



The status of coral reefs in central Vietnam's coastal water under climate change

Le Doan Dung

Ho Chi Minh University of Food Industry (HUFI), 140 Le Trong Tan Street, Tan Phu District, Ho Chi Minh City, Vietnam

*Corresponding author: dungld@cntp.edu.vn

The coral reef ecosystem plays an important role in scientific research and economy. An assessment research on status of the coral reefs was carried out at 6 sites of coastal water from Nghi Son (Thanh Hoa province) to Vung Ro (Khanh Hoa province), Viet Nam between October and December 2015. The research was done using the manta tow method for rapid reef assessment and reef area determination, using reef check for detailed assessment of reef substrate types, etc. 288 species of hard corals under 57 genera and 14 families were identified from the study sites. These species mainly belonged to 4 families, namely Acroporidae, Faviidae, Poritidae and Fungiidae. The research showed the bad condition of the reef at all study sites through such indicators as a low live hard coral cover (average cover of 19.8%), high dead coral cover, recently killed coral, fleshy seaweed, etc. Most of surveyed transects had poor level of hard coral cover, the number of transects having good coral cover was insignificant. The total reef area of 6 surveyed sites was 809.5 hectares, mainly occupied in Son Tra and Vung Ro. This was the first time coral disease and bleaching widely ranged had been observed and described. However, the reason of this phenomenon has not been mentioned yet and there is a need for more detailed researches on these problems in the coming time to have a basis for protection and management of coral reef ecosystem in Vietnam's coastal water.

Keywords: biodiversity, coral bleaching, hard coral, reef area

Introduction

Coral reefs are believed to have a high biodiversity and to be one of the oldest ecosystems on the planet. They serve as habitat for about 4,000 species of fish, 800 species of reef-building corals and millions of other species. Nearly one-fifth of animal protein intake of the human is from marine organisms. Annual profit from exploitation of reef resources was calculated at US\$ 100 billion (Vo and Nguyen, 2001). Net profit of coral reef

fisheries of southeast Asian countries was estimated at US\$ 2.4 billion per year (Burke, 2002).

In Vietnam's seawaters, about 500 species of endemic coral reef fish was identified. The reef fish biomass in Truong Sa (Spratly) islands was estimated at 114 tons per square kilometer of reef, equal to US\$ 78,000-105,000 per square kilometer of reef (Vo and Nguyen, 2001). Apart from fish, coral reefs also support many species of high economic values such as tiger shrimp, abalone, pearl, sea cucumber, etc.

