JURNAL PERIKANAN DAN KELAUTAN
Volume 28 No. 1, February 2023: 116-124

e-issn : 2721-8902
p-issn : 0853-7607

Coral Reef Status after the 2018 Sunda Strait Tsunami Using the CPCe Program: A Case Study of Tanjung Lesung Banten

Status Terumbu Karang Pasca Tsunami Selat Sunda 2018 Menggunakan Program CPCe: Studi Kasus Tanjung Lesung Banten

Luthfi Anzani[1*], La Ode Alam Minsaris[1,2], Alya Dina Wilujeung[1], Cakra Rahardjo[1], La Ode Fajar Hasidu[3], Fajar Nugroho[4]

[1]*Department of Marine Information System, Indonesia University of Education*
Jl. Dr. Setiabudi No.229, Bandung, Indonesia
[2]*Department of Coastal Zone Development, Ministry of Marine and Fisheries Affairs*
Jl.Medan Merdeka Timur No. 16 Jakarta 10041, Indonesia
[3]*Department of Marine Science, Faculty of Agriculture, Fisheries, and Animal Husbandry, Universitas Sembilanbelas November Kolaka, Jl. Jend. Sudirman, Buton Tengah, 93762 Indonesia*
[4]*Marine and Fisheries Officers Training Center, Agency of Research and Human Resources of Marine and Fisheries, Indonesia Ministry of Marine and Fisheries Affairs*
Jln Medan Merdeka Timur No. 16 Jakarta 10041, Indonesia
**email: uthfi_anzani@upi.edu*

Received
2 January 2023

Accepted
8 February 2023

Abstract

Tsunami that swept the Tanjung Lesung coast in 2018 caused Anak Krakatau to collapse in Sunda Strait which hit the coastal areas of Banten and Lampung. Tanjung Lesung is one of the worst areas affected. Tsunami in Tanjung Lesung has taken lives, damaged infrastructure, and caused terrible natural damage. One of the damages affecting residents' lives in the Tanjung Lesung coastal community is exposure to the marine ecosystem. The main ecosystem that has the highest productivity level is the coral reef. Coral biota is the main benthic biota of reefs that are directly affected by earthquakes and tsunamis. However, until now there has been no data on the status of coral reefs after the 2018 Sunda Strait tsunami. Therefore, researchers feel the urgency of this research is high enough to determine the condition of coral reefs after the Sunda Strait tsunami in Tanjung Lesung. There are 3 research stations for data collection before the tsunami, and we conduct research in those 3 stations again after the tsunami. Then we added 3 research stations again, so there are 6 research stations. Observation of coral reefs uses the Line Intercept Transect (LIT) method. The line transect is made by stretching a roll meter with a scale parallel to the coastline along 25 meters with three replications with an interval of about 0-5 meters between replications so the total observed transect was 75 meters. The deterioration of coral reef conditions at three research stations (1-3) proved that the tsunami waves affected the damage to coral reefs. This has an impact on the diversity of coral reef species inhabitants that have decreased. Disturbance form coral-damaged structure and composition changes of the base substrate as habitat can have an impact on reef fish and coral reef inhabitants. So that this research is expected to be a reference for policymakers in determining rehabilitation steps for areas affected by the 2018 Sunda Strait tsunami.

Keywords: Coral Reef, LIT, Sunda Strait Tsunami 2018, Tanjung Lesung

Abstrak

Peristiwa bencana alam tsunami yang menyapu pesisir Tanjung Lesung tahun 2018 lalu disebabkan oleh runtuhan Anak Krakatau di Selat Sunda yang

