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Long-term changes of coral reef habitats in two islands with and without residents in outer Spermonde Archipelago, South Sulawesi revealed by satellite remote sensing

Nurjannah Nurdin[1,3*], Khairul Amri[1] , Dwia Aries Tina Pulubuhu[2], Chair Rani[1], M. Akbar AS[3], Teruhisa Komatsu[4,5]

[1]Marine Science Department, Hasanuddin University, Makassar 90245, Indonesia
[2]Sociology Department, Hasanuddin University, Makassar, 90245, Indonesia
[3]Center for Regional Development & Spatial Information, Hasanuddin University, Makassar 90245, Indonesia
[4]Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa 277-8564, Japan
[5]Present affiliation: Yokohama College of Commerce, Yokohama 230-8577, Japan

ABSTRACT

Spermonde Archipelago in South Sulawesi has been facing human impacts on a coral reef ecosystem providing important ecosystem services. It is important to identify damages of a coral reef ecosystem by human impacts to mitigate the adverse effects and to realize sustainable development of tropical islands. Remote sensing is a very practical tool to analyze spatial and temporal changes in coastal habitats through historical archives of satellite images. Multi-spectral images obtained with LANDSAT MSS, TM, ETM and OLI sensors from 1972 to 2016 were analyzed with unsupervised classification method for extracting coral reef habitats in Gondongbali (GI) and Pamanggangang Islands (PI) with and without residents, respectively, to compare human impacts on a coral reef ecosystem around the two islands. Overall accuracies of classification of six habitats, live coral, dead coral with algae, rubble, seagrass, sand and mix bottom, for GI and PI were 83.4% and 84.0%, respectively. The overall accuracies allow the unsupervised application for mapping coral reef habitats. A temporal change of live coral area showed a decreasing tendency with a speed of about 1%/yr of 1972 in both islands since 1972. Its speed of GI was slightly greater than that of PI. Decreased areas of live coral changed to dead coral with algae, rubble and mix bottom. The seagrass habitat in GI showed a stepwise increase from 1972 to 2016, suggesting influence of nutrients discharge from land into the lagoon.

KEYWORDS

coral reef ecosystem, human impact, spatio-temporal change, remote sensing, landsat

INTRODUCTION

Coral reefs need our attention because of their high biodiversity in the tropical marine biosphere and the ecological services they provide. These fragile ecosystems are under growing human pressures from communities of surrounding land areas and natural impacts such as global warming (Nurdin et al. 2016; 2015). Effective management and conservation of coral reefs require periodic monitoring to detect environmental changes. However, in situ monitoring of protected coral reef habitats is often constrained by their remote location and their vast extent. Satellite remote sensing is a practical tool to monitor spatial and temporal coverages of coral reefs routinely with in situ survey campaigns and also after catastrophic events (e.g. Bahuguna et al. 2008). It is requested for remote sensing scientists to make efforts to accurately monitor and assess changes in compositions of coral reef communities by satellite imagery at variety of spatial and temporal scales.

The Spermonde Archipelago is an important case-in-point (Fig. 1) where overfishing with dynamite and cyanide have damaged remote reefs (Nurdin et al. 2015). These fishing practices destroy live corals and change them to other habitats such as dead coral, dead coral with algae, seagrass and so on. LANDSAT project of USA has provided multi-spectral images obtained with Landsat MSS, TM, ETM and OLI sensors since 1972. In this study, we examined whether different LANDSAT optical sensors can provide image data useful for assessing coral reef habitats. After the examination, we traced temporal changes of spatial distributions of coral reef habitats around two tropical islands located in outer Spermonde Archipelago with and without residents to

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***Corresponding Author:**
Nurjannah Nurdin. Marine Science Department and Center for Regional Development & Spatial Information, Hasanuddin University, Makassar 90245, Indonesia

compare human impacts on their changes by using LANDSAT image data from 1972 to 2016.

Study area

The study was done in the lagoons of Pamanggangang Island (PI) without residents and Gondongbali Island (GI) with residents in outer Spermonde Archipelago, South Sulawesi, Indonesia (Fig. 1). PI has not been permanently populated by humans and has no source of freshwater except rainfall.

Satellite image data and processing

A total of 11 LANDSAT satellite images from 1972 to 2016 were obtained via the US Geological Survey Data Center and analyzed in this study (Table 1). They were taken with four sensors, Landsat Multi Spectral Scanner (MSS), Landsat-5 Thematic Mapper (TM), Landsat-7 Enhanced Thematic Mapper (ETM+) and Landsat-8 Operational Land Imager (OLI) and Thermal Infrared (OLI_TIRS). All scenes were obtained from path/row number 114/63, cloud-free, and projected to universal transverse Mercator (UTM) 50 zone at reference datum of world geodetic system (WGS) 84. A spatial resolution of LANDSAT MSS is 60 m and those of the other sensors are 30 m (Table 1).

All images were geo-registered before classifiying habitats in coral reef ecosystems with a software of satellite image analysis (ERDAS ER Mapper, HEXAGON AB). When light penetrates water, its intensity decreases exponentially with increasing depth. This process is known as attenuation in water column, which depends on wavelength and exerts a profound effect on remotely sensed data of aquatic environments (Green et al. 2000). Mapping of submerged substrates is confounded by water column light attenuation (Mumby et al. 1997). The effects of variable depths on spectral signatures were corrected using the model of Lyzenga (1978) called Depth-Invariant Index (DII) that removes influences of atmosphere and water column on the images and obtaine ratios of spectral bands of sea bottom covers in logarithmic without seawater and air (Lyzenga, 1981). We used green and blue bands to calculate DII.