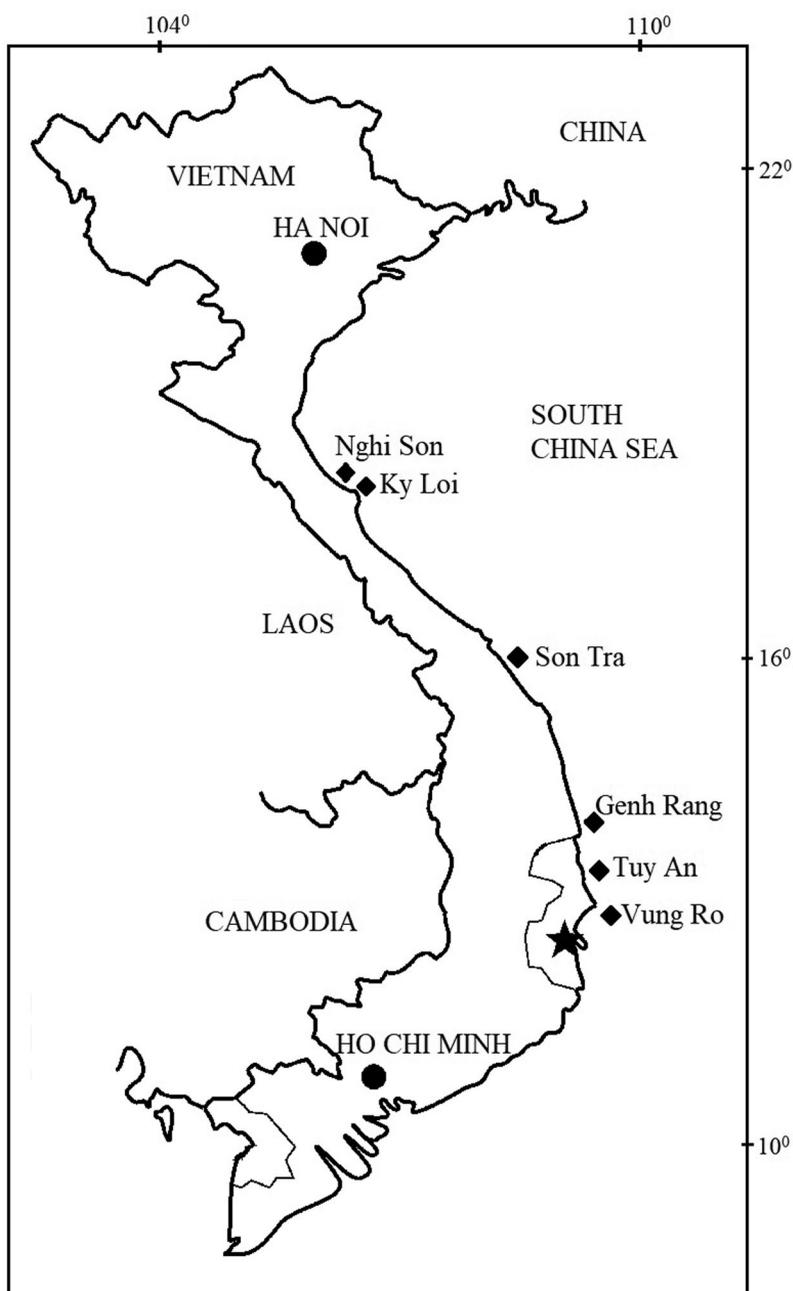


Figure 1. Map of Vietnam showing the six study sites with solid rhombus in 2015.

Because many reef-inhabiting organism groups have biological activities and medicinal properties, coral reefs are considered as a repository of precious medicines at sea. The value of coral reefs is also known in terms of entertainment and tourism (Vo et al., 2008). The coral reefs in coastal areas also works as underground

dikes protecting the coastal communities from bad effects of the erosion, tides and storms.

Like many coral reefs in the coastal area of Vietnam and other countries in the world (Wilkinson, 2000, 2008), coral reefs of central Vietnam are being negatively affected and being degraded. The present study shows species

Table 1. Species composition of hard corals in six study sites.

No.	Study site	Family	Genus	Species
1	Nghi Son-Thanh Hoa	10	25	48
2	Ky Loi-Ha Tinh	10	23	80
3	Son Tra-Da Nang	14	41	105
4	Ghenh Rang-Binh Dinh	13	41	148
5	Tuy An-Phu Yen	14	43	103
6	Vung Ro-Khanh Hoa	14	54	235
Total		14	57	288

composition, coral cover, coral area, and some information on coral bleaching at some locations in Central Vietnam. The results on the status of coastal coral reefs will help scientists and managers to put forward effective solutions for protection, rational utilization and sustainable development of the coastal coral reef ecosystem.

Material and methods

Study sites and time

The coral ecosystem in coastal zone was surveyed at six sites, including Nghi Son (Thanh Hoa province), Ky Loi (Ky Anh, Ha Tinh province), Son Tra peninsula (Da Nang city), Ghenh Rang (Binh Dinh province), Tuy An (Phu Yen) and Vung Ro (Khanh Hoa province) (Fig.1). All coral reefs are fringing reefs. The average values of water salinity and dissolved oxygen were 26.5‰, 7.1 mg l⁻¹ in Nghi Son; 28.3‰, 6.2 mg l⁻¹ in Ky Loi; 28.8‰, 6.2 mg l⁻¹ in Son Tra; 26.0‰, 6.4 mg l⁻¹ in Ghenh Rang; 30.5‰, 6.9 mg l⁻¹ in Tuy An; and 31.6‰, 5.9 mg l⁻¹ in Vung Ro, respectively.

On-site surveys were conducted between October and December 2015.

Biodiversity of hard corals

The method used to investigate the biodiversity was line transect. Each study site had ten reef locations in order to present the biodiversity in the reefs. One transect of each location was established perpendicular to the shoreline and lay along the bottom of the profile to a water depth of 15 meters. Then the hard corals found on-site were classified based on their colony formation, external structure and natural color (Latypov,

2011; Veron and Stafford-Smith, 2000). For the coral species which were impossibly classified on-site, their photographs and the specimens were taken for laboratory study based on their external morphology and skeleton formation of coral polyps (Latypov, 1990, 1992, 2011; Veron and Stafford-Smith, 2000).