menghantam daerah pesisir Banten dan Lampung. Tanjung Lesung merupakan salah satu daerah terparah yang terdampak tsunami. Salah satu kerusakan yang berpengaruh pada kehidupan penduduk masyarakat pesisir Tanjung Lesung adalah terpaparnya ekosistem laut oleh bencana ini. Ekosistem utama yang memiliki tingkat produktivitas tertinggi adalah terumbu karang. Biota karang adalah biota bentik utama terumbu yang terpengaruh langsung akibat peristiwa gempa dan tsunami. Namun, sampai sekarang belum ada data mengenai status terumbu karang pasca kejadian tsunami Selat Sunda tahun 2018. Sehingga peneliti merasa urgensi penelitian ini cukup tinggi untuk mengetahui kondisi terumbu karang pasca tsunami Selat Sunda di Tanjung Lesung. Data identifikasi karang diperoleh dengan mengambil foto transek di setiap meternya menggunakan bingkai dengan ukuran 58 cm × 44 cm dengan panjang line transek sepanjang 50 meter. Foto – foto tersebut kemudian dipilah dan diidentifikasi menggunakan software CPCe (*Coral Point Count with Excel Extensions*). Hasil penelitian menunjukkan bahwa tutupan terumbu karang di daerah yang terdampak tsunami 2018 mengalami perubahan yang cukup signifikan dari keadaan sebelumnya namun, hitungan total masih menunjukan kondisi yang cukup baik dimana karang massive yang bertahan melawan tsunami sedangkan dari genus Acropora bercabang mengalami penurunan signifikan setelah terjangan tsunami. Sehingga penelitian ini diharapkan dapat menjadi acuan bagi pemangku kebijakan dalam penentuan langkah rehabilitasi bagi kawasan yang terdampak tsunami Selat Sunda 2018.

Kata kunci : CPCe, Tanjung Lesung, Terumbu karang, Tsunami Selat Sunda

1. Introduction

Tanjung Lesung is a coastal area located in Tanjungjaya Village, Panimbang District, Pandeglang Regency, and has long been known as a tourism area because it has white sand and beautiful panoramas, both on land and underwater (Kartini *et al.* 2017). However, on 22 December 2018, a tsunami disaster occurred in Sunda Strait, a strait that separates Java and Sumatra Island, Indonesia. This tsunami hit the coastal areas of these two islands, especially the Banten and Lampung provinces. Tsunamis are usually caused by seabed tectonic earthquakes, but in this case, they originated from the Anak Krakatau seamount collapsed material, one of the most active seamounts in Indonesia. The well-known "Parent" of Anak Krakatau seamount, the Krakatoa seamount ever erupted on 26-27 August 1883, its greatest eruption caused a mega-tsunami that produced an altitude of up to 42 m above sea level. The legendary Krakatoa eruption caused extreme climate change in parts of the world due to the enormous explosion. From that disaster, the Krakatoa seamount disappeared, then a new seamount appeared called "the child of Krakatoa seamount" Anak Gunung Krakatau (Kartini *et al*. 2017).

Not much different from its "parent", Anak Krakatau seamount is an active volcano until in 2018 it collapsed material that caused the tsunami. One of the worst affected areas by this tsunami is Tanjung Lesung, a Special Economic Zone (SEZ), one of 10 National Priority Tourism Destinations, and includes a special conservation area (Kartini *et al.* 2017). Geographically, Tanjung Lesung's position directly faces the Sunda Strait and Anak Krakatau Seamount. That is the reason why Tanjung Lesung is one of the worst affected areas. This tsunami caused the loss of hundreds of lives, damaged infrastructure, and damaged ecosystems.

The ecosystem that is vulnerable to tsunami exposure is the coral reef ecosystem because coral reefs were exposed for a long time to the water surface and were stranded due to tsunami impact (Wilkinson *et al.*, 2006). Damage to coral reef ecosystems includes several broken coral colonies, overturned and some died because they were covered by sediment. The most damaged coral groups found were hard coral. In general, damaged coral reefs occur in not dense layers, easily loose, and on ocean slopes (Purbani *et al*. 2014). Damage to coral reefs from the Sunda Strait tsunami has been uneven, depending on location and environmental conditions such as coastal bathymetry and land damage. In addition, coral reef damage can result from physical impacts from washed-off land debris (Wilkinson *et al.*, 2006).

Based on Wilkinson *et al.* (2005) coral reefs have a very important role in the lives of coastal communities. Coral reef in tropical country like Indonesia has high biodiversity, both coral diversity which are the main constituents of the ecosystem, and other marine creature diversity. Various types of fish, mollusks, crustaceans, and echinoderms that have high economic value are associated with this ecosystem. Economical marine biota is the main target for fishermen who have become fishermen's livelihoods. The damaged coral reef will follow by a declining population of other marine biotas, especially those with a strong association with coral reefs.

