Depik
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
p-ISSN: 2089-7790, e-ISSN: 2502-6194 http://jurnal.unsyiah.ac.id/depik

RESEARCH ARTICLE

DOI: 10.13170/depik.8.2.13422

Ratio of coral reefs to macroalgae: An ecosystem approach management

Aditiyawan Ahmad[1,2*], Achmad Fahrudin[34], Mennofatria Boer[3], Yusli Wardiatno[3], M. Mukhlis Kamal[3]

[1]Coastal and Marine Resources Management Program, Post-graduate School of Bogor Agricultural University, Bogor, Indonesia; [2]Aquatic Resource Management Study Program, Faculty of Fisheries and Marine Science, Khairun University, Ternate, Indonesia; [3]Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor, Indonesia; [4]Center for Coastal and Marine Resources Studies, Bogor Agricultural University, Bogor, Indonesia; *Corresponding author: aditiyawan_ahmad@yahoo.com

Received: 28 March 2019
Accepted: 09 July 2019

Abstract. *The decline in the quality of coral reef ecosystems is not only caused by human activities but also caused by competition in ecosystems, including competition for space and nutrients. Research on the comparison of coral reefs with macroalgae is one of the determinants of coral reef health which is the basis for the management of coral reefs with an ecosystem approach. The purpose of this study was to analyze the comparison of coral reef cover with macroalgae. The research method used is Line Intercept Transect (LIT), the research location is 13 stations divided into 3 locations, namely north, centre, and south from Ternate Island in North Maluku. The results showed that the condition of coral reefs ranged from 24 – 86.60%, based on the condition categories of 13 observation locations, the coral reefs of Ternate Island were in very good condition at 15.38%, good conditions at 46.16%, adequate conditions at 30.77%, and damaged conditions 7.69%, while the condition of macroalgae cover ranged from 0 - 30.60% in the area of coral reef ecosystems. The ratio of the of coral reefs to algae ranges from 0 to 1.117, based on the ratio value, it is classified as low, medium to high, spread in the coral reef ecosystem of Ternate Island. Coral reef management strategies on Ternate Island include a continuous monitoring program for coral reef ecosystems, education on coral reef ecosystems, creating a conscious community of waste, and limiting the capture and restoking of herbivorous fish in coral reef areas.*
Keywords: *Coral reef, ecosystem approach management, macroalgae, Ternate Island*

Introduction

The coral reefs ecosystem is a coastal ecosystem with high productivity because it consists of the organism from the low-level organism (producer) to top-level organism which dominated by carnivore fishes. The organism that constructs the coral reef ecosystem includes reef-producing coral animals, plankton which determines the waters fertility, macroalgae, macrobenthos, and reefs fish (Azovsky, 2009; Wang et al., 2011; Cleary et al., 2016). In general, the composition of organisms composing coral reef ecosystems forming a complex system and related to environmental parameters, but has different behaviors in the ecological system (Wang et al., 2011). Based on preliminary studies in 2017, the coastal waters of Ternate island are 70% covered by coral reefs ecosystem, while the other 30% was seagrass ecosystem, sand, and rocks from the eruption of Gamalama mountain.

The coral reef is vulnerable to global pressure that caused coral disease, where that pressure is such as climate warming, poor water quality, and overfishing. The disease not only resulting in the dead of corals but also affected significantly to the community structure, species diversity and the organism that composed the coral reef ecosystem, including an increase in macroalgae, resulting in the competition (Weil and Hooten, 2008; Cruz et al., 2016; Zao et al., 2016; Veiga et al., 2016). Ternate Island is a small island that has high activity so it is vulnerable to the garbage disposal and household waste. The high level of household waste can lead to an increase in macroalgae which can threaten the existence of coral reef ecosystems, including competition between macroalgae and coral reefs, resulting in a decrease

Depik
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
p-ISSN: 2089-7790, e-ISSN: 2502-6194 http://jurnal.unsyiah.ac.id/depik

in the quality of coral reef cover. To prevent the degradation of coral reef ecosystems, a fast method is needed to determine the condition of coral reef ecosystems.