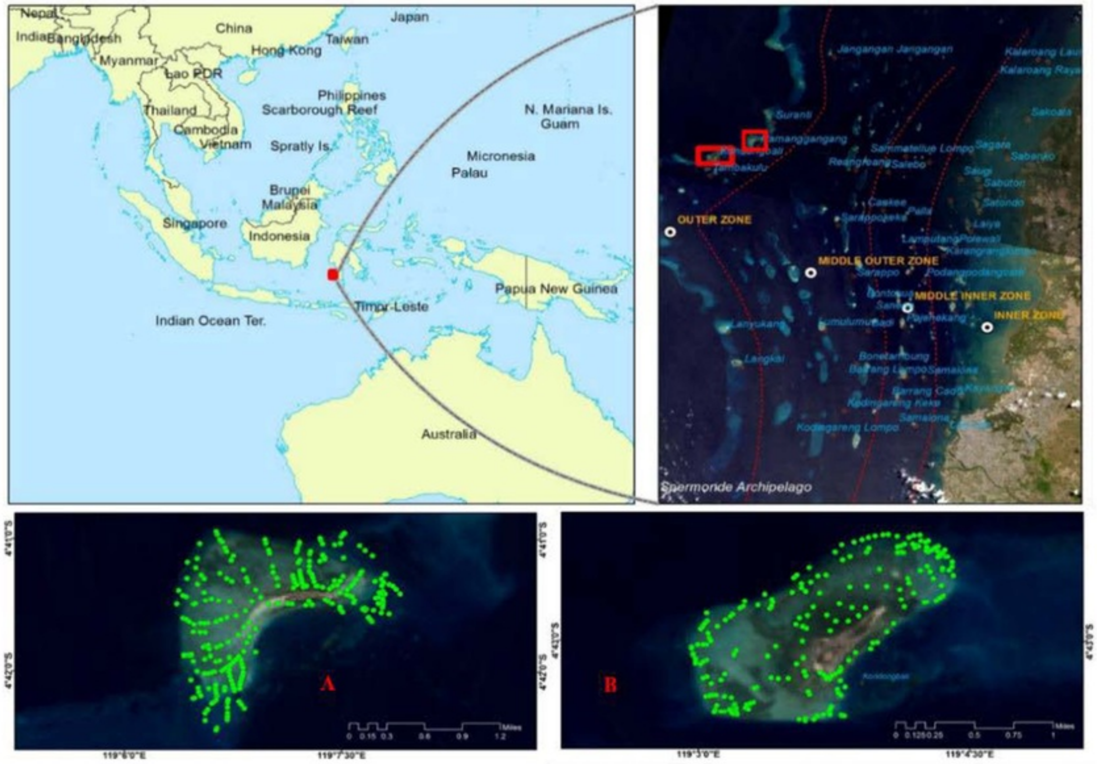

Figure 1. Maps showing two small islands located in an outer zone of Spermonde Archipelago, South Sulawesi, Indonesia (upper maps) and ground truth points (green dots) in Pamanggangang Island without residents (lower left panel: a) and Gondongbali Island with residents (lower right panel: b).

Table 1. Data of LANDSAT images analyzed in this study

No	Satelite	Sensor	Resolution (m)	Acquisition
1	Landsat 1	MSS	60	28 October 1972
2	Landsat 3	MSS	60	02 November 1978
3	Landsat 2	MSS	60	26 October 1981
4	Landsat 4	TM	30	16 December 1990
5	Landsat 5	TM	30	23 June 1993
6	Landsat 5	TM	30	28 April 1996
7	Landsat 7	ETM	30	04 September 2005
8	Landsat 7	ETM	30	19 August 2008
9	Landsat 7	ETM+	30	04 October 2011
10	Landsat 8	OLI_TIRS	30	04 October 2013
11	Landsat 8	OLI_TIRS	30	10 September 2016

Satelite images were analyzed with an unsupervised classification which automatically groups pixels in an image into separate clusters, depending on their spectral features. Although several methods are available for the unsupervised classification, we used ER-Mapper's unsupervised ISO class algorithm to simultaneously classify pixel information of DII into six clusters of habitats in a coral reef ecosystem: live coral, dead coral with algae, rubble, seagrass, sand, and mix bottoms. Figure 3 shows pictures of rubble and dead coral with algal habitats.

Ground truthing and accuracy assessment

Ground truthing was conducted to determine actual habitat distributions by taking pictures with a waterproof digital camera (Tough TG Tracker, Olympus). Time synchronization of a GPS logger (m-241, Holux) was done and the camera was automatically linked to location coordinates of a picture taken in situ. Information of seabottom covers and their locations identified with pictures and GPS was entered to a geographic information system (GIS) (ArcGIS, ESRI). Data from 256 sites in PI (without residents) and 224 sites in GI (with residents) were obtained by field surveys using a boat from 16 to 20 August 2016 (Fig. 1).

Actual bottom covers were then compared to habitat types classified with the unsupervised classification from the satellite image taken in 2016 to examine an accuracy of a map (Campbell 2007) (Fig. 2). The accuracy of the habitat map was assessed using a standard error matrix. Producer's accuracy is a probability that the predicted class actually represents what is on the ground and is useful for assessing the accuracy of individual classes (Mumby et al. 1997). Overall accuracy is useful for assesing the accuracy of habitat map.

Temporal changes in spatial distributions of habitats in coral reef ecosystem

Temporal changes in coral habitats are examined for identifying, describing, and quantifying differences by comparing habitat maps of the same scene at different times (Lillesand and Kiefer 2000). In this study, we examined percentage covers of six habitats in two islands in each LANDSAT image from 1972 to 2016 by using habitat areas based on the above-mentioned classification.

RESULTS

Overall accuracy of unsupervised classification of LANDSAT images in 2016

Classified habitats from LANDSAT images for 2016 are shown in Figs. 4 and 5. The accuracy assessment showed overall accuracies of 83.5% (Table 2) for the six habitats types (i.e., live coral, dead coral cover with algae, rubble, mix bottom, seagrass and sand) for PI and 84.0% for GI (Table 3). The results mean that the unsupervised classification can obtain sufficient accuracy for classification of habitats. Therefore, we applied the method to images for other years supposing that the unsupervised classification can classify the LANDSAT images for other years at an accuracy of classification sufficient for mapping similar to that for 2016.