This study compares data before and after the tsunami. We took data before the tsunami in 2016 when we studied in IPB University's postgraduate marine science study program. Then data after the tsunami was taken in 2020 through research grants from the Indonesian University of Education. The data before the tsunami was then compared with the current data research that we conduct in 2020 to see the changes and differences. Observations of condition, diversity, and mortality were carried out to see if there were differences in composition before and after the 2018 Sunda Strait tsunami. Up Until now, there has been no data on coral reefs' status before and after Sunda Strait Tsunami in 2018. So this research is expected to be used as a basis for future rehabilitation decisions

2. Material and Method

2.1. Time and Location of Research

This research consists of two processes; primary data collection and secondary data processing. Primary data is form coral reef ecosystems data collected on 13-14 September 2020, which becomes after tsunami data. Whereas secondary data is from data on 29-30 January 2016. Secondary data was used as initial information and comparative data before the tsunami. Meanwhile, primary data is useful for describing the impact of the tsunami that occurred on coral reef ecosystems.

Both data were taken at the same location, Tanjung Lesung coastal area, Pandeglang Regency, Banten province. The sampling location points were at the same locations where data was collected before the 2018 tsunami occurred. There are 3 research stations for data collection before the tsunami, and we conduct research in that 3 stations again after the tsunami. Then we added 3 research stations again, so there are 6 research stations (Figure 1). This is expected to be informed as well as additional data to determine conditions in a wider area.

Figure 1. Coral reef ecosystem observation map.

Note: Station 1,2,3 are data collection points before and after the tsunami in 2018. Stations 4,5,6 are additional points observed after Tsunami.

2.2. Data Collection and Tabulation

2.2.1. Water Quality

Water quality intake is carried out at all stations. This is to monitor Tanjung Lesung's water condition and whether it good category for coral reefs to survive. Water quality variables measured were temperature, salinity, pH, and clarity.

2.2.2. Coral Reef

Observation of coral reefs uses the Line Intercept Transect (LIT) method. The line transect is made by stretching a roll meter with a scale parallel to the coastline along 25 meters with three replications with an interval of about 0-5 meters between replications so the total observed transect was 75 meters. Repetitions and intervals were performed to reduce excess bias between data. Coral reef observations were recorded based on life forms, biota, and other abiotic components along the transect line (English *et al*., 1994). The rubble or coral fragments are separated into abiotic groups because rubble is considered an indicator of coral damage from tsunamis. In addition, the dominant coral genus and condition of each colony were recorded as tsunami impact.

2.3. Data Analysis

Coral reef conditions were calculated in percent of basic habitat cover (Gomez & Yap, 1988) and coral mortality index (Estradivari *et al.*, 2007). Diversity data was calculated using the Shannon-Winner diversity

index (Odum 1971; Krebs 1985), the uniformity index (Odum 1971), and the Simpson dominance index (Odum 1971).

3. Result and Discussion

The tsunami that hit the Tanjung Lesung area and its surroundings has caused changes in the coral reefs' composition which play an important role in the marine sector in this special economic zone. This change is urgently studied considering the comparative absence of data on coral reefs before and after the Sunda Strait tsunami, especially in the Tanjung Lesung coastal area.

This research was conducted 2 years after the Sunda Strait tsunami in 2018. It is suspected that there has been a composition change in coral reefs so this study can still describe changes in coral reef conditions. Observations were made at 6 stations representing areas exposed to direct tsunami attacks (Figure 2). Where stations 1-3 are tourism areas, while stations 4-6 are residential areas.

