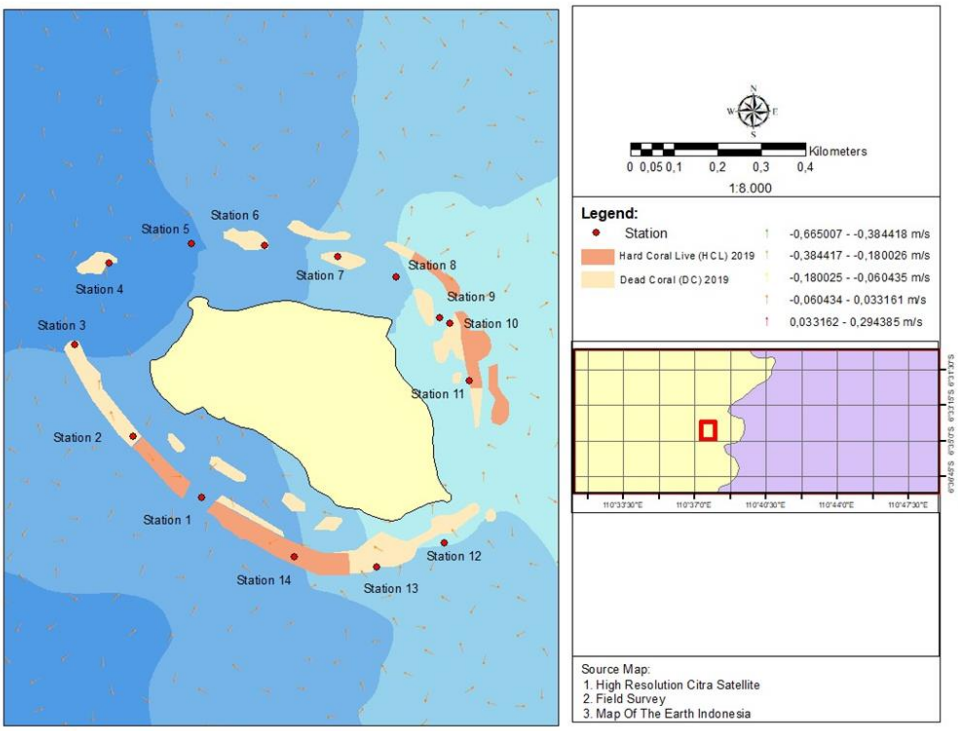

Figure 4. The change of coral reef area and current hydrodynamic of coral reef in Panjang Island of Central Java Indonesia In 2019

coral tissue. The environmental requirements must be met for the optimal growth and development of coral reefs. Change of ecology of coral reefs either directly or indirectly can affect coral reef conditions. Pollution from the mainland will instantly change the quality of water so that it can damage the reef coral (Wibawa and Luthfi, 2017).

The level of exposure to coral reefs by waves strength is quite high, this is presumed as one factor that causing the damage and decline of hard coral (HC) coverage in Panjang Island. Rachmawati *et al*., (2018) reported wave heights above 1 m that damage to coral reefs in the waters of Panjang Island, especially during the rainy season (December-March) as the waters of Panjang Island is part of the northern Java sea, therefore influenced by western monsoons season from South China Sea (Susiati *et al*., 2011; Suryono *et al.,* 2017). Purwanto *et al.* (2020) reported a wave height of 0.251-0.792 m with a wave period of 3.663-4.717 sec. in Lirang Island, Southwest Maluku. Supiyati (2008) stated that in the east monsoon the dominant waves occurred with a height of 1.0-3.0 m. Kurniawan *et al*. (2011) also reported that the wave height reaches 1.25 - 2.5 m. Widhiarno and Yati (2016) conducted wave forecasting in Indramayu and reported that the value (Hs) was as high as 0.4-0.5 m. Arianti *et al*. (2017), reported significant wave height occurred in July, from 0.21 m to 1.47 m in Palu Bay waters. Hidayat *et al. (*2013) reported that the waves on Parang Island Karimunjawa have a transitional wave type (medium) with a significant height of 0.231 m and wave period of 1,578 seconds. All the study results mentioned above confirmed that wave height and wave periods affect the structure and growth of coral reefs. The current was another factor that influenced coral reef growth (Adjeroud, 1997; Richards *et al.,* 2012; Wenger *et al.*, 2016; Guan *et al.*, 2015). Current hydrodynamic was one of the physical oceanography factors that can affect coral reefs health (Monismith, 2007) so that the distributions of coral reefs were influenced by the current (Halid *et al*., 2016). Currents affected the growth of coral reefs (Dollar, 1982), and are significant factors that determine the construction of the coral reef ecosystem (Halid *et al*., 2016; Giyanto *et al*., 2017). Currents are sources of disturbance that provide risks to coral reef resilience (Osborne *et al.*, 2011). Currents are needed to provide water flow which carries food and oxygen intake and protect coral reef from the influence of sedimentation. Current carry new plankton to feed coral polyps (Nybakken, 1992), and cleaning coral reef structure from silt (Burke, 2011). Nurulita *et al.* (2018) investigated the movement of the coral larva (planula) Acropora in the Islands of Seribu, the Island of Biawak, and Islands of Karimunjawa based on oceanographic conditions, and showed that the current pattern and velocity was affected by tidal conditions. Apart from that current effect on structure

and growth of a coral reef, the distribution and attachment of coral larvae were driven by current, as has been reported by Munasik *et al. (*2006), on Study the role of Current on coral Planula in Panjang Island Jepara. So that the currents are a factor that plays a role in the recruitment process in coral reef resilience (Adjeroud *et al*., 2016; Rogers, 2013; Markey *et al*.,2016; Nurita *et al*.,2018)

Conclusion

The bottom substrate cover in Panjang Island waters has poor to the moderate condition of hard coral (HC). Abiotic, dead coral (DC), and hard coral (HC) bottom substrates were three of the six categories found with high percentages. The abiotic substrate was dominated in almost every station. The mortality index of coral reefs is in the medium category with an average of 0.52. During periods of research, Panjang Island waters were characterized by higher sea surface temperature (SSTs) i.e. 29.34-3094 °C and the chlorophyll-*a* were between 0 mg.m^{-3} to 2.65 mg.m^{-3}, and an average of salinity was 32 ‰. The direction of currents come from all side of the island so that all sides of the coral reef are exposed to currents. However, the speed of the currents is weak, so that the coral reefs are not extremely exposed by the strong currents. The direction of waves comes from the east of the island then the energy decreases after being blocked by coral reefs on the eastern side of the island, so that coral reefs in the northeast and south sides of the island are safer to be exposed. Hydrodynamic ecology directly or indirectly affects the biology of coral reefs in the waters of Panjang Island, Java Sea.

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