Time series of classified habitats in PI and GI

Figures 4 and 5 show the habitat distributions in PI and GI from 1972 to 2016. Spatial distributions of coral reef habitats showed a continual changes from 1972 to 2016. This indicates that the analysis method is appropriate for mapping coral habitats. In PI, the live coral habitat changed to rubble, mix bottom or dead coral with algae in the south and east areas of the

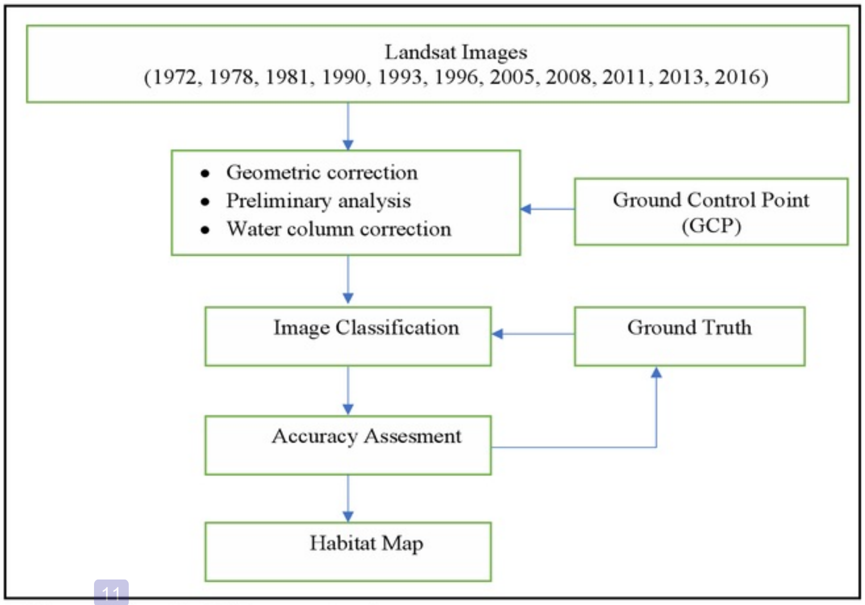

Figure 2. Flow chart of image processing

PI lagoon since 1978 (Fig. 4). Since 2005, the live coral habitat in an inner area located west of the lagoon in 1996 directly changed to the rubble habitat and that in fringe areas southwest and east of the lagoon changed to dead coral with algae or rubble habitats. In the southwest area of the lagoon, the live coral habitat and dead coral with algae habitat in 1996 changed to the dead coral with algae and rubble habitats in 2005, respectively, and these changes have expanded gradually till 2016. The seagrass habitat increased from 1990 and were relatively stable from 2015 to 2016 occupying a small part of the lagoon.

In GI, habitats of a live coral and sand encircled semicircular-concentrically the island in 1972 (Fig. 5). The live coral habitat located near the sand habitat has started to be turned partly to a rubble habitat since 1978. In 2005, the live coral habitat in the outer reef and that located at a broad band area onshore ward from the outer reef in 1996 changed to the dead coral with algae habitat and rubble habitat, respectively. The latter has expanded till 2016. In 1990, a large area of the sand habitat encircling the island in 1981 changed to a seagrass habitat. In 2005, the seagrass habitat in 1996 extended the area to the east and west, which remained till 2016.

Temporal changes of coral reef habitats in two islands

The results of satellite image analysis for 1972-2016 indicated that the total areas of six habitats in each image were relatively constant, ranging between 427.7 and 438.6 ha for PI (Table 4) and between 337.6 and 340.3 ha for GI (Table 5). The area of live coral in PI decreased by 174.4 ha, while the rubble

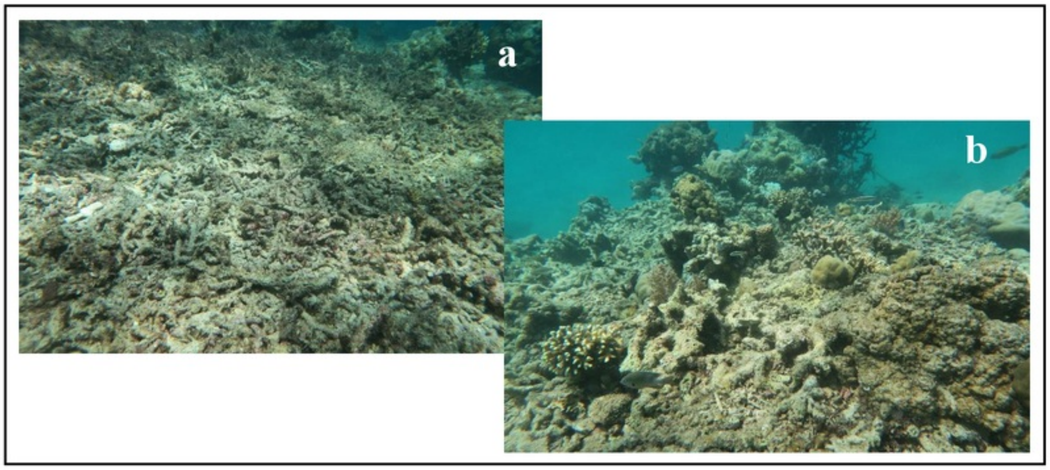

Figure 3. Underwater pictures of a rubble habitat (a) and a dead coral habitat (b) in the lagoon of Gondongbali Island taken during a field survey

Table 2. Confusion matrix of unsupervised classification of the LANDSAT OLI image on Pamanggangang Island (without residents) taken in 2016

Habitats Classification	Reference Data						Row Total	Commission error	User's accuracy
	Live coral	Dead coral	Rubble	Sand	Sea-grass	Mix bottom			
Live coral	51	3	2	1	0	4	61	10	83.6
Dead coral	0	35	4	0	0	5	44	9	79.6
Rubble	3	2	37	0	2	1	45	8	82.2
Sand	0	0	2	24	0	1	27	3	88.9
Seagrass	0	0	2	0	27	3	32	5	84.4
Mix bottom	0	0	4	1	1	41	47	6	87.2
Coloum total	54	40	51	26	30	55	256	41	
Ommission error	3	5	14	2	3	14	41		
Producer's accuracy	94.4	87.5	72.6	92.3	90.0	74.6			
Overall accuracy									**84.0**

Table 3. Confusion matrix of unsupervised classification of the LANDSAT OLI image on Gondongbali Island (with residents) taken in 2016