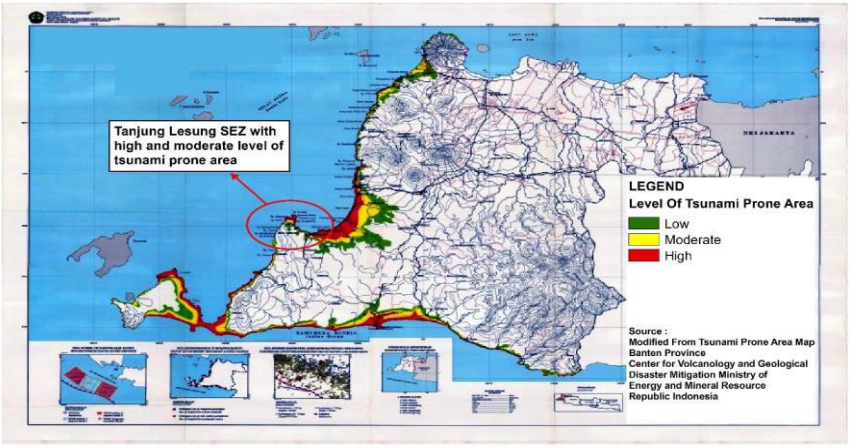


Figure 2. Expose the area to the Sunda Strait tsunami 2018

Tanjung lesung is a tsunami-exposed area with a high to moderate level (Figure 2). Based on statistical analysis, the effect of time and station location on the percent hard coral cover was not significantly different at the 95% confidence interval ($F = 1.209$; $P = 0.255$). In general, it can be concluded that the coral cover before and after the tsunami at all stations (stations 1-3) did not change significantly, although there is evidence of the magnitude of damage to coral reefs caused by the tsunami (Figure 3).

Figure 3. Coral fractures that were carried inland by the 2018 Sunda Strait tsunami.
Note: a. Coral fractures form a hill of coral fractures approximately 1 km long. b. Tsunami victim (Z) (108 years old), a tsunami survivor who was collecting plastic waste on a coral reef rubble along Tanjung Lesung coastal area

3.1. Water Conditions

Retrieval of water condition data aims to determine whether the waters of Tanjung Lesung are still good enough for coral reef growth after the tsunami. The research data showed that the water conditions were still optimal for coral reef growth (Table 1).

Table 1. Physical parameter data of Tanjung Lesung coral reef environment

Parameter	Station					
	1	2	3	4	5	6
Temperature (^oC)	27.5	27	27	28	27	27.5
Salinity (ppt)	35	36	37	36	36	37
pH	6.9	6.8	6.9	6.9	6.8	6.9
Clarity (m)	2.8	4.52	5	3	4.47	4.5

Gomez & Yap (1988) divided four categories of coral reef cover percentages. The criteria can be seen in Table 2.

Table 2. Coral Reef Cover Percentage Categories

Percentage of cover (%)	Category
0-24.9	Bad
25-49.9	Medium
50-74.9	Good
75-100	Excellent

The temperature of Tanjung Lesung waters has an average of 27.3^{o}C where coral reefs can develop optimally at temperatures of 25 to 30^{o}C (Nybakken, 1988). Then the salinity of Tanjung Lesung waters is in the range of 36.2 ppt where the salinity range that can be tolerated by coral reefs ranges from 27 to 40 ppt (Nontji 1993). The range of pH values suitable for coral reefs is 7 to 8.5 where the pH of the Tanjung Lesung sea waters is around 6.86 so the waters of Tanjung Lesung can be said to be more acidic than the optimal pH needed for coral reefs to thrive. This can be due to environmental issues regarding the acidification of seawater (Caldeira & Wickett, 2003). Green *et al.* (1996), states that if the depth is less than 20 cm, it indicates that the waters are muddy, while the Tanjung Lesung waters have an average depth of 4 m in brightness, indicating that Tanjung Lesung waters have clear water conditions. This shows the availability of sufficient sunlight intensity so that the photosynthesis process can take place optimally which directly supports coral growth.

3.2. Coral Reef Condition

Coral reef observation in Tanjung Lesung was carried out to determine coral reefs condition such as coral percent cover, benthic biota, and substrate. Spatially, coral reefs distribution based on the station is directly in front of Sunda Strait and Anak Krakatau Seamount. All observation stations are spread out in a series of fringing reefs, so it is assumed that they have almost the same structure and composition as coral communities. Before the tsunami, the condition of the coral reefs at station 1 was in a good category with a percentage of hard coral cover of 52.12% (Figure 4). Good category in the range of 50-74.9% (Gomez & Yap. 1988).