Coverage of hard living coral and other substrates

Survey to assess benthic cover was conducted using SCUBA at ten reef locations of each study site. Two 100m long line transects were laid at shallow (3-5 m) in reef flat and deep (8-15 m) in reef slope contours of each location. Each line transect was divided into four segments with an interval of 5m: 0-20m, 25-45m, 50-70m and 75-95m. Cover of benthic components were recorded along 20 m of each the four segments in the 100 m transect line using the point intercept method with an interval of 0.5 m. According to Reef Check technique, 11 categories of substrate include hard coral (HC), soft coral (SC), dead coral (DC), recently killed coral (RKC), fleshy seaweed (FS), sponges (SP), rock (RC), sand (SD), silt/clay (SI) and other (OT).

Estimation of reef area

The manta tow method (English et al., 1994; Kenchington, 1984) was used in combination with the global positioning system GPS to record the boundary coordinates of reefs.

Calculation of reef area: the geographic coordinates of ending points of the reefs and field data are input data for MapInfo 10.0 software to estimate the coral reef area. Measurements of the distance of some GPS points representative of sampling sites were verified in order to minimize calculation errors.

Results

Coral species composition in the study areas

288 species of hard corals belonging to 57 genera, 14 families were identified at 6 study sites, of which the highest number (235) of

Table 2. Average coverage of 11 types of substrate in six study sites (Unit: %).

Site	Benthic components										
	HC	RC	DC	RKC	SC	FS	SP	Rb	SD	SI	OT
Nghi Son	3.8±4.6	32.5±12.5	3.7±5.2	0	0	5.8±8.3	4.3±2.9	6.4±9.3	18.8±17.5	10.4±9.6	14.3±11.2
Ky Loi	19.5±14.3	21.6±12.3	7.6±8.5	0.8±2.5	2.7±4.3	4.3±2.1	2.8±3.6	7.4±4.8	12.5±9.6	6.9±5.4	13.9±9.2
Son Tra	19.8±16.2	36.5±18.4	5.2±4.9	1.0±1.6	1.5±2.6	5.1±4.3	1.6±1.4	5.4±5.7	9.5±10.1	3.7±4.5	10.7±14.9
Ghenh Rang	32.2±18.6	28.5±16.8	2.2±1.4	1.2±1.3	0.8±2.1	1.4±1.9	0.8±1.7	11.3±8.5	13.9±7.4	4.8±3.9	2.9±1.7
Tuy An	17.7±12.8	28.5±15.4	2.0±1.6	0.8±1.8	1.7±1.4	3.2±3.8	2.6±5.3	8.5±7.2	10.3±10.8	7.8±6.3	16.9±13.5
Vung Ro	25.3±17.5	22.4±9.8	4.0±3.2	1.6±2.5	0.6±1.6	2.4±1.7	1.4±2.7	10.3±13.8	12.5±8.3	9.8±8.1	9.7±5.2
Average	19.8±9.4	28.3±5.7	4.1±2.1	0.9±0.5	1.2±0.9	3.7±1.7	2.3±1.3	8.2±2.3	12.9±3.3	7.2±2.7	11.4±4.9

Abbreviations: HC-Hard coral, RC-Rock, DC-Dead coral, RKC-Recently killed coral, SC-Soft coral, FS- Fleshy seaweed, SP-Sponge, Rb-Rubble, SD-Sand, SI-Silt/clay, OT-Other.

species was recorded in Vung Ro, Khanh Hoa province (south central water of Vietnam), the fewest number (48) of species in Nghi Son, Thanh Hoa province (north centre of Vietnam) (Table 1).

The species number of hard corals is mainly from 4 families, including Acroporidae (78 species, 27.1%), Faviidae (63 species, 21.9%), Poritidae (36 species, 12.5%), Fungiidae (25 species, 8.7%). The remaining families have 2-18 species. *Acropora* is the most diverse genus with 51 species (17.7%), followed by *Montipora* (23 species, 8.0%), *Porites* (17 species, 5.9%), *Goniopora* (14 species, 4.8%).

Endangered species of hard corals

According to Vietnam Red Book 2007 (Dang, 2007) and the Decision No.82/2008/QĐ-BNN of 17 July 2008 regarding regarding declaration of the list of endangered aquatic species in Vietnam which need protection, reproduction and development, 10 species in 5 genera and 3 families in the list of coral species composition were identified and classified in this study (Appendix 1).