Several biological indicators can be used to assess coral reef ecosystems, such as the abundance of species from the family of Chaetodontidae, the coral covers, the abundance of Acanthaster planci, and the ratio of coral reef to macroalgae. From those indicators, the most used are the abundance of species from the family of Chaetodontidae and the coral covers, where have advantages and disadvantages. Therefore, to cover the deficiency of both approaches, it can use the comparison ratio indicators between coral reef and macroalgae. Ecologically, this indicator can determine the existence of the organism in the next upper level, where macroalga was a low-level organism in the ecosystem as a producer. The assessment using this ratio indicators can be done in a wide area within a quick time, and using a single method. With these indicators can also determine the strategy for managing the coral reef ecosystems. The aiming of the study was to analyze the comparison ratio between coral reefs to macroalgae, as the base in coral reef management plans with the ecosystem approach.

Materials and Methods

Study site

The study was conducted from November to December 2017 at Ternate island. The sampling site are at 13 site, where 4 site in the north region, 3 site in the center region, and 6 site in the south region of the island (Figure 1 and Table 1).

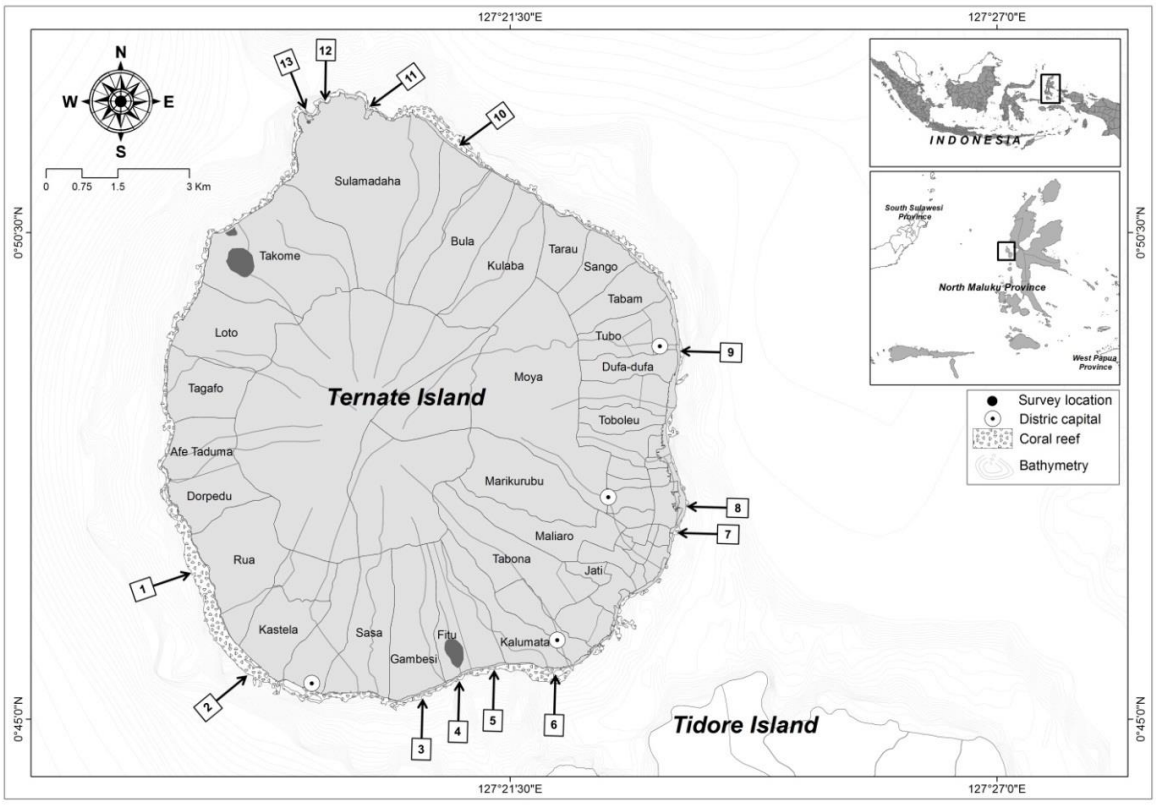

Figure 1. Maps of the study site

Depik
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
p-ISSN: 2089-7790, e-ISSN: 2502-6194 http://jurnal.unsyiah.ac.id/depik