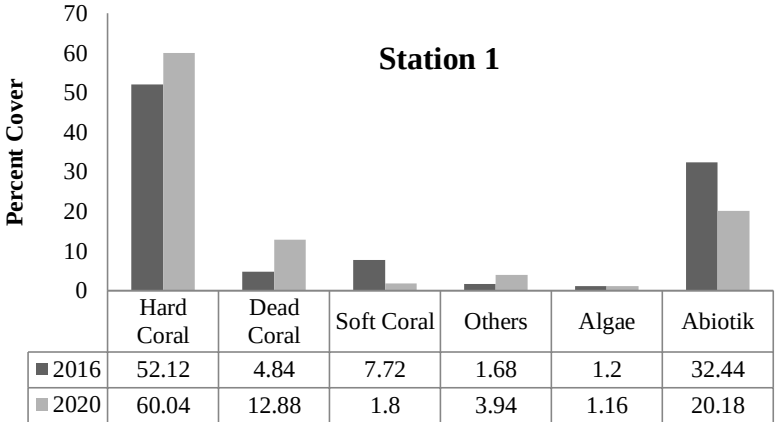
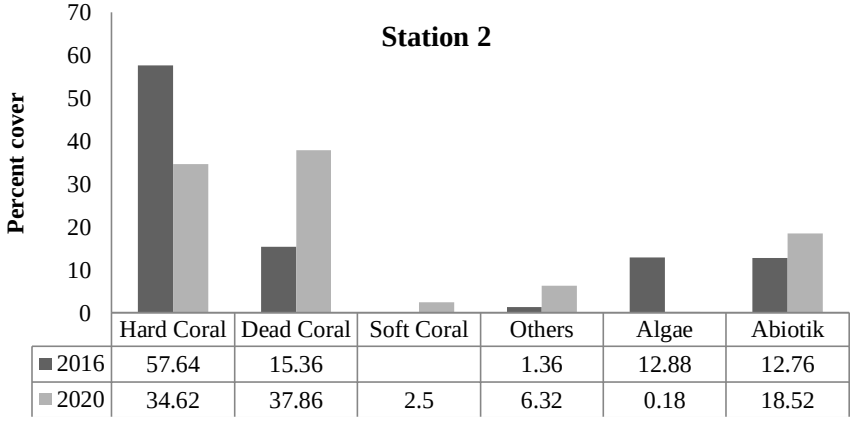


Figure 4. Station 1 coral reef percent cover before the tsunami (2016) and after the tsunami (2020)

After the tsunami, this station showed an increase in data of coral percent cover to 60.04%. Because this area is a tourism area where coral reef conservation is often carried out in the form of planting coral gardens (Figure 5) after 2 years of observing the first data in 2016, it is suspected that there is an increase in coral reef cover. But after that, a tsunami occurred so it seemed as if the cover rate had increased. This was evidenced by the increase in the amount of coral cover, but the percentage of dead coral cover increased from 4.84% to 12.88%. Dead coral colonies were found in the form of broken and overturned coral which was have been caused by the tsunami.

Figure 5. Coral gardens before tsunami (2016) at Tanjung Lesung tourist site as an effort to conserve coral reefs

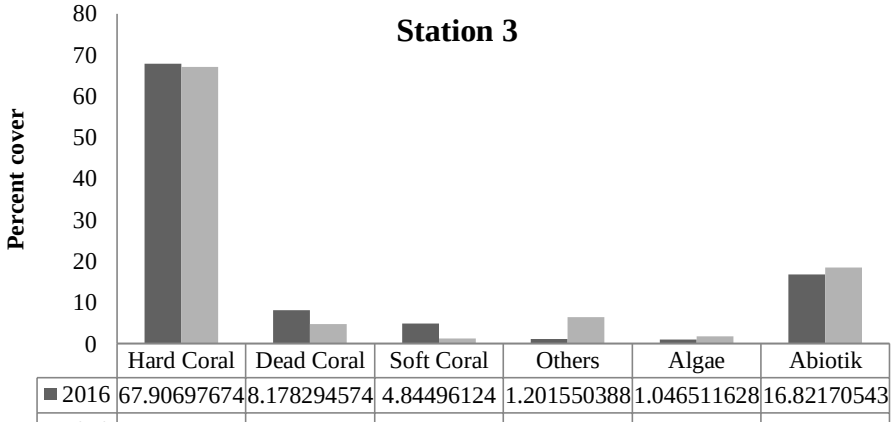
At station 2 coral reef percent cover have the most drastic changes. Coral reef cover was almost half of what it was before the tsunami. The coral cover before the tsunami was 57.64% while after the tsunami it was 34.62% (Figure 6). Coral reef cover before the tsunami was in the good category, while after the tsunami it was in the medium category (25-49.9%). Dead corals found along the transect showed a significant increase from 15.36% to 34.62%. The condition of the dead coral was in the form of broken coral and inverted tabulate corals. Broken and overturned corals are dominated by colonies of the table and branching corals (Kamarumtham *et al.*, 2016).



