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New Data on Spatio-temporal Stability and Variability of the Vietnamese Reefs

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Abstract

Research work on reefs of open South-China Sea and clause bay (South Vietnam), and the Gulf of Thailand investigated in the beginning of the 80s of the previous century were conducted in 2005-2007. A distinct dependence of the level of coral communities' degradation on their closeness to settlements and aquaculture areas were established. Appreciable changes due to anthropogenic impact have occurred on the reefs that are the nearest to the city. There was a reduction in substrate cover by reef-building corals, a substitution of dominant scleractinian species, and a decrease in the numbers and diversity of common species of corallobionts. The index of species diversity for scleractinian also decreased. The seaweeds *Chnoospora* and *Halimeda* spread into all zones of the reefs. Changes in coral communities on more distant and protected reefs were not so marked

Keywords: Reef; Community; Stability; Variability; Vietnam

Introduction

The first studies of reefs of Vietnam, R. Serene held at the end of the 1930s [1], then Dawydoff [2] went on the reef study. The works of these scientists were related to describing the species richness of corals and other invertebrates in reefs of the South Vietnam. Since the 1980s, as a result of joint Soviet-Vietnamese marine and land expeditions, as well as thanks to the World Wildlife Fund, the systematic comprehensive studies of different types of reef species composition and structure of reef communities in the region began [3-9]. The last decade of this century, repeated studies were conducted on the same transects of previously studied reefs [10-13] which, on the one hand, revealed significant changes over a quarter century in the species composition and structure of some reef communities, on the other hand, corroborated a satisfactory sustainability of some reefs. Beyond, during the expeditions of recent years, 16 species of reef-building scleractinian previously unknown in reefs of Vietnam have been found.

In 2005 and 2007, the expedition of the A. V. Zhirmunsky Institute of Marine Biology FEB RAS on research vessel "Akademik Oparin " again explored a number of visited coral reefs, species composition and structure of the population which were first described by a quarter of a century ago (Figure 1). Examined reefs differ by geomorphology, degree of wave effect and connection with open sea, in accordance with which they classified as reefs of open capes and islands, reefs of closed bays, and reefs of channels [14-16].

In the first decade of the twenty-first century, there have been repeated studies on the same sections of the previously studied reefs [11-13] to determine their status. These studies showed, on the one hand, the significant changes in a quarter of a century in the composition and structure of some species of reef communities and on the other hand confirm satisfactory stability of some reefs. Also during the expeditions of recent years were found 16 species of reef building scleractinian that were previously unknown in the reefs of Vietnam. Because of the identified species, richness of corals of the Vietnam has increased by more than 4% and totaled 376 species.

Figure 1: Schematized map of the surveyed regions. 1: Bai Tu Long Archipelago; 2: Ze Island; 3: Cape Danang, Cham and Son Tra islands; 4: Re Island; 5: reefs of the Khanh Hoa Province; 6: Thu Island; 7: Ca Thuik Islands; 8: Con Dao Islands; 9: Tho Chu Island; 10: An Thoi Archipelago and Namsu Islands; 11: Rach Gia bay; 12: Royal Bishop and Astrolab shoals; 13: Spratly Islands.

Materials and Methods

In May 2005 and 2007, during the expeditions on board the RV "Akademik Oparin", the species composition and distribution of scleractinian, common species of macrobenthos and community structure in each of the reef zones near the islands An Thoi, Tho

Chau , Namsu, Con Dao, Thu, Hon Mieu, Lý Sơn (Ré) and Cu Lao Cham (Figure 1) were studied applying SCUBA gear in ten sections corresponding to the sections surveyed in 1984-1987. The work was carried out by standard hydrobiological technique using counting frames and transects [17]. Appling frame divided into 100 squares of 10 cm^2 along 100-200 meter transect, we assessed the number of common species of molluscs, echinoderms, of branchy, massive, encrusting and foliate colonies of scleractinian and degree of their substrate covering. 17 transects were resurveyed. The index of species diversity was determined by the formula: H=-Σ [(ni/N) (ln ni/N)], where H is the Shannon index; ni – the number of individuals belonging to i-n species; N – the total number of individuals [18]. For cameral treatment of community composition and species diversity of scleractinian, more than 2,500 photos of general view of reef communities and underwater landscapes shot with the Olympus and Lumix cameras were used.

Results

Near the open coasts on reefs of Khanh Hoa province (Den, Lon and Mun Islands) and near the south-western end of Gom peninsula, under the conditions of active hydrodynamics, coral colonies of comparatively small length (up to 25-100 m off the coast), confined to steep and vertical rocky and stony walls, usually occur. The reefs are characterized by high species diversity of scleractinian (not less than 200 species), and the same high degree of substratum covering (60-100%), by the presence of a big number of young corals settled comparatively not long ago. Among the community species, which can be met on the most reefs of Indo-Pacific area, are the most common: *Pocillopora verrucosa, Acropora cytherea, A. florida, A. gemmifera, Montipora hispida, M. vietnamensis, Porites lobata, P. cylindrica, Favia maritima, Favites flexuosa, Platygyra daedalea, Leptoria phrygia, Diploastrea heliopora, Goniastrea pectinata, Hydrophora microconos, Lobophylla hemprichii, Galaxea fascicularis, Fungia fungites, Sandalolitha robusta, Podabacia crustacea, Merulina ampliata, Pectinia paeonia, Turbinaria peltata* and many others. Macroalgae mostly *Padina auastralis* and *Chnoospora implexa*, occurs as shoots mainly in littoral.

From 1982 to 2005, these reefs did not change very much in their species composition and community structure. Diversity of *Acropora*, totaling not less than 30-35 species, remained high as before. The bulk of species diversity, as on the most Indo-Pacific reefs [16,19,20], formed by scleractinian from five families: Acroporidae, Faviidae, Fungiidae, Poritidae and Dendrophylliidae, making more than 60% of their total number. Representatives of five genera – *Acropora* (15-20 species), *Montipora* (10-15), *Porites* (11-13), *Favia* (7-10) and *Fungia* (7-10) – are the most diverse and numerous in coral communities of these reefs. For the recent twenty years, the area of substratum covering by corals was substantially reduced on these reefs (down to 10-30%). Small massive coral colonies (5-10 cm), mainly from Faviidae and Poritidae families, began to prevail noticeably in the community structure of the reef slope (not more than 3-5 colonies per sq. m). Silting of substratum, which even can be clearly visualized, increased due to closeness of a big number of mariculture installations. In addition to that in all areas of intensive mariculture development active aggression of predatory gastropoda *Drupella rugosa*, which density is from 8-20 individuals per a colony of 10 × 13 × 18 cm size to 3000 individuals in some aggregations of branched *Acropora* colonies, against various scleractinian species of *Acropora*, *Porites* and *Montipora* genera was observed.

A reef near Mju Island attributed to the channel between the densely populated islands. It situated in the immediate vicinity to Nha Trang city and port, which surrounded from every quarter with mariculture farms and tourist complexes. Here the changes in reef community composition are especially obvious due to heavy silting of substratum, corals and other representatives of macrobenthos in the area of the reef slope. In the surrounding waters, values of sedimentation flow are extremely high: 35.3-48.6 $g \cdot m^2 \cdot day^{-1}$. For the past two decades the degree of substratum covering by corals reduced, number and size of colonies of reef-building scleractinian decreased, and abundance of algae *Halimeda opuntia, H. discoidea* and *Ch. implexa* increased. Species diversity of corals, especially of *Acropora*, reduced. Various species of lamellar and branched *Acropora* and *Montipora*, common here earlier, were considerably replaced by monosettlement of fine-branched *Montipora porites*. Alga *Ch. implexa* settled in all reef zones, occupying actively substratum and space between coral branches, and its covering made 60-75% of substratum area (Figures 2-4). Coral covering of substratum overall rarely exceeds 40-50%. As before, small (2-5 cm) regenerating colonies of scleractinian *Montipora*, *Porites*, *Favites*, hydroids *Millepora*, which diversity and abundance, nevertheless, 1.5-2 times dropped, can be met on branched debris of dead corals. The changes also affected the macrobenthos accompanying corals. 20-25 years ago sea urchin *Diadema setosum* (not less than 5 individuals per sq. m), holothurians *Holothuria edulis* and *H. atra* (1-2 ind/m^2), sea-stars *Linckia laevigata*, *Culcita novaeguineae, Acantaster planci* (0.1-0.2 ind/m^2), mollusks *Atrina vexillum* (up to 0.2 ind/m^2), *Tridacna crocea* (0.5 ind/m^2), *T. squamosa* (0.1 ind/m^2), *Lambis chiragra, L. scorpius, L. lambis, Trochus niloticus, Cypraea tigris, Mauritia arabica* (0.2-0.5 ind/m^2) and other invertebrates could be frequently met here. In 2004-2005 only single individuals of *Trochus*, *Atrina*, sea urchin *Diadema* and holothurians *H. atra* were observed, but the sea star *A. planci* became very common (0.15 ind/m^2).

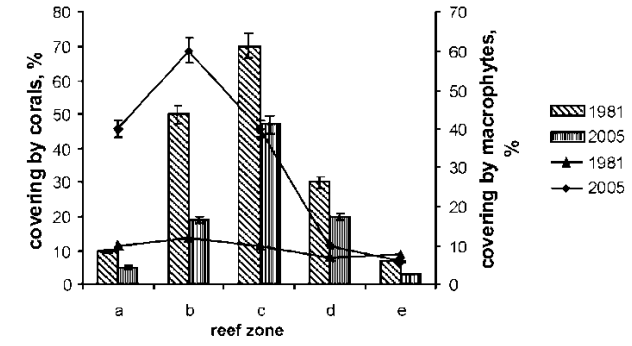

Figure 2: Substratum covering of corals and macrophytes in various zones on Mju Island reef. Rectangles correspond to corals, lines – macrophytes, a-lagoon, b-reef flat, c-reef slope, d-reef slope base, e-for reef platform

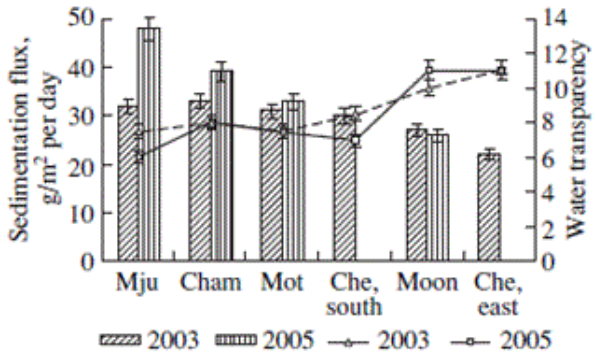

Figure 3: Sediment flux and water transparency on the various reefs in 2003 and 2005. Islands are ranged in order of increasing distance from the shore.

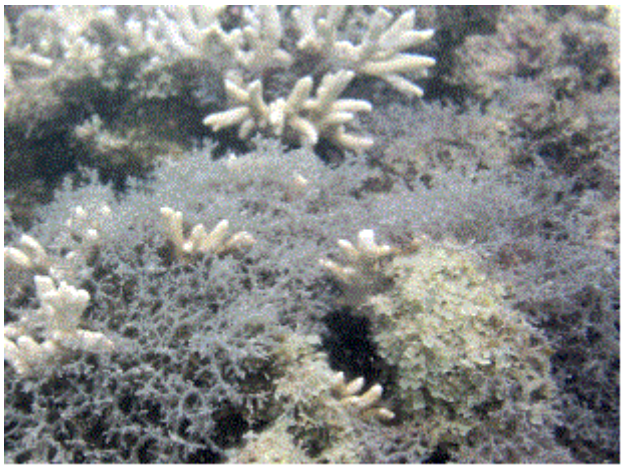

Figure 4: Distribution Chnoospora implexa on Mju Island reef.

Erosive consequences of urban development along the coastline, and intensification of mariculture farms in multiple land and island bays greatly increase sedimentation flows and eutrophication of waters of Wan Phong and Nha Trang Bays [21,22]. Connection between sedimentation growth and reduction of species diversity of corals, degree of substratum covering by corals, low growth rates shown in many works [23-25]. Moreover, the increase of the degree of substratum covering by macrophytes observed under conditions like that [26]. Crude sewage and wastes from mariculture farms usually bring nutrient subsidy and toxic materials in water depth and bottom sediments. The increase in the number of fertilizers and pharmaceuticals near reefs increases the content of chlorofyll. This in turn leads to increased levels of nutrients and turbidity is the major causes of the significant changes of corals near the coast [27].

Differences found in changes of coral communities on island reefs, outlying inhabited localities and aquaculture areas (Den, Mun), and on reefs exposed to intensive anthropogenic press (Mju, Ong et al.) serve as a striking example of differentiated anthropogenic impact. Species diversity index of scleractinian is more than 2.5 times higher on remote and relatively clean reefs in comparison with that of the reefs exposed to the intensive anthropogenic effect (Figures 5 and 6). Reefs of islands, similar to Mju Island, are located in the immediate vicinity to the city and port of Nha Trang. Crowded settlements and tourist complexes are located on its coasts, and multiple mariculture farms operate in its bays. Islands of Mun Island type are farther from the city, and their reefs situated in the reserved protected zone, where there is no population or it consists of not numerous representatives of guards and reserve administration. Water clarity near Mju Island and water exchange intensity over coral reefs here is 1.48 times lower than near Mun Island. At the same time, sedimentation flow is 1.3 times greater. Great degree of anthropogenic influence causes growth of eutrophication of waters, surrounding Mju Island, and intensification of substratum silting [28,29]. Because of these changes, the degree of substratum covering by corals reduces, and the area of its covering by macrophytes increases. Reduction of diversity of reef- building corals and accompanying mass macrobenthos species takes place. Replacement of *Acropora*, dominated earlier on Mju Island reefs, by fine-branched *Montipora*, having greater total surface area of a colony, can be considered as a possible consequence of high content of dredge, deposited in this area (1.3 times higher than in other places).

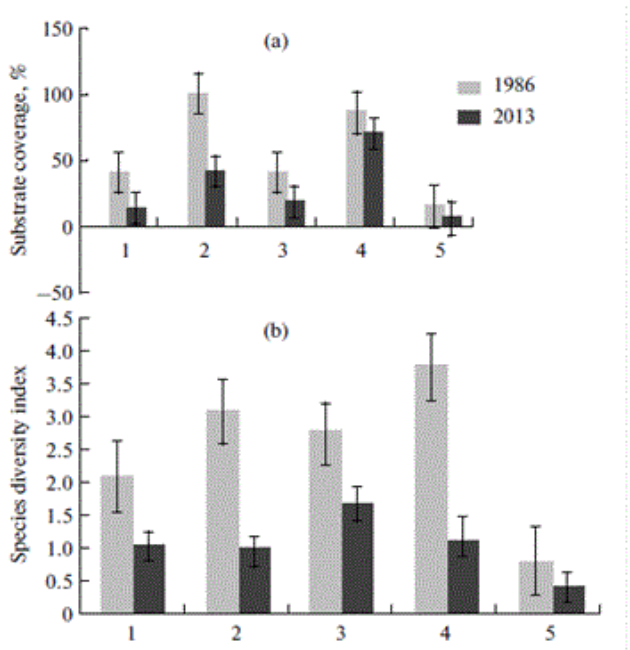

Figure 5: Variation in the substrate coverage; (A) and the species diversity index (B) in reef communities of Tho Chau Island. 1, coastal polyspecies community; 2, *Acropora nobilis* + *A. microphthalma* facies; 3, *Acropora* + *Diploastrea* community; 4, reef slope community; 5, *Junceella fragilis* + *Diaseris distorta* community.

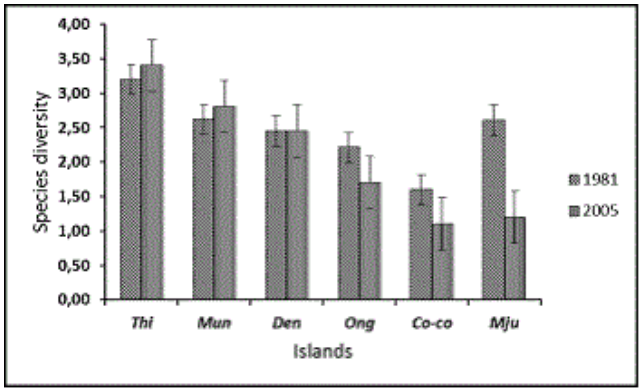

Figure 6: Variations of a specific diversity on the investigated reefs.

Discussion

Repeated studies of reef open part of the South China Sea and the Gulf of Thailand to notice that the reef with moderate or low anthropogenic impact, and even more so in places where environmental measures are satisfactory and remain even with optimal conditions for existence of reef communities. These reefs are characterized by a high degree of substrate coverage of living corals, are rich in species of hermatypic corals and associated fauna, including fish. An example are the reefs of Hon Den, Mun Islands at the Khanh Hoa province under State protection, reefs Bath Longvi island and the Spratly archipelago [30-32] as evidenced by the results of the study, the ecosystem of Con Dao Islands, is not subject to any explicit human impacts, including mariculture farms.

It is shown that fringing reefs of Con Dao and Thu islands open part of the South China Sea on the morphology, the degree of development of coral structures, the qualitative and quantitative composition of corals are comparable to other reefs of South Vietnam [16,33]. 256-365 species of scleractinian found on these reefs, 80 – 83% of the species occur on other reefs of Vietnam, we studied. Along with developed reef, with a clear physiographic zoning, to the East and North of the of Con Dao and Thu Islands built around the middle stage of development characterized by massive forms of corals development of macrophytes, and mild zoning. The same features and similar zoning with each zone communities of algae and corals, wide development bioherms with domination of *Acropora palifera*, *Porites cylindrica*, *Millepora dichotoma* and *Heliopora coerulea* we saw near the of Coetivy Island (Seychelles). A similar feature other Seychelles reefs bring Rosen [34] and Latypov [35]. Thus, the results of earlier studies showed that the island reefs of the Gulf of Thailand and South Vietnam characterize as an obvious commonality with other reefs Indo-Pacific and obvious traits of identities that require detailed study and conservation. These areas of Vietnam into the active zone, fisheries, tourism and intensive construction, therefore, to determine the reasons for the negative and positive change on reefs need repeated studies previously studied coral reefs. Such studies are relevant also in the light of the extensive planetary changes in reef communities, taking place under the influence of natural climatic processes [30,32].

In many works, which are not necessary to cited here, they analyze the level of physical and biological effects, resulting in disruption of species composition and structure of coral communities. At that, it universally recognized that the state of coral reefs is noticeably becoming worse on the global level. At present, it is essentially to know what we are trying to preserve diversity of corals on a certain reef, its fish resources or ecosystem as a whole. Changes may take place on the level of an individual, population, ecosystem and landscape. Impacts affecting these levels can be short-term and long-term. Short-term impacts can shadow long-term ones. Only long-term monitoring, including single, short-term and long-term natural and anthropogenic impacts, will allow us to estimate stability of coral reef communities and to identify the tendency and reasons of changes. At the same time, it is necessary to observe strictly technologies of marine objects cultivation in the areas of aquaculture, to expand areas and number of preserved and protected zones together with artificial restoration of biological diversity of reef-building scleractinian on reefs. All that will allow us not only to preserve and restore, but also to use rationally the unique ecosystem of Vietnamese reefs.

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