Habitats Classification	Reference data obtaine by ground truthing						Row total	Commission error	User's accuracy
	Live coral	Dead coral	Rubble	Sand	Sea-grass	Mix bottom			
Live coral	39	4	2	1	0	3	49	10	79.6
Dead coral	0	29	3	0	0	3	35	6	82.9
Rubble	2	2	27	0	1	2	34	7	79.4
Sand	0	0	2	25	0	2	29	4	86.2
Seagrass	0	0	1	0	36	2	39	3	92.3
Mix bottom	0	0	3	2	2	31	38	7	81.6
Coloum total	41	35	38	28	39	43	224	37	
Ommission error	2	6	11	3	3	12	37		
Producer's accuracy	95.1	82.9	71.1	89.3	92.3	72.1			
Overall accuracy									**83.5**

area increased from 0.7 ha to 66.4 ha (Table 4). The areas of live coral in GI decreased from 173.8 ha to 62.4 ha (Table 5). In contrast, the areas of dead coral with algae and rubble increased from 0.7 and 2.6 ha to 32.5 and 43.4 ha, respectively (Table 5).

We compared six habitat areas in percentages in each image to avoid a difference of the total areas among images although the total areas of six habitats from LANDSAT images obtained with sensors with different spatial resolutions were constant as mentioned above. Figure 6 shows that the percentages of live coral to the total area in each year from 1972 to 2016 when those in 1972 were set to 100%. In both islands, the decreasing tendency was very clear. The decreasing speed of live coral habitat in GI was slightly greater than that in PI.

Percentages of a live coral habitat area were compared with other habitat area consisting of dead coral with algae, rubble and mix bottom in PI. A decreasing speed of live coral habitat area was about 1% of the total area of six habitats in 1972 per year while an increasing speed of other habitats was 1% per year (Fig. 7). In GI, a decreasing speed of live coral habitat area was about 0.8% of the total area per year while an increasing speed of other habitats was 0.6% per year (Fig. 8). Percentages of sand to the total habitat area in GI was compared with seagrass habitat area (Fig. 9). An increasing tendency of seagrass habitat area was compensated with a decresing tendency of sand habitat area. The increase of seagrass habitat and the decrease of sand habitat occured stepwise in three periods: from 1972 to 1981, from 1990 to 1996 and from 2005 to 2016.

DISCUSSION

An increase in sea surface temperatures due to global warming has caused mass bleaching of corals resulting in corals and other symbiotic invertebrates losing their characteristic brown color. Williams and Bunkley-Williams (1990) reported that mass

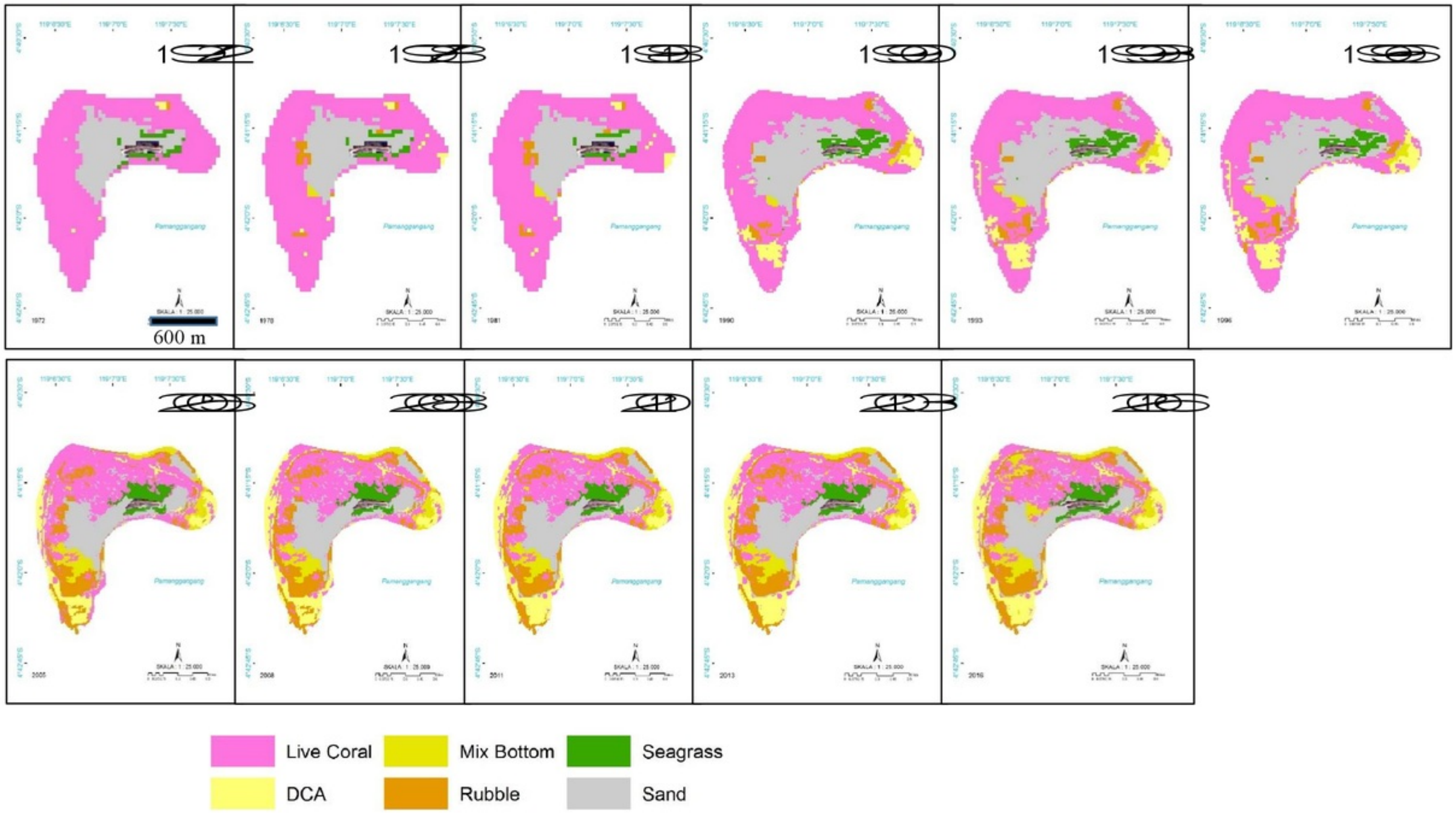

Figure 4. Temporal changes in coral reef habitat distributions in Pamanggangang Island without residents from 1972 to 2016. DCA is a habitat that dead coral is covered with algae.