	Hard Coral	Dead Coral	Soft Coral	Others	Algae	Abiotik
2016	57.64	15.36		1.36	12.88	12.76
2020	34.62	37.86	2.5	6.32	0.18	18.52

Figure 6. Station 2 coral percent cover before the tsunami (2016) and after the tsunami (2020)

At station 3 the coral reef cover did not change significantly from before the tsunami to after the tsunami. Before the tsunami, the percent coral cover in this area was 67.9% and after the tsunami, it decreased slightly to 67.1% (Figure 7). This condition falls into the category of good coral reefs (Gomez & Yap 1988). The percentage of dead coral cover has also decreased; this is presumably because many coral fragments were washed ashore at the time of the tsunami.



	Hard Coral	Dead Coral	Soft Coral	Others	Algae	Abiotik
2016	67.90697674	8.178294574	4.84496124	1.201550388	1.046511628	16.82170543
2020	67.1	4.76	1.32	6.48	1.84	18.5

Figure 7. Station 3 coral percent cover before the tsunami (2016) and after the tsunami (2020)

Stations 4, 5, and 6 are less dense residential areas. The land area is hilly with steep coral. Stations 4, 5, and 6 only show data after the tsunami. Among these three stations, station 4 has the highest hard coral cover

(52.86%) and is in a good category, while at stations 5 and 6 it is 46.6% and 47.58% and it is in the medium category (Gomez & Yap, 1988) (Figure 8). Piles of dead coral were found forming a hill along the coast.

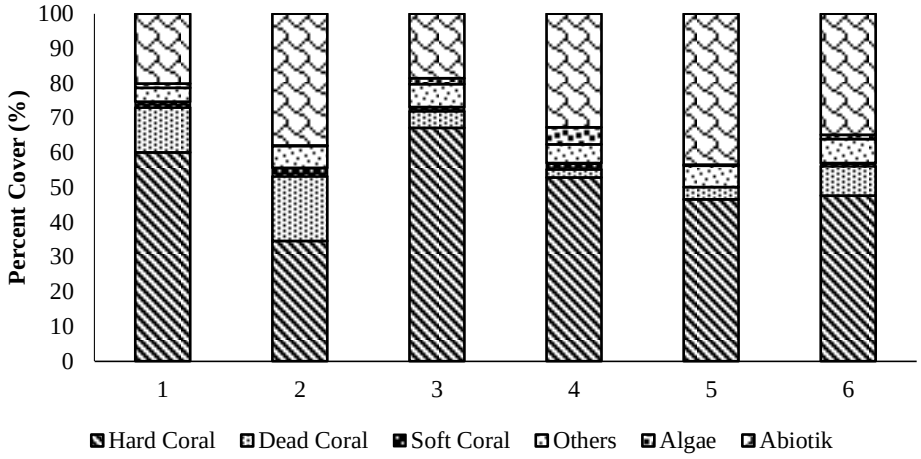


Figure 8. Coral reef percent cover of all stations after the tsunami (2020)

3.3. Coral Diversity

Based on the observations result, there are 26 genera of coral in Tanjung Lesung. In general, the distribution of coral genera dominated by *Pachyseris* was around 33.42%, *Cyphastrea* was around 33.02%, and *Acropora* ± 30.10 and was followed by other genera, while the distribution of the smallest coral genus found was *Ctenactis* around 0.22% (Figure 9).