Though two coral species of *Porites lobata* Dana, 1846 and *Pocillopora damicornis* Linnaeus, 1758 were included in the list of endangered, precious and rare species (Dang, 2007), the results of this study show that these two species are popularly observed in most surveyed sites (Nguyen et al., 2015). These two species were found in transects with rather high frequency. Therefore, it is possible to consider these two species to be excluded from the list of Red Book. In contrast, the two species of *Symphyllia valenciennesii* Edwards & Haime, 1849 and *Seriatopora dendritica* Veron, 2000 tend to be rare and endangered, so they are proposed to be added to the list of vulnerable (VU) species. Both species are now found very few, only in Vung Ro (Khanh Hoa).

Live coral cover and other benthic components

The lowest average cover of hard coral was found in the coastal area of Nghi Son-Thanh Hoa (3.8%) and the highest one in Ghenh Rang-Binh Dinh (32.2%) (Table 2). There were almost no

hard corals in Nghi Son seawater, only a few corals of Faviidae occurred here. In contrast, some areas in Vung Ro (Khanh Hoa) and Ghenh Rang (Binh Dinh) have many large colonies of hard corals. *Acropora* corals whose branches are over 1m high, and colonies of plate and encrusting corals of *Turbinaria*, *Montastrea* and *Goniastrea* genera with 1.5-2m in diameter were found rather rich. Rocky bottom substrate (RC) was found at a high level in all surveyed sites. The cover of sponge cover was insignificant, dead coral increased at some areas of Ky Loi (Ha Tinh), Son Tra (Da Nang) and Vung Ro (Khanh Hoa). Fleshy seaweed is one of the important components in the coral reef ecosystem but its coverage was very low in the study areas.

Assessment of coral reef health using a 4-point index established by Gomez and Alcalá (1984) with four categories of hard coral cover: level 1 - poor (0-24.9%); level 2 - fair (25-49.9%); level 3 - good (50-74.9%); level 4 - excellent (75-100%) showed that of 60 surveyed transects in total of the 6 study sites, 42 transects (70% of the transects) were in poor condition, 7 transects (11.7%), 8 transects (13.3%) and 3 transects (5.0%) had fair, good and excellent conditions, respectively (Fig. 2). Nghi Son area had the lowest level of live coral cover (less than 5%), while Ghenh Rang had the highest level (50-70%).

The direct observation in surveys found that many dead coral branches and debris scattered in the bottom substrate, even in some areas, colonies of live corals were being buried by silt or killed by coral bleaching (Fig. 3). The coverage of recently killed hard coral in 6 study sites was estimated at 0.9% and this was observed to be more frequent in 2 sites of Vung Ro and Ghenh Rang.

The area of coral reef in surveyed sites

In the surveyed sites, live corals and coral reefs are distributed along the coastline but most of them are narrow reef, only about 60-100m from the coastline, corals are distributed at the depth of 15-20m, so the determination of coral distribution using the method of diving and direction observation is feasible. Therefore, the results of coral reef area calculation are completely reliable.

The total area of coral reefs in 6 surveyed sites was 809.5 ha (Table 3), the largest area was of Son Tra (360 ha), and the smallest area was of Nghi Son (41.5 ha). Son Tra peninsula is large with distribution of live coral and rock around the island. Similarly, Vung Ro along the shoreline, which is formed by mountains and rocks, is an area with very favorable conditions for hard corals.

Corals are found widely distributed on rocky bottoms and smooth sloping bottoms. In contrast, reefs with the small area of distribution have unfavorable environmental conditions such as low transparency, sediment deposition, slope bottom or reefs limited by soft bottoms around the island.

Status of exploitation and utilization of coral reef resources

Exploitation of the reef resources for food

Coral reef resources are popularly exploited for food in Vietnam. The target species include marine fishes, crustaceans, mollusks, sea cucumbers, sea urchins and seaweeds. The fishing methods are very diverse, including hooks and lines, gill net or diving.

Exploitation of the reef resources for handicrafts

Marine species with aesthetic values are exploited and sold to tourists. The target species are corals, mainly *Pocillopora*, *Acropora*, and *Fungia* genera, snails with beautiful shapes and attractive colors such as cowries, tritons, helmet shells, rock shell, Chiragra spider conch, lobsters (*Panulirus orantus*, *P. longipes*), puffer fish, Hawksbill sea turtle, green sea turtle, etc. Because of increasing demand of tourists for handicrafts, the exploitation of these species is increasing, many of them are becoming rare and in danger of extinction.