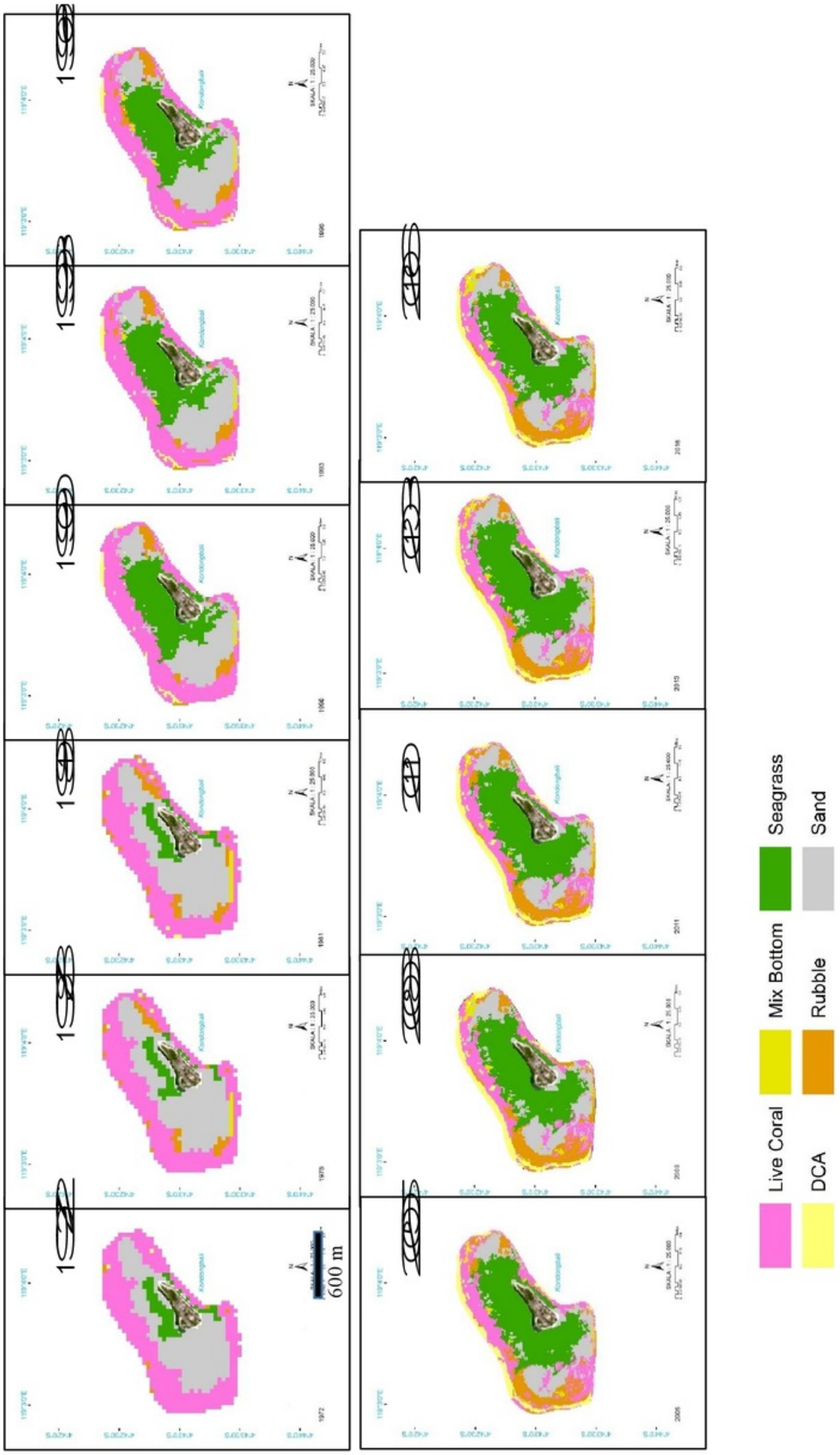

Figure 5. Temporal changes in coral reef habitat distributions in Gondongbali Island with residents from 1972 to 2016. DCA is a habitat that dead coral is covered with algae.

Table 4. Areas of coral reef habitats of Pamanggangang Island estimated from satellite image analysis from 1972 to 2016

Pamanggangang Island	Areal (Ha)										
	1972	1978	1981	1990	1993	1996	2005	2008	2011	2013	2016
Live Coral	317.0	302.6	300.1	248.5	234.8	229.5	175.0	155.6	151.9	150.1	142.6
Dead Coral with Algae	2.6	5.9	7.4	26.0	33.6	37.0	48.1	58.3	61.9	61.9	62.4
Rubble	0.7	9.5	10.3	12.4	15.9	17.6	61.3	69.9	68.8	69.6	66.4
Sand	98.9	100.3	101.1	126.4	127.5	128.3	92.2	92.0	92.7	93.4	87.6
Seagrass	12.5	11.1	10.3	18.9	17.8	17.0	20.7	20.9	21.1	21.3	23.2
Mix Bottom	0	2.2	2.6	6.3	8.9	9.2	31.7	32.3	32.5	32.6	45.5
Total	431.7	431.6	431.8	438.5	438.5	438.6	429	429	428.9	428.9	427.7

Table 5. Areas of coral reef habitats of Gondongbali Island estimated from satellite image analysis from 1972 to 2016

Gondongbali Island	Areal (Ha)										
	1972	1978	1981	1990	1993	1996	2005	2008	2011	2013	2016
Live Coral	173.8	153.1	147.2	127.2	122.7	117.9	79.8	71.9	67.0	66.4	62.4
Dead Coral with Algae	0.7	1.1	2.2	6.6	7.5	8.0	27.1	29.5	31.8	32.0	32.5
Rubble	2.6	18.8	22.9	15.4	17.6	21.2	36.9	42.1	44.3	41.8	43.4
Sand	133.9	138.7	137.3	93.9	94.1	95.3	63.1	62.8	62.5	65.2	71.1
Seagrass	26.6	21.8	23.2	94.9	94.6	93.4	128.2	128.5	128.8	128.3	122.5
Mix Bottom	0	4.1	4.8	2.0	3.3	4.0	5.2	5.5	5.8	6.6	8.4
Total	337.6	337.6	337.6	340	339.8	339.8	340.3	340.3	340.2	340.3	340.3