Table 1. Coordinates of the sampling site

Site number	Sampling site name	Coordinate		Region
		Latitude (North)	Longitude (East)	
1	Rua	$0^0$46'14.38"	$127^0$18'03.99"	South
2	Kastela	$0^0$45'39.96"	$127^0$18'24.76"	South
3	Gambesi	$0^0$45'05.01"	$127^0$20'07.68"	South
4	Fitu	$0^0$45'20.33"	$127^0$20'50.01"	South
5	Ngade	$0^0$45'34.31"	$127^0$21'30.43"	South
6	Kalumata	$0^0$45'27.78"	$127^0$21'52.05"	South
7	Falajawa	0°46'59.75"	127°23'20.14"	Center
8	Gamalama	$0^0$47'18.41"	$127^0$23'28.85"	Center
9	Daulasi	$0^0$49'28.27"	$127^0$23'24.27"	Center
10	Tobololo	$0^0$51'18.32"	$127^0$21'12.03"	North
11	Sulamadaha	$0^0$51'50.43"	$127^0$19'53.99"	North
12	Talaga Nita	0°51'57.92"	127°19'25.52"	North
13	Jikomalamo	$0^0$51'48.71"	$127^0$19'12.32"	North

Data collection

The data was collected according to the purpose of the study, such as data of coral reef and macroalgae. The Line Intercept Transect (LIT) were deployed in this research, within 5 to 10 meter depth at the coral reef ecosystem (Rogers *et al.*, 1983; English *et al.*, 1997; Leujak and Ormond, 2007; Facon *et al.*, 2016).

Data analysis

The analysis of the condition of coral reef and macroalga are using the percent cover, where for the coral reef it used lifeform identification approach. The lifeform data of coral reef and macroalgae from the LIT method than calculated for their percent cover using the equation (English *et al.*, 1997):

$$PC_i = \frac{Li_i}{L} x100\%$$

where, PC_i is the percent cover of coral reef and macroalgae (%), Li is lifeform length of the coral of (i) and macroalgae of (i) in cm, and L is length of transect line (cm).

Results

Coral reefs

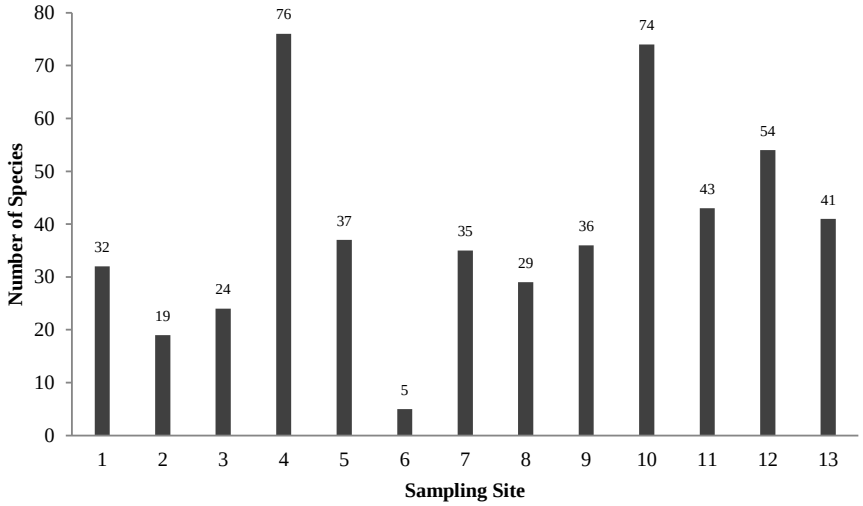

Figure 2. Number of coral reef species founded in Ternate island waters.

Depik
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
p-ISSN: 2089-7790, e-ISSN: 2502-6194 http://jurnal.unsyiah.ac.id/depik

There was 204 species of coral reefs founded in Ternate island waters that spread on 13 observation site. The most species were founded in 2 site of the island, which is in the south region (Fitu) and north site (Tobolo) (Figure 2). The dominant species is from genus of *Acropora* within 47 species.