Collecting ornamental organisms

Presently, the demand for marine aquarium trade is increasing in both domestic and foreign markets, so the main contributors of reef aquariums include hard and soft corals, reef fishes, crustaceans, mollusks, etc.

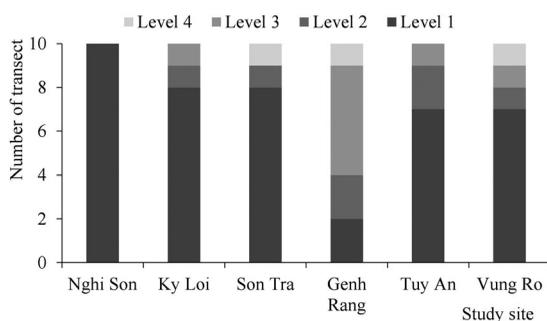


Figure 2. Coral reef quality in the surveyed transects using a 4-point index.

Exploitation of coral reef organisms for medicines

The use of marine resources as medicine in Vietnam is still limited, however, some species are quite popularly used such as algae (to cure goiter), sea snakes, seahorses, sea cucumbers (for energy boosters). Coral reefs are considered as a valuable source of medicines thanks to their rich and diverse sources of medicinal properties and bioactive compounds. Soft corals and sponges have natural compounds with high bioactivity such as antibiotics, antioxidants, endotoxins to kill cancer cells, etc.

Coral disease and bleaching

Coral bleaching was previously recorded in Vietnam as Con Dao island (Ba Ria-Vung Tau), north Binh Thuan province, Nha Trang Bay during the summer of 1998 (Chou, 2000; Vo, 2002; Vo and Nguyen, 2001) and various areas in the world (Burke, 2002; Wilkinson, 2002). This phenomenon is caused by El Nino, La Nina, hot-cold water currents, transform faults of the Earth's crust, etc. which make the seawater temperature change. In recent years, the coral bleaching phenomenon has become more common due to the effects of global warming. Many scientists have mentioned and predicted this phenomenon of coral bleaching (Goreau, Global Coral Reef Alliance, Cambridge, England, pers. comm).

In the six surveyed areas, coral disease and bleaching was observed to be often occurred in almost areas (Fig. 3). Dead corals by disease and bleaching were recorded in an area of tens square meters, such as in Ghenh Rang (Binh Dinh) (Fig. 3B), Cu Mong lagoon (Phu Yen) (Fig. 3C) or in

some places where the bleached corals were found near the shoreline and could be seen from the shore, like in Vung Ro (Khanh Hoa) (Fig. 3D). Up to now, there have been no intensive studies as well as investigations into the causes of the coral disease and bleaching in order to propose measures and solutions for bleaching prevention and effective protection of coastal coral reefs in Vietnam. However, the coral bleaching in these studied areas could be explained by some reasons, as follows: in Cu Mong lagoon (Phu Yen), the bleaching site occurred near the lagoon outlet which connects the lagoon with the sea. In 2015, there were some heavy rains in this area, rainwater and water from the mainland flow into the lagoon, then from the lagoon to the sea, which caused a freshening of the water in the place between the lagoon and the sea leading to the coral bleaching; Like the case of Vung Ro (Khanh Hoa), the area of bleached corals located just down the side of the steep mountain. Heavy rains created flows with large volume, which could freshen some water areas down the mountain causing the coral bleaching. Most bleached corals of Cu Mong lagoon and Vung Ro were branching corals that are more sensitive with the change of water environment. The dead corals of Ky Loi (Ha Tinh) and Ghenh Rang (Binh Dinh) could be explained by disease. Unfortunately, coral diseases in these areas have not been studied in detail yet.

Discussion

In Vietnam, the diversity of hard corals shows a normal distribution of organisms; that the lower latitude is, the more diverse the species composition of hard corals will be (Nguyen, 2003; Veron, 1998). The trend of increasing number of coral species and reef fishes from north to south was also recorded in some previous studies (Chou, 2000; Nguyen et al., 2015; Vo et al., 2008). The coral reefs in the coastal waters of Vietnam are characterised by the highly diverse coral fauna. This is most likely due to the geographical location of Vietnam, which is in close proximity to the dispersal centre in the Philippines and Indonesia (Vo et al., 2008). This is also due to Vietnam's coastline crossing many latitudes and the related gradients in physical and chemical environments. These are main factors affecting the biodiversity of corals (Veron, 1998).