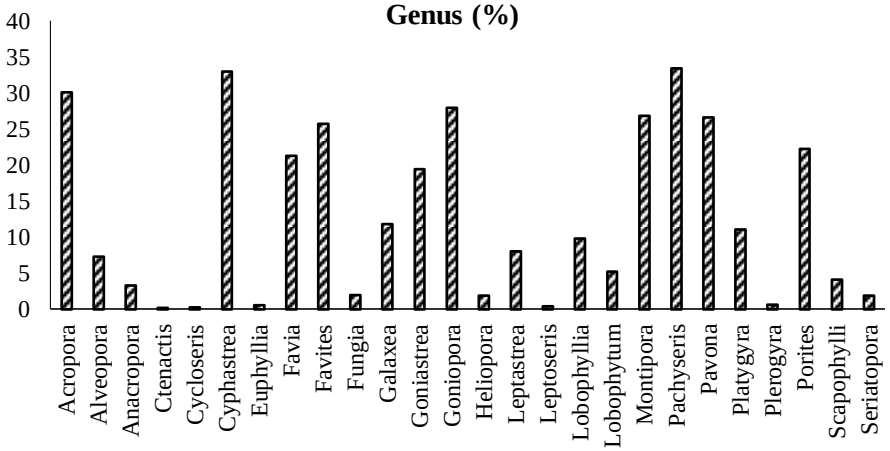


Figure 9. Coral genus found in Tanjung Lesung (2020)

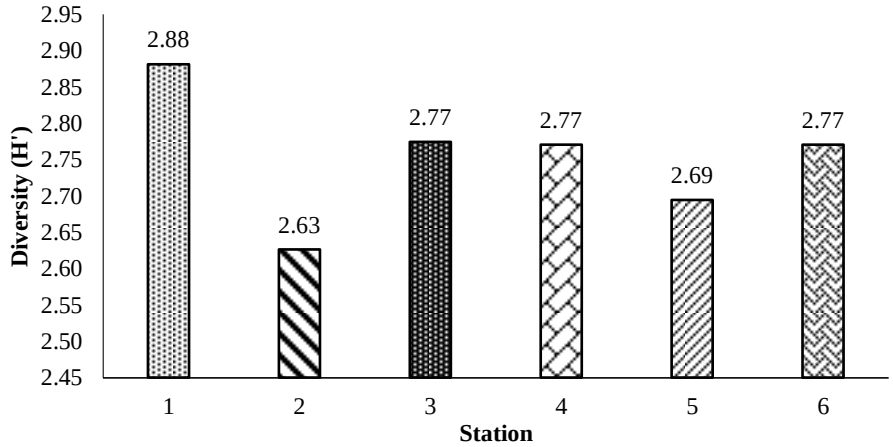


Figure 10. Diversity (H ') of Tanjung Lesung Coral Reef

The Shannon-Wiener Index formula is used to measure diversity. This index is most often used for ecological studies that measure species diversity. The results of the observation of coral reefs in Tanjung Lesung

that are spread over six stations show differences in diversity between one station and another. The lowest diversity value was found at station two, 2.63, and the highest at station one with a value of 2.88 (Figure 10).

3.4. Coral Mortality

The highest mortality index is at station 2 as previously mentioned that this area has the most significant decline in coral cover with a coral mortality index of 0.13 (Figure 11). While the lowest mortality index is at station 1 with a value of 0.07. An increase in the coral mortality index value followed by an increase in the percent cover of dead coral indicates the pressure caused by the tsunami waves hitting the waters.

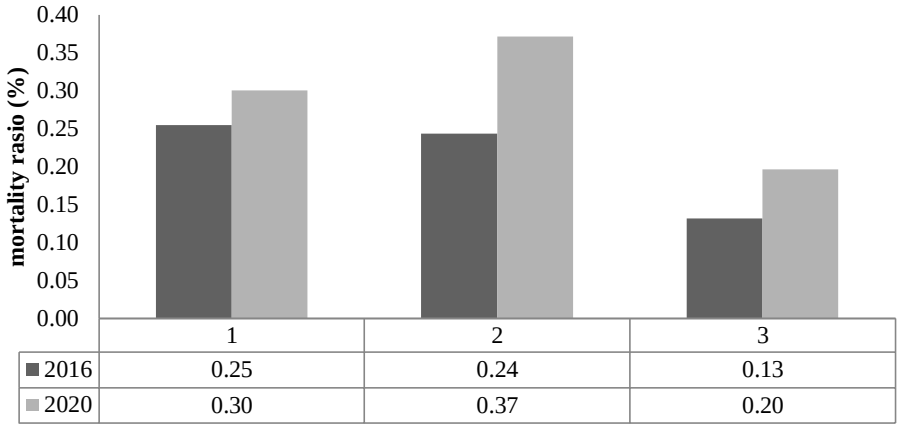


Figure 11. Tanjung Lesung coral mortality index before and after the tsunami 2018