The highest area of coral reefs is located at south (Gambesi and Fitu) and north (Talaga Nita and Jikomalamo) region of Ternate island (Figure 3). The highest percentage of coral reefs area on both region due to the wide of coral reefs that half of the waters area of each sampling site.

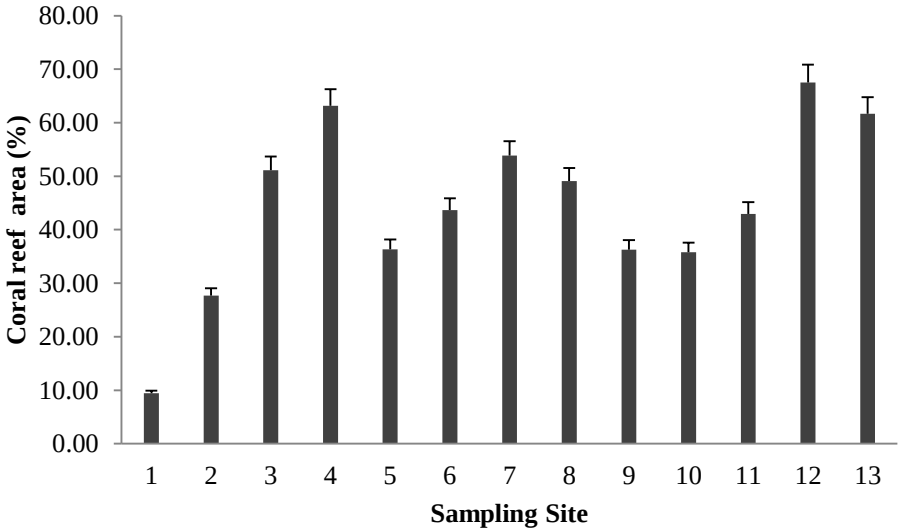

Figure 3. The wide of coral reefs area at Ternate Island

The coral reef cover at Ternate Island range from 24% to 86,60% (Figure 4). Based on the condition categories of the 13 sampling site of coral reefs at Ternate Island, it resume that 15,38% is in very good condition, 46,16% in good condition, 30,77% in adequate condition, and 7,69% is in damage condition.

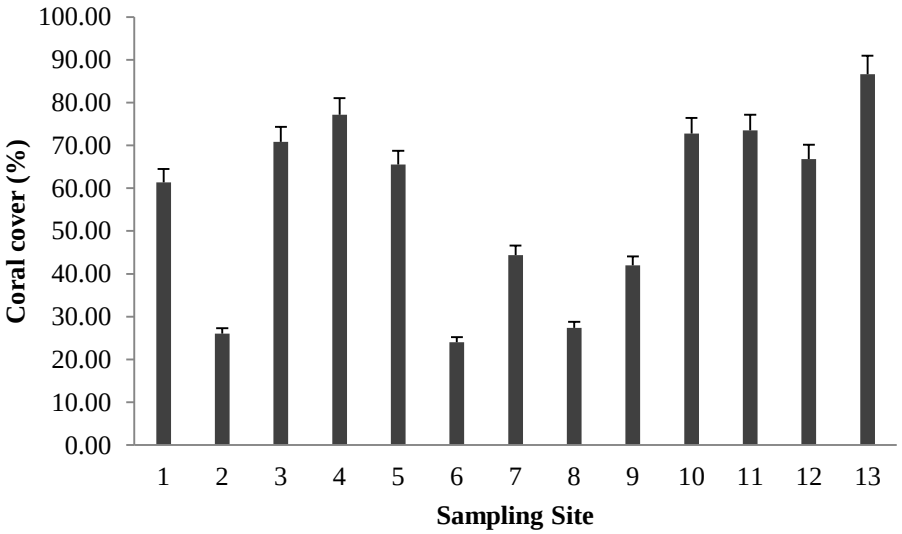

Figure 4. The percent of coral cover at Ternate Island.

Depik
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
p-ISSN: 2089-7790, e-ISSN: 2502-6194 http://jurnal.unsyiah.ac.id/depik

Macroalage

Macroalgae is one of the primary producer component that composed the coral reef ecosystem, and as indicators of the health of coral reef ecosystem. The macroalgae covered in the coral reef ecosystem at Ternate Island varied between 0 – 30.60%. The highest covered of macroalgae are founded in the center region (Falajawa and Gamalama) of the island (Figure 5), which indicated that there is a competition between the coral reefs and macroalgae, where ecologically due to low density of herbivore fishes which play as balancer in coral reef ecosystem as consumer of macroalgae. Meanwhile, from the water quality approach, those two site were near the residential areas so they will ease to be contaminated by the phosphate from domestic waste.

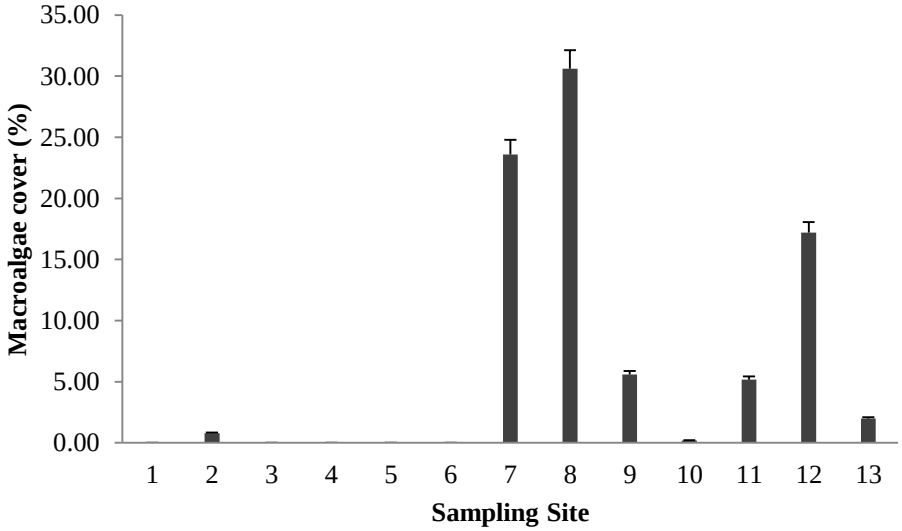

Figure 5. The percent of macroalgae cover at Ternate Island.

Ratio of coral reefs to macroalgae

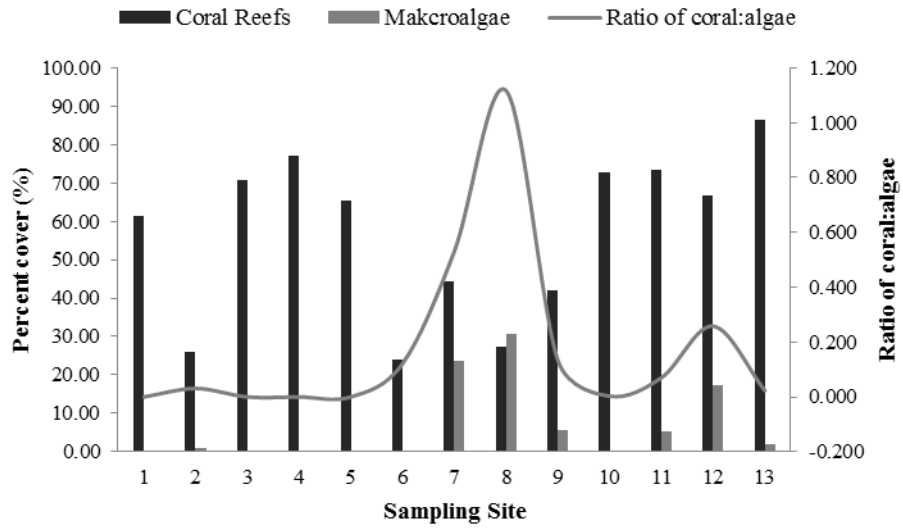

Figure 6. The coral reefs and macroalgae cover comparison.

The ratio of coral reefs to macroalgae at Ternate Island is range between 0 to 1.117. The higher ratio was founded at the center region (Falajawa and Gamalama) within value of 0.532 and 1.117 respectively (Figure 6). The ratio value show that the cover of macroalgae is more dominate than the coral reef at Gamalama site, while there is a competition happened

at Falajawa site. This condition will rise the degradation for coral reefs at both area. Meanwhile, at the south and north region of the island, there is no significant competition of corals and macroalgae not founded, resulting the good condition of coral reefs (Figure 6).

Ratio of coral reefs to macroalgae

The result of regression analysis showed that the impact of macroalgae to the condition of coral reef was 13.47% within regression value are y = 61.755 – 0.756x (Figure 7). If the covered of macroalgae is rise, there will be reducing in coral reefs cover.

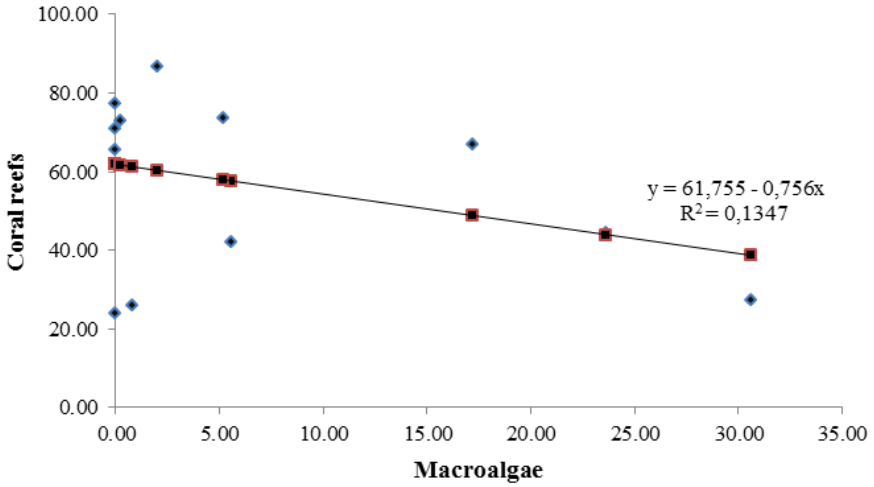

Figure 7. The regression model of coral reefs and macroalgae comparison.

Discussion

Coral reefs

The corals spread in Indonesia reach 569 species of corals. The total richness of hard corals (order of Scleractinia) in Ternate Island reach out of 204 species or about 36% of total species of corals in Indonesia. According to LIPI (2017), the high richness of corals species were found in the seas of Bird Head of Papua and their surround areas, including Raja Ampat and Halmahera, and become less to the west and south region of Indonesia.

The number of species of coral reefs is influenced by the bottom contours of the water column and relative calm of the waters condition. The bottom of the waters columns of those two site (Fitu and Tobololo) was sloping. Besides that, the sun light penetration also play a role in the richness of the coral species, where the sloping form of the bottom contours made the penetration of the sun light up to 90% to the bottom of the water. Total area of coral reefs at Ternate Island are 53.59 Ha.

The difference in coral reef cover was affected by the environment condition and location of the ecosystem, where the very good condition of coral reef was located at south (Fitu) and north (Jikomalamo) region of the island. Both location is in protected area and lay at the narrows area, where in the south was protected by Maitara Island, and in the north was protected by Hiri Island. The existing of those two island made a strait current for the regions that made quick change for water mass, also drive a lot of larvae biomass and nutrient, where this factors caused the good condition of coral reefs. The current speed is the flow of waters that drive the nutrient and organic matters for the needs of corals and zooxanthella in the photosynthesis process, larvae, and protecting the corals from the impact of sedimentation (Chacon-Gomez *et al.*, 2013; Cowburn *et al.*, 2018).

Macroalage

Macroalgae had a positive and negative impact to coral reef ecosystem, where the positive impact is as the oxygen supplier and as consumption for the herbivore fishes. The negative impact is from the fast growth of them, where if it not controlled (their fast growth) than they will dominated the coral reef ecosystem, and there will be rise a competition in occupying the bottom of water column, thus threatening the existence of coral reefs (Bahartan *et al*., 2010; Bender *et al*., 2012; Zao et al., 2016; Veiga et al., 2016; Saalmann *et al*., 2018).

Ratio of coral reefs to macroalgae

The macroalgae is one of the component that constructs the coral reef ecosystem at the low trophic level as producer. In the normal environment condition, macroalgae was an important component to the ecosystem, while in the environment with high nutrient, the growth of macroalgae will up rise so it can be a competitor to the coral reefs, both in the competition for photosynthesis process and the space competition for growth habitat ((Bahartan *et al*., 2010; Vermeij *et al*., 2013; Swierts and Vermeij, 2016). Ecologically, macroalgae can be controlled by the present of herbivore fishes (Cheal et al., 2010; Vermeij *et al*., 2013; Hixon, 2015; Cruz et al., 2016).

Coral reef management

The coral reefs damages can be happened by natural or anthropogenic process. The result of this study show that the damage of the coral reef at Ternate Island is caused by the increasing of the macroalgae organism at the central region of the island waters, due to the direct waste of residential to the waters area, caused the increasing of nutrient composition in the waters, also the less abundance of the herbivore fishes that become a target catch of the fishing activity at the island.

The coral reef management approach was applied based on the real condition on the study area. The management approach purposed to prevent, overcome, and design the programs so the stability of the coral reef ecosystem will sustain. The coral reef management strategic at Ternate Island was:

1) Monitoring program for coral reef ecosystem
   The continuous monitoring using the method, which can covered all coral reef ecosystem component. The monitoring result can be a base for management act. The Productivity and Susceptibility Analysis (PSA) can be used as monitoring method, so all the coral reef ecosystem component can be disclosed, or else the ratio of coral reefs to macroalgae can be used to prevent the damage of coral reef ecosystem.
2) Education about the coral reef ecosystem
   The education is an important program to rise up the community understanding about the important function of the ecosystem, and the cause of coral reef ecosystem degradation, so there will be produce the concern community that cares on the sustainability of the coral reef ecosystem.
3) Creating a community aware of littering
   The purpose of this programs is to create a community awareness to the domestic waste, so it can not directly trashed to the waters column, which can increase the growth of macroalgae organism.
4) Limiting the catch and the restocking of the herbivore fishes in the coral reef areas
   This strategic is to preserve the stability of the coral reef ecosystem by limiting the catch of the herbivore fishes, while the restocking can be done through the carrying capacity value of the coral reef ecosystem for the herbivore fish.

Conclusion

Based on the result of the study, it can be concluded that the highest comparison ration was in the center region of Ternate Island waters, where the value of macroalgae cover is higher than the coral reef cover. The cause of this high value is due to the increasing of the nutrient from domestic waste and the lower abundance of the herbivore fishes due to the fishing activity. The implementation of management strategy based on the issue can be done through continuous coral reef ecosystem monitoring programs, education about the coral reef ecosystem, creating a community aware of littering, and limiting the catch and the restocking of the herbivore fishes in the coral reef areas.

Acknowledgement

We were grateful to the diving team from Lembaga Kajian Ekosistem Pesisir (M-JIKO Pesisir) for their participation along the research.

Reference

Azovsky, A.I. 2009. Structural complexity of species assemblages and spatial scale of community organization: A case study of marine benthos. Ecological Complexity, 6(3): 308-315.

Bahartan, K., M. Zibdah, Y. Ahmed, A. Israel, I. Brickner, A. Abelson. 2010. Macroalgae in the coral reefs of Eilat (Gulf of Aqaba, Red Sea) as a possible indicator of reef degradation. Marine Pollution Bulletin, 60(5): 759-764.

Bender, D., G.D. Pulido, S. Dove. 2012. Effects of macroalgae on corals recovering from disturbance. Journal of Experimental Marine Biology and Ecology, 429(1): 15-19.

Gomez, I.C.C., D.S. Monreal, M.L.R. Enzastiga. 2013. Current pattern and coral larval dispersion in a tropical coral reef system. Continental Shelf Research, 68:(1) 23–32.

Cheal, A.J., M.A. MacNeil, E. Cripps, M.J. Emslie, M. Jonker, B. Schaffelke, H. Sweatman. 2010. Coral–macroalgal phase shifts or reef resilience: links with diversity and functional roles of herbivorous fishes on the Great Barrier Reef. Coral Reefs, 29(4): 1005-1015.

Cleary, D.F.R., A.R.M. Polónia, W. Renema, B.W. Hoeksema, P.G. Rachello-Dolmen, R.G. Moolenbeek, A. Budiyanto, Y. Yahmantoro, Y. Tuti, G. Giyanto, S.G.A. Draisma, W.F. Prud'homme van Reine, R. Hariyanto, A. Gittenberger, M.S. Rikoh, N.J. deVoogd. 2016. Variation in the composition of corals, fishes, sponges, echinoderms, ascidians, molluscs, foraminifera and macroalgae across a pronounced in-to-offshore environmental gradient in the Jakarta Bay–Thousand Islands coral reef complex. Marine Pollution Bulletin, 110(2): 701-717.

Cowburn, B., M.A. Samoilys, D. Obura. 2018. The current status of coral reefs and their vulnerability to climate change and multiple human stresses in the Comoros Archipelago, Western Indian Ocean. Marine Pollution Bulletin, 133: 956-969.

Cruz, I.C.S, V.H. Meira, R.K. Papa de Kikuchi, J.C. Creed. 2016. The role of competition in the phase shift to dominance of the zoanthid *Palythoa* cf. *variabilis* on coral reefs. Marine Environmental Research, 115: 28-35.

English, S., C. Wilkinson, V. Baker. 1997. Survey manual for tropical marine resources. 2nd edition, Australian Institute of Marine Science, Australia. 390p.

Facon, M., M. Pinault, D. Obura, S. Pioch, K. Pothin, L. Bigot, R. Garnier, J.P. Quod. 2016. A comparative study of the accuracy and effectiveness of Line and Point Intercept Transect methods for coral reef monitoring in the southwestern Indian Ocean islands. Ecological Indicators, 60: 1045-1055.

Hixon, M.A. 2015. Reef fishes, seaweeds, and corals. In: Birkeland, C. (Ed), Coral reefs in the Anthropocene. Springer, Dordrecht, pp 195-215.

Leujak, W., R.F.G. Ormond. 2007. Comparative accuracy and efficiency of six coral community survey methods. Journal of Experimental Marine Biology and Ecology, 351(1-2): 168-187.

[LIPI] Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia). 2017. Status of coral reefs in Indonesian. 42 p. (in Indonesian)

Rogers, C.S., M. Gilnack, H.C. Fitz. 1983. Monitoring of coral reef with linear transect: a study of strom damage. Journal of Experimental Marine Biology and Ecology, 66(3): 285-300.

Saalmann, F., F. Roth, T. Thomson, D.J. Coker, R. Villalobos, B.H. Jones, C. Wild, S. Carvalho. 2018. Coral reef degradation affects the potential for reef recovery after disturbance. Marine Environmental Research, 142: 48-58.

Swierts, T., M.J.A Vermeij. 2016. Competitive interactions between corals and turf algae depend on coral colony form. PeerJ, 4:e1984.

Veiga, P., I. Sousa-Pinto, M. Rubal. 2016. Meiofaunal assemblages associated with native and non-indigenous macroalgae. Continental Shelf Research, 123: 1-8.

Vermeij, M.J.A., R.A. van der Heijden, J.G. Olthuis, K.L. Marhaver, J.E. Smith, P.M. Visser. 2013. Survival and dispersal of turf algae and macroalgae consumed by herbivorous coral reef fishes. Oecologia, 171(2): 417-425.

Wang, D.R., Z.J. Wu, Y.C. Li, J.R. Chen, C. Min. 2011. Analysis on variation trend of coral reef in Xisha. Acta Ecologica Sinica, 31(5): 254-258

Weil, E., A.J. Hooten. 2008. *Underwater cards for assessing coral health on Caribbean reefs*. The CRTR Program, Australia. 28 pp.

Zhao, F., N. Xu, R. Zhou, M. Ma, H. Luo, H. Wang. 2016. Community structure and species diversity of intertidal benthic macroalgae in Fengming Island, Dalian. Acta Ecologica Sinica, 36(2): 77-84.

How to cite this paper:

Ahmad, A., A. Fahrudin, M. Boer, Y. Wardiatno, M.M. Kamal. 2019. Ratio of coral reefs to macroalgae: An ecosystem approach management. Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan, 8(2): 108-116.