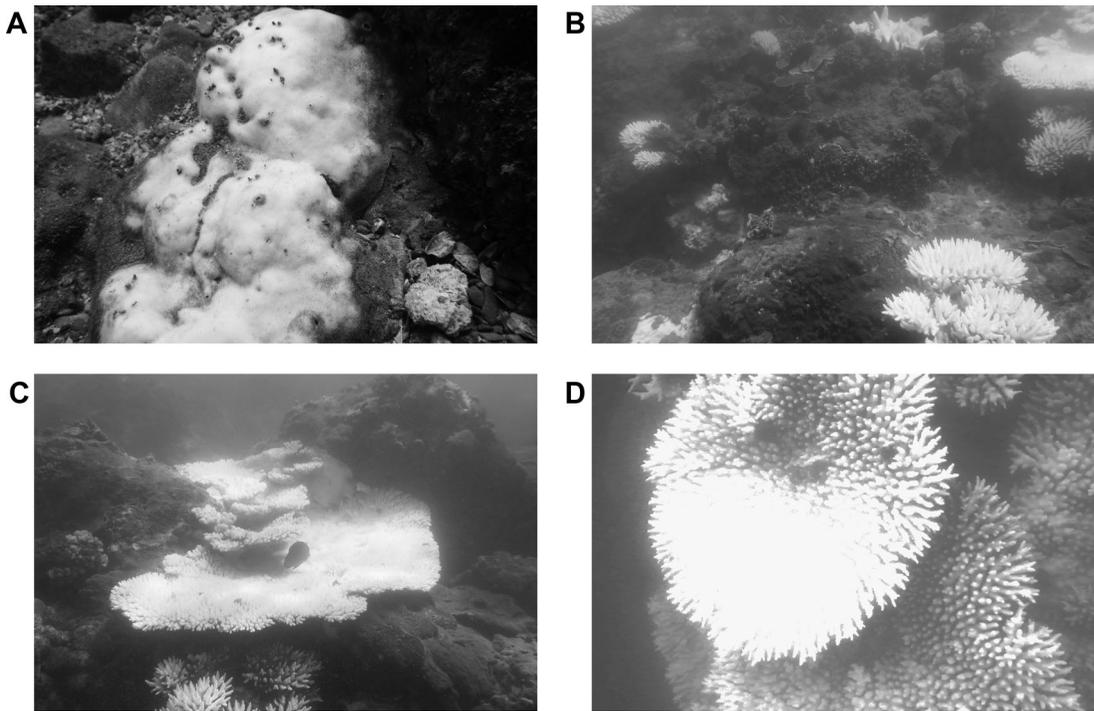


Figure 3. Dead coral by disease and bleaching in Ky Loi - Ha Tinh (A); Ghenh Rang - Quy Nhon (B); Cu Mong lagoon - Phu Yen (C) and Vung Ro - Khanh Hoa (D) (Photo by Le Doan Dung, 2015).

Table 3. The area of coral reefs distributed in six study sites.

Site	Total of length of reef (m)	Average of width of reef (m)	Total area (ha)	Average live coral cover (%)
Nghi Son	5,191	80	41.5	3.8
Ky Loi	10,200	77	78.5	19.5
Son Tra	30,000	120	360.0	19.8
Ghenh Rang	10,400	85	88.4	32.2
Tuy An	9,200	75	69.0	17.7
Vung Ro	18,500	93	172.1	25.3
Total			809.5	19.8

Two species of hard corals *Porites lobata* Dana, 1846 and *Pocillopora damicornis* Linnaeus, 1758 were in the list of vulnerable (VU) species of Vietnam Red Book (Dang, 2007) because these two species had small biomass and density at that time. However, since 2007, thanks to good management, the two species have been gradually recovered and presently they are found in almost the surveyed sites with rather high frequency. Therefore, these two species are suggested to be removed from the list of VU species in Vietnam Red Book. On the contrary, of the six

study sites, snake brain coral (*Symphyllia valenciennesii* Edwards & Haime, 1849) and stony coral (*Seriatopora dendritica* Veron, 2000) have been found only in some transects of Vung Ro - Khanh Hoa with very low biomass. Hence, it is suggested that the two species be added in the list of vulnerable species (VU) of Vietnam Red Book. The distribution of live coral cover in the six surveyed areas was in line with the status and common trend of the coastal coral reefs in Vietnam (Chou, 2000; Vo et al., 2008; Vo et al., 2014) and other regions in the world such as the

Philippines, the Andaman Sea (Chou, 2000), Indonesia (Tun et al., 2008), Japan (Fujiwara et al., 2000), Taiwan (Kimura et al., 2008), etc. Many surveillance and reseaches on coral reef status by Vo (2002); Le and Nguyen (2009); Le et al (2010); Nguyen et al (2015) showed that many coral reefs in the coastal areas and near islands of Vietnam had low coverage of live corals and most of the studied transects had poor level of live coral cover (level 1).