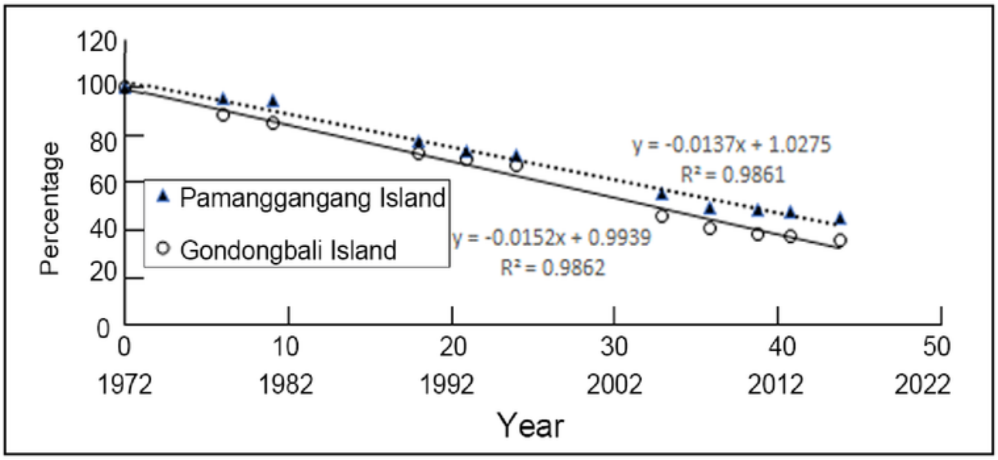

Figure 6. Percentages of live coral habitat areas in Pamanggangang and Gondongbali Islands obtained from analysis of the LANDSAT images

bleaching events occurred approximately at every 3- to 4-year intervals since 1979 accompanied by a significant mortality of bleached corals. On the other hand, three global events occurred in 1998, 2010 and 2015/16 (Heron et al. 2016). Moreover, mass bleaching events due to periods of elevated ocean surface temperatures have increased in frequency over the past decades (Hoegh-Guldberg 1999; Eakin et al. 2009). If the mass bleaching occurred in Spermonde Archipelago, it is estimated that the live coral habitat was massively changed to dead coral habitat. Since the decreasing speeds of live coral habitat in the lagoons of PI and GI were constant, it is possible that the intervals of 11 satellite images analyzed are too long to know the impacts of mass bleaching through habitat mapping. Mass bleaching events have continuously changed the live coral habitat to dead coral with algae, rubble or mix bottom habitats at intervals of 2 to 5 years for 44 years in the Spermonde Archipelago. Since repeated bleaching might diminish recovery capacity of corals (Schoepf et al. 2015), it is thought that the decreasing speeds of live coral habitat in both islands were constant for 44 years and the difference of decreasing speed between two islands of GI and PI is small because mass bleaching occurred at a regional scale.

Another possible cause for the observed decrease of the live coral habitat is a human impact such as cyanide and dynamite fishing. Dynamite (blast) fishing destroys the live coral reef (Pauly et al. 1989) which is an important habitat for fishes and invertebrate. Although dynamite fishing was banned in Indonesia in 1985, it is still applied in many areas (Djohani, 1995), including the Spermonde Archipelago. Illegal fishing is conducted in lagoons of islands not only without residents but also with residents if these lagoons produce fish resources. Since blast fishing operations used boats in Indonesia (Pet-Soede et al. 1999), live corals in PI without residents are also impacted by the destructive fishing. Thus, the difference in the decreasing speeds of the live coral habitat in both islands with and without residents was very small.

The rubble habitat appeared in the inner area of live coral habitat in PI in 2005 and in GI in 1978. If the waves and surface temperature damaged live corals, the former hits those in the crest or outer reef and the latter destroys those in the shallowest area in the lagoon. Thus, it is possible that the alteration of live corals to rubble in the inner area of live coral habitat in PI and GI is caused by blast fishing because the live corals directly changed to rubble not dead coral with algae, since the latter being the case where live corals changed after mass bleaching.

A seagrass habitat has expanded greatly in GI (with residents) since 1990s although PI and GI are under very similar marine conditions. In Ishigaki Island, Japan, seagrass densities in two study sites were compared. Densities of dominant seagrasses such as *Thalassia hemprichii* within 200 m of the coastline was 500–1,500 shoots/m^2 at Shiraho Reef, but only 0–100 shoots/m^2 at the Kabira Reef (Tanaka 1999). Since environmental factors such as texture of sediments and bottom depths at both seagrass sites are similar, the above difference in seagrass densities may be caused by the difference in anthropogenic nutrient supplies (Umezawa et al. 2002). Crossland (1982) pointed to the high nitrogen concentrations in groundwater as a significant factor in the high biomass of macroalgae along the upper littoral fringe at Okinawa. Umezawa et al. (2002) estimate that

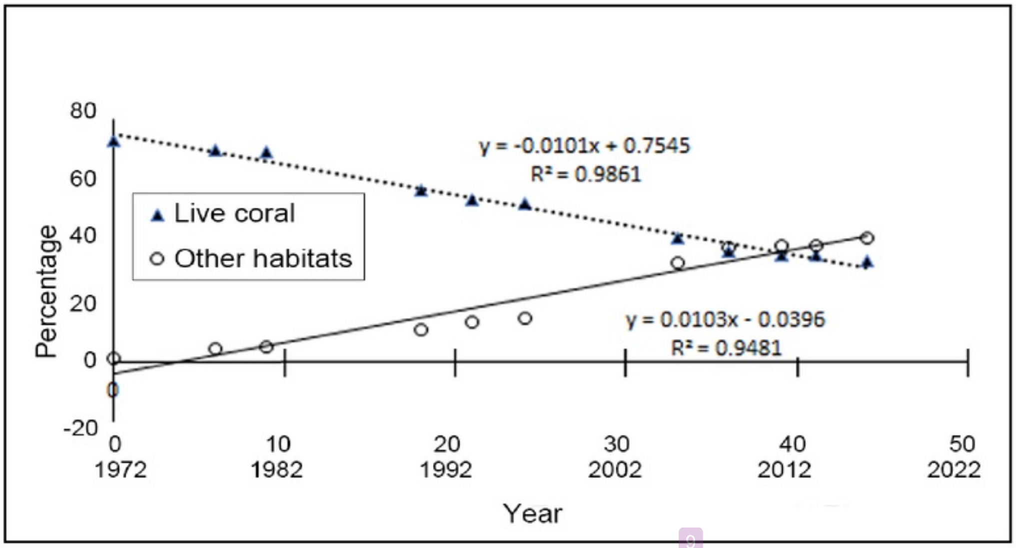

Figure 7. Percentages of a live coral habitat area and other habitat area consisting of dead coral with algae, rubble and mix bottom to the total area in Pamanggangang Island obtained from analysis of the LANDSAT images.

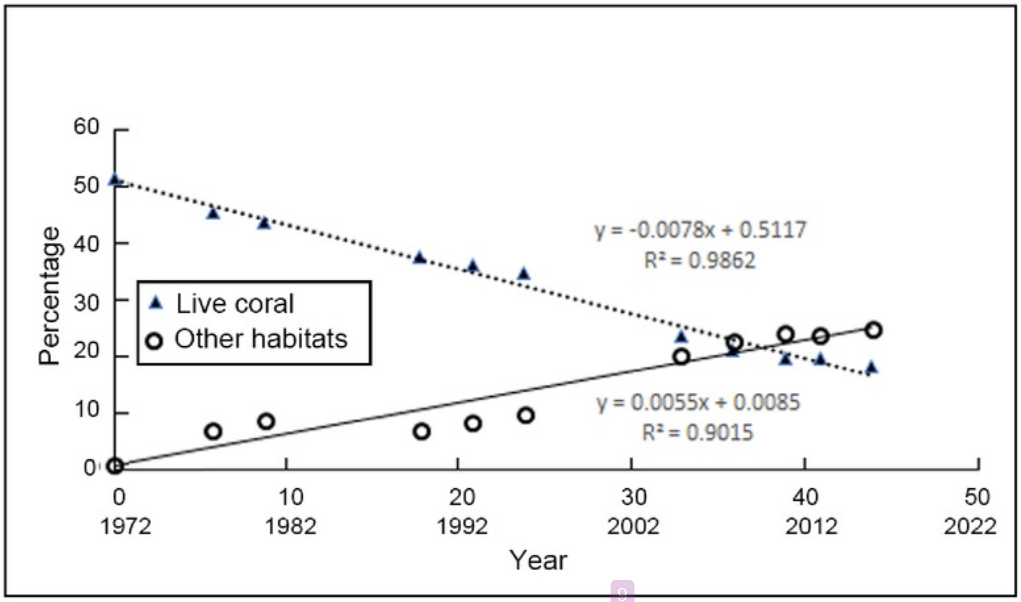

Figure 8. Percentages of live coral area and other habitat area consisting of dead coral with algae, rubble and mix bottom in Gondongbali Islands obtained from analysis of the LANDSAT images.

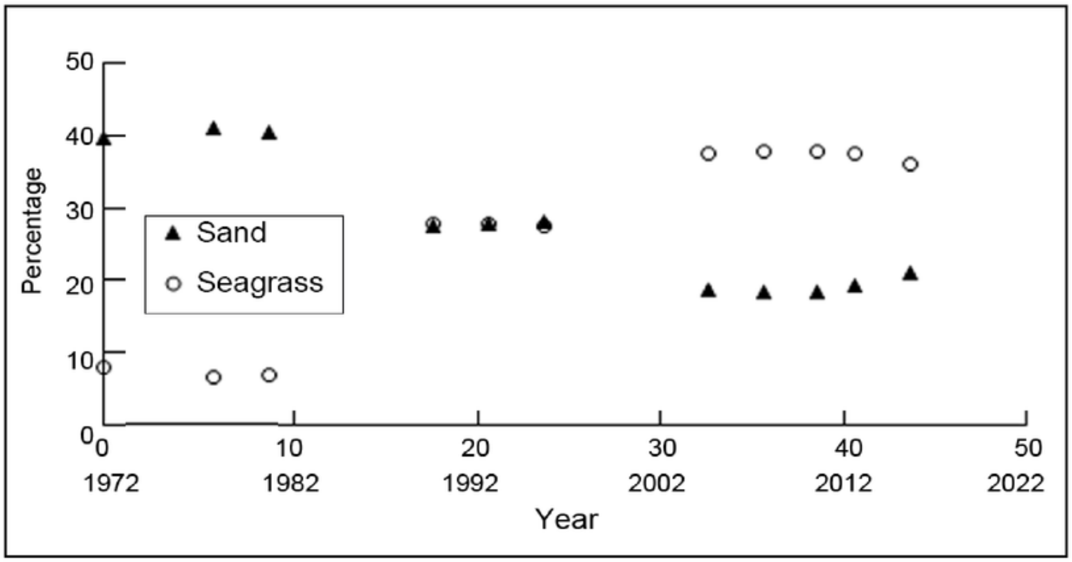

Figure 9. Percentages of sand and seagrass habitat areas to the total habitat area in Gondongbali Islands obtained from analysis of the LANDSAT images in years when LANDSAT images were taken.

land use and area of the adjacent watershed are responsible for the abundance and production of nearshore reef vegetation (e.g. seagrass and benthic algae) and conclude that land-derived nitrogen delivered through groundwater has an important role in the nitrogen cycle of the nearshore reefs. In the Great Barrier Reef lagoon, impacts of eutrophication on coral reefs namely, increased dominance of macroalgae and filamentous algae and expansion of seagrass beds into regions which in the past were renowned for their corals, has been recorded (Bell 1992). These reports suggest a possibility that the expansion of a seagrass habitat in GI is caused by a nutrient input from groundwater originated from house sewage including nutrients discharged by residents in GI while the area of seagrass habitat has remained narrow in PI without residents during the same period. Since a level of nutrients may be changed by the number of residents in GI, the seagrass habitat area in GI could be changed stepwise from 1972 to 2016. According to two census on demography in Spermonde Archipelago, Ministry of Maritime and fisheries Affairs reported 1,171 residents in GI in 2007 and Central Bureau of Statistik, Pangkep Regency, South Sulawesi did 1,725 residents in 2017. These data support the above discussion. It is noted that the decreasing speed of a live coral in GI with residents is slightly higher than in PI without residents.