4. Conclusions

Coral reefs' condition after the Sunda Strait tsunami 2018 on the Tanjung Lesung coast was generally damaged compared to before the tsunami. The damage that occurs is different for each station. This can be seen from the decrease in the percentage of hard coral cover from 0.8% -23%, with a mortality index of 0.07-0.13. The percentage of hard coral cover before and after the tsunami at all research stations did not change significantly. The effect of time and location of the research station on the percentage of hard coral cover was not significantly different at the 95% confidence interval. The deterioration of coral reef conditions at three research stations (1-3) proved that the tsunami waves affected the damage to coral reefs. This has an impact on the diversity of coral reef species inhabitants that have decreased. Disturbance form coral-damaged structure and composition changes of the base substrate as habitat can have an impact on reef fish and coral reef inhabitants. If the quality and quantity cannot be recovered and will continue to decline in the future, the life of coral-dwelling communities can be predicted to decline and hurt the local tourism and fisheries sector.

5. Acknowledgments

The major contributors to the preparation of the manuscript and funding are the Fund for the Annual Work Plan and Budget for the Assignment of Research and Community Service Institutions Indonesian University of Education for the 2020 Fiscal Year With a Rector's Decree Number: 1079 / UN40 / PM / 2020. Before tsunami data is from IPB University Marine Science Postgraduate. Thank you to all those who have helped in the process of data collection, writing, funding, and moral support.

6. References

Caldeira, K., & Wickett, M.E. (2003). Anthropogenic carbon and ocean pH. *Nature*. 425 (6956): 365. Https://doi.org/10.1038/425365a

English, S., Wilkinson, C., Baker, V. (1994). *Survey manual for tropical marine resources*. ASEAN-Australia Marine Science Project: Living Coastal Resources

Estradivari., Syahrir, M., Susilo, N., Yusri, S., Timotius, S. (2007). *Terumbu karang Jakarta: pengamatan jangka panjang terumbu karang Kepulauan Seribu (2004–2005).* Yayasan TERANGI, Jakarta: 87hlm

Gomez, E.D. & Yap, H. (1988). *Monitoring Reef Condition. Coral Reef Management Hand Book*.Unesco Regional Office for Science and Technology for South East Asia. Jakarta.

Green., Morton, B., New, S. (1996). *Purchasing and Environmental Management: Interactions, Policies, and Opportunities.* Business Strategy and Environmental.

Kamarumtham, K., Ahmad, Z., Halid, N.H., Saad, S., Khodzori, M.F.A., Yusof, M.H., Hanafiah, M.H.M. (2016). Diversity and Distribution of Coral Lifeforms in Tioman Island. *Transactions on Science and Technology*, 3(2): 367-373

Kartini, D.S., Mulyawan, R., & Yuningsih, N.Y. (2017). Kapitalisme Pedesaan di Kawasan Ekonomi Khusus (Kek) Tanjung Lesung Kabupaten Pandeglang Provinsi Banten. *Jurnal Ilmu Pemerintahan. CosmoGov* 55(3): 1

Krebs, C.J. (1985). *Ecology: The experimental analysis of distribution and abundance*. Harper & Row, New York. 800 p

Nontji, A. (1993). *Laut Nusantara*. Penerbit Djambatan. Jakarta.

Nybakken, J.W. (1988). *Bilogi Laut Suatu Pendekatan Ekologis*. Terjemahan M. Ediman, Koesoebiono, D.G Bengen, M. Hutomo, & S. Sukardjo. Jakarta: PT. Gramedia.

Odum, E.P. (1971). *Dasar- Oceanography*. 4ed. Thomson Learning, Inc.USA.

Purbani, D., Louise, T.K., Takwir, A. (2014). Kondisi Terumbu Karang Pulau Weh Pasca Bencana Mega Tsunami (Coral Reef Condition after Mega Tsunami Disaster). *Jurnal Manusia dan Lingkungan*, 21(3): 331-340

Wilkinson, C., David, S., Jeremy, G. (2006). *Status Terumbu Karang di Negara-Negara yang Terkena Tsunami 2005 (terjemahan)*. Institute of Marine Science, Townsville, Australia