Coral reefs in the six study sites located in the coastal areas which are presently managed based on some regulations and decrees of the State, especially for seawaters with coral reefs, such as the Law on Environmental Protection (Vietnam National Assembly, 2014), the Fisheries Law 2017 (Vietnam National Assembly, 2017), Decision on approving the program of aquatic resources protection and development by 2020 (Vietnam Government, 2012). Therefore, net fishing activities are prohibited in these areas, anchorage of boats/vessels are not permitted on coral reefs, socio-economic activities on the mainland are not allowed to affect the coral reefs. However, in fact, these legal instruments have low effect level. In many areas, anchors of boats/vessels on coral reefs or coral colonies were burried under silt/sand, solid wastes were still found. The coral reefs in Ky Loi (Ha Tinh) were near the Formosa factory. The Formosa's wastewater discharge was discovered in April 2016, but this activity happened before, so the coral reefs in this area were suffered bad effects of this company's wastewater. In November 2015, when investigating the coral reefs, many dead corals and snails were found here. So that, the waste water from Formosa could be a factor causing the dead coral in Ky Loi (Ha Tinh) as reported in this study (Fig. 3A).

Conclusions

Most of coral reefs had a poor coverage of live coral (less than 25%), only 5% of coral reefs was in excellent level (higher than 75% coral coverage). Although the state management of the coastal coral reefs has been implemented, the efficiency is still low. In fact, the coral reef resources are considered to be "open access", so many socioeconomic activities often occur here leading to the poor health of coral reefs in the study sites.

Many corals died from disease and through bleaching. Unfortunately, there have been no intensive studies as well as investigations into the causes of the dead coral. In order to propose measures and solutions for effective protection and management of coastal coral reefs in Vietnam, more detailed studies on coral disease and bleaching are needed.

Supplemental Material

Supplemental material and a statement indicating: Supplemental material for this article is accessible on the publisher's website.

Acknowledgements

I wish to thank the members of Research Department of Marine Conservation, Research Institute for Marine Fisheries (Hai Phong city, Vietnam) for their support during my field trips as well as during my working in the laboratory. I am deeply grateful to the editor and the referees who carefully reviewed my manuscript.

References

- Burke, L., Selig, L., Spalding, M., 2002. Reefs at risk in Southeast Asia. In: R.S Pomeroy (Ed.), *How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected area*, pp. 485–502. doi: Ocean & Coastal Management 48.
- Chou, L.M., 2000. Southeast Asian Reefs-Status update: Campodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. In: C. Wilkinson (Ed.), *Status of coral reefs of the World: 2000*, pp. 117–130. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.
- Dang, N.T., 2007. *Invertebrates. Vietnam Red Book. Part I. Animals*. Publishing house for Sciences and Technology, Vietnam. (in Vietnamese).
- English, S., Wilkinson, C., Baker V. (Eds), 1994. *Survey manual for tropical marine resources*. Australian Institute of Marine Science, Townsville, Australia.
- Fujiwara, S., Shibuno, T., Mito, K., Nakai, T., Sasaki, Y., Chang-Feng, D., Gang, C., 2000. Status of coral reefs of East and North Asia: China, Japan and Taiwan. In: C. Wilkinson (Ed.), *Status of coral reefs of the World: 2000*, pp. 131–140. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.