This study suggests the global warming and illegal fishing are main drivers of decrease in live corals as well as several other studies (Crean 2000; Haynie et al. 2009). It is possible to control the latter driver through social norms as regulators for the use of marine resources as a common property. The fishers regarded the size of their boats as limiting rather than the available resource space in Indonesia (Pet-Soede et al. 1999). Therefore, an awareness campaign is important to explain to villagers conditions of live corals through their participation to monitoring program of coral reefs. It succeeded in Komodo National Park, Indonesia (Pet-Soede et al. 1999). Another key factor is that interventions to ban blast fishing must include the development of alternative livelihoods for local fishers such as offshore fishing, aquacultures. If and when enforcement programs are effective in pushing the blast fishers out of the practice, other income opportunities need to be available. Another suggestion is to set an area of which resources local fishermen manage by creating ownership in order to promote conservation of coral reef based on local wisdom. However, blast fishing boats must be controlled by the police strictly.

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LITERATURE CITED

Bahuguna A, Nayak S, Roy D. 2008. Impact of the tsunami and earthquake of 26th December 2004 on the vital coastal ecosystems of the Andaman and Nicobar Islands assessed using RESOURCESAT AWiFS data. International Journal of Applied Earth Observation and Geoinformation 10: 229–237.

Bell PRF. 1992. Eutrophication and coral reefs—some examples in the Great Barrier Reef lagoon. Water Research 26(5): 553-568.

Campbell LM. 2007. Local conservation practice and global discourse: A political ecology of sea turtle conservation. Annals of the Association of American Geographers. 97(2): 313-334.

Crean K. 2000. Contrasting approaches to the management of common property resources: An institutional analysis of fisheries development strategies in Shetland and the Solomon Islands. Australian Geographer 31(3): 367-382.

Crossland CJ .1982. Dissolved nutrients in reef waters of Sesoko Island, Okinawa: a primary study. Galaxea 1: 47–54

Djohani R. 1995. The combat of dynamite and cyanide fishing in Indonesia. Jakarta: The Nature Conservancy. p. 47.

Eakin CM, Lough JM, Heron SF. 2009. Climate variability and change: monitoring data and evidence for increased coral bleaching stress. In: van Oppen MJH and Lough JM, editors. Coral bleaching: patterns, processes, causes and consequences. Berlin: Springer. pp. 41–67.

Green E, Mumby P, Edwards A, Clark C. 2000. Remote Sensing: Handbook for Tropical Coastal Management. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO). 316 p.

Haynie AC, Hicks RL, Schnier KE. 2009. Common property, information, and cooperation: Commercial fishing in the Bering Sea. Ecological Economics. 69(2): 406-413.

Heron SF, Maynard JA, van Hooidonk R, Eakin CM. 2016. Warming trends and bleaching stress of the World's coral reefs 1985-2012. Scientific Reports 6: 38402. Available from: https://www.nature.com/articles/srep38402

Hoegh-Guldberg O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research 50: 839–866.

Lillesand, T. M., and R. W. Kiefer. 2000. Remote sensing and image interpretation, 4th ed. New York: Wiley. 736 p.

Lyzenga D. 1978. Passive remote sensing techniques for mapping water depth and bottom features. Applied Optics 17(3): 379–383.

Lyzenga D. 1981. Remote sensing of bottom reflectance and water attenuation parameters in shallow water using aircraft and Landsat data. International Journal of Remote Sensing 2(1): 71–82.

Mumby PJ, Green EP, Edwards AJ, Clark CD. 1997. Coral reef habitat mapping: how much detail can remote sensing provide?. Marine Biology 130(2): 193-202.

Nurdin N, Komatsu T, Agus, Akbar AS M, Djalil AR, Amri K. 2015. Multisensor and multitemporal data from Landsat images to detect damage to coral reefs, small islands in the Spermonde Archipelago, Indonesia. Ocean Science Journal 50(2): 1-9.

Nurdin N, Komatsu T, Rani C, Supriadi, Fakhriyyah S, Agus. 2016. Coral reef destruction of small island in 44 years and destructive fishing in Spermonde Archipelago, Indonesia. IOP Conference Series: Earth and Environmental Science 47(1): 012011. Available from: http://iopscience.iop.org/article/10.1088/1755-1315/47/1/012011

Pauly D, Silvestre G, Smith IR. 1989. On development, fisheries and dynamite: a brief review of tropical fisheries management. Natural Resources Modelling 3(3): 307–29.

Pet-Soede C, Cesar HS, Pet JS. 1999. An economic analysis of blast fishing on Indonesian coral reefs. Environmental Conservation 26(2): 83-93.

Schoepf V, Grottoli AG, Levas SJ, Aschaffenburg MD, Baumann JH, Matsui Y, Warner ME. 2015. Annual coral bleaching and the long-term recovery capacity of coral. Proceedings of the Royal Society B: Biological Sciences 282(1819): 20151887. Available from: http://doi.org/10.1098/rspb.2015.1887

Tanaka Y. 1999. Seagrass distribution and its ruling factors in Ishigaki Island, Okinawa, Japan (in Japanese with English abstract). Master Thesis, Department of Geography, University of Tokyo. Tokyo: University of Tokyo. P. 76.

Umezawa Y, Miyajima T, Yamamuro M, Kayanne H, Koike I. 2002. Fine-scale mapping of land-derived nitrogen in coral reefs by δ^{15} N in macroalgae. Limnology and Oceanography 47(5): 1405–1416

Williams Jr EH, Bunkley-Williams L. 1990. The world-wide coral reef bleaching cycle and related sources of coral mortality. Atoll Research Bulletin 335: 1-71.

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