- Gomez, E.D., Alcalá, A.C., 1984. Survey of Philippine coral reefs using transect and quadrat techniques. UNESCO 21, 57–69.
- Hodgson, G., Waddell, S., 1997. *International Reefcheck Core Method*. University of California at Los Angeles.
- Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C., Torres, R. (Eds.), 2006. *Reef check instruction manual: A guide to reef check coral reef monitoring*. Reef Check Foundation, Pacific Palisades, California, USA.
- Kenchington, R.A., 1984. Large area survey of coral reefs. In: UNESCO, *Comparing coral reef survey method*. Reports in Marine Science 21, 92–103.
- Kimura, T., Dai, C.F., Park, Heung-Sik., Hui, Huang, Ang, P.O., 2008. Status of coral reefs in east and north Asia (China, Hong Kong, Taiwan, south Korea and Japan). In: C. Wilkinson (Ed.), *Status of coral reefs of the World: 2008*, pp. 145–158. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.
- Latypov Iu. Ia. (Ed), 1990. *Hard coral of Vietnam I. Thamasteriidae Astrcoeniidae Pocilloporidae*. Nauka Publishing House, Russia (in Russian).
- Latypov Iu. Ia. (Ed), 1992. *Hard coral of Vietnam II. Acroporidae*. Nauka Publishing House, Russia (in Russian).
- Latypov, Y. Y., 2011. Scleractinian corals and reefs of Vietnam as a part of the Pacific reef ecosystem. *Open Journal of Marine Science* (1), 50–68. doi:10.4236/ojms.2011.12006
- Le, D.D., Nguyen, V.H., 2009. Results on coral reef ecosystem surveillance in Cat Ba marine protected area, Hai Phong (in Vietnamese).
- Le, D.D., Do, T.A., Nguyen, H.N., 2010. Results on coral reef ecosystem surveillance in Cat Ba marine protected area, Hai Phong (in Vietnamese).
- Ministry of Agriculture and Rural Development, 2008. Decision No.82/2008/QĐ-BNN regarding declaration of the list of endangered aquatic species in Vietnam which need protection, reproduction and development (in Vietnamese).
- Nguyen, V.H., Phung, V.G., Le, D.D., 2015. Coral species composition diversity and reef structure in 5 studied islands. Report in the Research Institute for Marine Fisheries, Hai Phong (in Vietnamese).
- Nguyen, X.H., 2003. Fisheries biology. Ha Noi National University, Vietnam (in Vietnamese).
- Tun, K., Ming, C.L., Yeemin, T., Phongsuwon, N., Amri, A.Y., Ho, N., Sour, K., Long, N.V., Nanola, C., Lane, D., Tuti, Y., 2008. Status of coral reefs in Southeast Asia. In: C. Wilkinson (Ed.), *Status of coral reefs of the World: 2008*, pp. 131–144. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.
- Veron, J.E.N. (Ed), 1998. *Corals in space and time. The biogeography and evolution of the scleractinia*. UNSW Press, Sydney NSW, Australia.
- Veron, J.E.N., Stafford-Smith, M. (Eds), 2000. *Corals of the World, Vol 1,2,3*. Australian Institute of Marine Science, PMB 3, Townsville MC, Qld 4810, Australia.
- Vietnam Government, 2012. Decision No.188/QĐ-TTg approving the program on protection and development of aquatic resources through 2020 (in Vietnamese).
- Vietnam National Assembly, 2014. Law on Environmental Protection. No. 55/2014/QH13 (in Vietnamese).
- Vietnam National Assembly, 2017. Fisheries Law. No.18/2017/QH14 (in Vietnamese).
- Vo, S.T., 2002. The corals at Con Dao Archipelago (South Vietnam)-Before, during and after the bleaching event in 1998. In: Moosa, M. Kasim. (Ed.), Proceedings of the 9th International Coral Reef Symposium, Vol. 2 (Bali), pp. 895–899, Indonesia.
- Vo, S.T., Nguyen, H.Y., 2001. Additional research, update and systemization of documents on coral reefs in Vietnam seawaters. Institute of Oceanography, Nha Trang (in Vietnamese).
- Vo, S.T., Nguyen, H.Y., Pham, V.L., 2008. National report on coral reefs in the coastal waters of the south China sea-Vietnam. Focal Point for Coral Reef.
- Vo, S.T., DeVantier, L., Tuyen, H.T., Hoang, P.K., 2014. Ninh Hai waters (south Vietnam): a hotspot of reef corals in the western South China Sea. *Raffles Bulletin of Zoology* 62, 513–520.
- Wilkinson, C. (Ed.), 2000. *Status of coral reefs of the World: 2000*. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.
- Wilkinson, C. (Ed.), 2002. *Status of coral reefs of the World: 2002*. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.
- Wilkinson, C. (Ed.), 2008. *Status of coral reefs of the World: 2008*. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia.