

Changes of Reef Community near Ku Lao Cham Islands (South China Sea) after Sangshen Typhoon

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Received February 15, 2012; revised March 7, 2012; accepted March 16, 2012

ABSTRACT

Coral reefs of Ku Lao Cham Islands in the Central Vietnam were studied over a quarter of a century. It was established that the reefs of these Islands were lost after the Sangshen typhoon and a heavy flood, which happened in 2006. As a result of these natural phenomena a significant part of coral populations was physically destroyed, and a powerful export of clay substances from the nearest Vietnamese coast and from the Bung River, flowing into the sea opposite the Islands, causing abundant sedimentation and death of almost all the remaining scleractinian corals. At present, where formerly there were coral reefs, now there is algal-alcyonarian stage of succession of reef communities. This is typical, as a rule, for restoration of reefs after a destructive typhoon effect.

Keywords: Sangshen Typhoon; Reef Community; Change; Succession

1. Introduction

Bays along the coast and islands of the Central Vietnam are usually open and sandy, subject to the effect of wind. Their underwater slopes are formed by rubble-lump breakdowns mostly of granite rocks, turning with depth into stony deposits and further into sandy-silty platforms. A big Bung River, bringing daily thousands of tons of fresh and highly silted water, flows into the sea opposite the Ku Lao Cham Islands [1]. This continental outflow can be especially great in the periods of heavy floods and typhoons. Such peculiarity of coastal geomorphology and hydrology of this region has an effect on formation of its sparse reefs, which were thoroughly investigated for the first time by a joint Soviet-Vietnamese expeditions in 1984, 1987, and later by the WWF in 1992-1993 [2,3]. Species composition of corals (more than 200 species), population density of common species of macrobenthos (from 7 - 10 up to 200 ind/m²), and degree of substrate cover by corals (75% - 100%), formation of continuous settlements *Acropora cytherea* 20% - 45% of substrate cover were investigated. Communities revealed on the basis of these data displayed is possible to examine completely satisfactory condition (optimal temperature and high transparency of the water, the lack of its eutrophication), as well as similarity of these reefs with those of the North and South Vietnam.

In October of 2006 10 provinces of Central Vietnam went through a powerful Sangshen typhoon. According to data provided by the meteorological center wind velocity

exceeded 133 km/h and sometimes reached 160 km/h. Heavy pouring rains, caused by the natural disaster, resulted in a fast rise of water level in local rivers. In many areas precipitation level reached 200 - 230 mm. Erosion of rice fields, coastal and beach areas caused the loss of 80% of mangrove bushes and 95% of coral reefs (based on an unpublished UNU-IAS Seminar Report). As is known, torrents of storm sewage are characterized by great desalination and turbidity due suspended matter, which is harmful for coral communities and results in their partial or at times complete mortality [4,5].

When studying the same reefs at the same locations in 2010, considerable changes in composition and structure of reef communities were found. The community composition changes in this region are of interest for comparative studies with previous data, thereby increasing spatial validity of changes described for reefs of central and southern Vietnam but may be relevant for some areas of the Pacific in which there were similar typhoons.

2. Materials and methods

Using SCUBA, we investigated the composition, distribution of scleractinian corals and mass species of macrobenthos, structure of communities in reef zones at seven (four studied earlier and two new control ones) sections in sandy and stony inlets and near rocky coasts (**Figure 1**). Investigations were carried out in accordance with the standard hydrobiological technique using quadrats and transects [6,7]. Abundance of mass species of

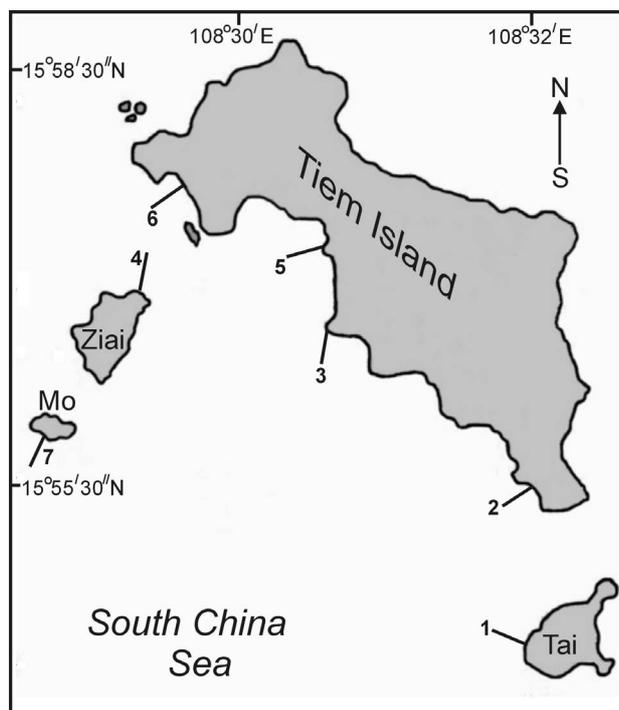


Figure 1. Location of transects at Ku Lao Cham Islands. 1-6—location of transects.

mollusks and echinoderms, branched, massive, encrusted and funnel-shaped scleractinian colonies, as well as the degree of substrate cover by corals were estimated along a 100 m transect frame divided into 100 squares with the area of 10 cm² each. Photographing of reef landscapes, and their flora and fauna was conducted. More than 500 photos by Olympus and Canon digital cameras were made for later analysis of species composition [8,9] and structure of community of coral reef survey methods [10,11].

3. Results and Discussion

In 1987 the species diversity on various reefs ranged from 483 to 590 species, among them scleractinians composed 219 species. More than 20 species prevailed: macrophytes *Padina australis*, *Caulerpa racemosa*, *Halophyllia ovalis*, alcyonarians *Sinularia dura* and *Sarcophyton trocheliophorum*, scleractinian *Acropora cytherea*, *A. robusta*, *A. humilis*, *A. digitifera*, *Montipora aequituberculata*, *M. hispida*, *Porites lobata*, *P. rus*, *Goniopora stokesi*, *Pavona decussata*, *Platygyra daedalia*, *Diploastrea heliopora*, *Galaxea fascicularis* and *Lithophyllum undulatum*, mollusks *Tridacna maxima*, *Ovula ovum* and *Cypraea arabica*, echinoderms *Diadema setosum*, *Holothuria atra*, *Linckia laevigata* and *Ophyocoma nigra*. Only one alcyonarian species (*S. dura*) formed monospecific settlements of colonies on significant areas in various reef zones, and two scleractinian species—*A. cytherea* and *P. lichen*—formed patches of mono-colonies

in the reef-flat zone. Formation of several communities could be clearly traced [2].

The Algal-coral community was formed from the lower level of the intertidal zone to a depth of 2 - 2.5 m. It was characterized by predominant development of algae, subordinate role of scleractinia, and permanent presence of mollusks and echinoderms. Living corals were represented by separate massive and crustacean colonies of *Porites*, *Goniastrea*, *Favia*, *Favites*, *Galaxea*, *Hydnophora* and single branched *Pocillopora*, *Acropora*, *Seriatopora*. The degree of substrate cover by corals rarely exceeded 10% - 15%. Gastropods of the genera *Trochus*, *Cypraea*, *Lambis*, echinoderms *Holothuria atra*, *H. hilla*, *Stichopus chloronatus* and *Linckia laevigata* permanently occurred among macrophytes and corals.

Reef-flat community. Scleractinia *Acropora cytherea* or *Porites lichen* dominated both by the degree of substrate cover (20% - 45%) and by sizes of many-tier colonies reaching 3 m diameter. *Montipora aequituberculata* and *Pachyseris rugosa* were subdominants. Among the other corals *Acropora humilis*, *A. robusta*, *Montipora digitata*, *Porites lobata*, *Goniastrea pectinata* and *Pavona decussata* were the most frequently met. Echinoderms *H. atra*, *H. edulis* (density up to 4 spec./m², biomass 532.2 g/m²), *Linckia laevigata*, *C. novaeguineae*, mollusks *Tridacna maxima*, *Cypraea tigris*, *C. arabica* were permanent elements of the community. Small patches of the alga *Caulerpa racemosa* were met among coral colonies. Total substrate cover of corals was 60%.

A community of soft corals *Sinularia dura* + *Sarcophyton trocheliophorum* was formed at a depth of 4 - 15 m with the width of 20 - 80 m. It was typical for open capes and inlets with rocky and large-lump substrate. Dominating alcyonarian *S. dura* occupied up to 40% - 75% of substrate surface. Patches of combined colonies of the corals *A. cytherea* and *M. aequituberculata* with plate trochal colonies up to 3 m diameter were met in shallow parts of the community. Despite domination of soft corals in substrate cover, species diversity was ensured by scleractinian distributed in all part of the community. Acroporidae and branched Poritidae were the most frequent in its shallow part. Species of the genera *Turbinnaria*, *Porites*, *Goniopora*, *Galaxea*, *Hydnophora* and *Pachyseris*, as well as Faviidae and Fungiidae, especially that of the genera *Lithophyllum* and *Cycloseris*, were distributed near the deep part of the reef slope.

Echinoderms *Comatula pectinata*, *L. laevigata*, *O. nigra*, *Echinotrix calamaris*, *E. diadema*, *D. setosum*, *H. atra*, *H. edulis*, and mollusks *O. ovum* and *Lambis lambis* were permanent components of all facies of the soft corals community. *O. nigra* (5 - 7 spec./m²), *C. pectinata* (10 spec./m²) and *H. edulis* (4 spec./m²) were the most frequent.

A community of *Porites australiensis* + *Goniopora*

somaliensis with the width up to 40 - 60 m was observed from the upper reef slope up to pre-reef platform. It was typical for open inlets with stony and large-lump organogenic substrate. In the middle of the reef slope a facies of *M. aequituberculata* mono-colony could be formed, which ensured 100% substrate cover together with Poritidae. Massive *Porites* colonies (up to 4.5 m in diameter) with growing on them scleractinian *A. cytherea* and *M. aequituberculata* were clearly distinguished in the same place. Other corals of the genera *Pachyseris*, *Echinopora*, *Montipora*, *Porites*, *Micedium*, *Plesiastrea* and *Turbinaria* occurred in a form of separate colonies or patches of colonies. Faviidae (up to 20 colonies per m²) with a diameter of 7 - 17 cm were chiefly developed.

On the whole, sufficiently homogenous distribution of corals and accompanying macrobenthos was typical for the reefs of the central Vietnam [2,12]. Zonal distribution of corals could be traced most clearly in open stony reef slopes, at shallow terraces and reef-flats of closed inlets in the presence of organogenic substrate of even small capacity. A similar situation was observed by Dai [13] in Taiwan and by Latypov [14,15] in North and South

Vietnam.

Development of mono-colonies of Acroporidae of the types *A. cytherea* and *M. aequituberculata* in reef-flat zones and on the upper reef slopes, and plate-foveolate colonies of the types *Pachyseris*, *Mycedium*, *Echinophyllia* on the lower slope part and on the pre-reef platform permitted us to integrate the studied reefs with the majority of Indo-Pacific and Atlantic reefs [16-20].

Investigation of reefs of Ku Lao Cham Islands, conducted by us in the last decade of May of 2010, made a distressing and painful impression. Practically nothing was left from the former richness and beauty of reefs of the reserved islands (**Figure 2**). Only 26 scleractinian species were revealed a result of three days of intensive hydrobiological survey conducted by hydrobiological experts, who spent underwater more than 48 hours and were equipped with modern photo techniques. The species diversity was reduced 10-as a result of mortality of coral reefs along the entire coastline of these islands. There has been a reduction in the coverage of the substrate of Scleractinia and their replacement them by Alcyonarian (**Table 1**).



Figure 2. Physical destruction and covering *Acropora* mono-colony with sediments.

Table 1. Cover of hard corals and soft corals before and after the typhoon attack, % covering of substratum.

Subject	Algal-coral community	Inner reef-flat	Outer reef-flat	Soft coral community	<i>Porites</i> + <i>Goniopora</i> community	Reef slope
Macrophytes	10 - 40/5 - 7	7 - 10/10	3 - 5/7 - 10	3 - 5/10 - 12	3 - 5/10 - 20	1 - 5/5 - 7
Scleractinian	10 - 15/0	3 - 5/0.01	45 - 60/0.1	15 - 20/0.01	100/0.0	75 - 100/0.01
Alcyonarian	3 - 7/10 - 18	10/10	15/45	40 - 75/80 - 100	0.0/100	5 - 10/40 - 50

A heavy silting of substrate was the first thing noticed when diving. Even vagile animals were covered with a layer of sediments (**Figure 3**). At the same time, occurring almost everywhere alcyonarians and only single small scleractinian colonies, mostly also covered with silty sediments and various epibionts, were typical for the reefs [12,21-22]. Representatives of the Acroporidae family, which are mandatory members of all living reefs and usually form the bulk of their species diversity and a high degree of substrate cover by living corals, were completely absent at the reefs [23-25]. Reduction of species diversity of corals, degrees of substrate cover by corals, and growth delay with the increase of sedimentation have been mentioned in many publications [26-31]. Besides, intensive sedimentation can prevent coral larvae from settling and cause their high mortality after attachment to substrate due to mechanical abrasion. All that leads to fundamental changes in the scleractinian community and to a possible dominance of macrophytes and other coral competitors [32].

Single scleractinia, found here and there (2 - 4 colonies/m²), are presented mainly by suppressed colonies of massive shape with maximum size of 10 cm in diameter. Massive *Porites* colonies (40%) and representatives of *Favia* and *Goniastrea* (12% each) were the most frequent. Blue corals *Heliopora coerulea* are distributed practically at all transects with a frequency of 7% - 10%. In situations like that it is possible to talk about absence of any degree of substrate cover by live corals or about its

minimal size which as on the whole makes a small portion of 1%. Colonies of massive *Porites* up to 1.5 - 2 m in diameter, which can ensure up to 25% - 40% degree of substrate cover on some areas of the transect, were found only near Tai Island (transect 4). Distribution of massive *Porites* is generally caused by the fact that these corals are able not only to survive in stressful environmental conditions but to reach dominance over the other scleractinian in productivity of organic material, degree of substrate cover and species diversity [14,27,33-35].

Occurring everywhere 10 - 15 species of alcyonarian soft corals play the main role in formation of communities on the present reefs of Ku Lao Cham Islands. *Sarcophytum trochelioforum* and *Sinularia dura*, which earlier also prevailed among alcyonarians both in occurrence frequency and in the ability to ensure 100% cover of the substrate, dominate [2]. So far inessential but ubiquitous settlement of algae *Caulerpa racemosa*, *Padina australis*, *Halophyllia ovalis*, *Laurencia corymbosa* and *Asparagopsis taxiformis*, which a quarter of a century ago were registered on living reefs only in the coastal zone, where they ensured up to 40% - 60% of bottom cover on rocky substrate and dead corals, is now revealed on the reefs. As to macrobenthos, usually accompanying living coral communities and earlier forming mass assemblages, now single specimens of echinoderms *C. pectinata*, *L. laevigata*, *O. nigra*, *D. setosum*, *H. atra* and *H. edulis*, mollusks *L. lambis*, *C. tigris*, *C. arabica* and a number of other species—occur. It is necessary to mention



Figure 3. Substrate silting. Motile gastropod *Lambis lambis* at the left, a dead *Faviidae* colony at the right.

Sufficiently frequent occurrence of the predatory gastropod *O. ovum* (up to two specimens per one alcyonarian colony), for which soft corals serve as a main foodstuff. Distinct traces of *Ovula* attacks can be clearly seen on many alcyonarians colonies.

Morphological features and vegetative growth of soft corals permit them to endure easier stress situations, including mechanical damage by way of silting [36,37]. This adaptive strategy of alcyonarians permits them to form mono-dominant communities on many reefs of the Central Vietnam, which integrates them, on one hand, with reefs of Tonkin Bay and Taiwan with their special hydrodynamical conditions of increased sedimentation [13,31,38], and, on the other hand, with reefs of the South Vietnam in the open part of the South China Sea [15, 39].

This adaptability of alcyonarians can be clearly observed on the studied degraded reefs. Replacement of the former scleractinian-alcyonarian community by a mono-dominant alcyonarian has occurred. Patches of alcyonarian settlements with the area up to several tens of

square meters are distributed on all hydrobiological sections. At transects 2 and 3 they form compact settlements with 100% substrate cover for hundreds of square meters (**Figure 4**). Foraminifers, bryozoans, serpulids and drilling mollusks *Litophaga* spp. gain ground in the forming community together with scleractinian and macrophytes, which designates ecological type of succession of coelobitic and cryptic organisms [40]. Organisms with calcareous skeletons, especially crustacean calcareous algae, play the main role at the initial succession stages in formation of a stable substrate for settling and growth of hermatypic corals [41]. In 2 - 3 years after calcareous substrate formation the dominance of reef building coral colonies become appreciable, and only in 4 - 6 years after the beginning of a new reef colonization appearance of vast colonies of *Acropora* corals is possible [40,42].

However, a hope for restoration of the studied reefs is available, as we nevertheless managed to find single, very small, young, settled a new colonies of *Pocillopora verrucosa*—one scleractinian species on all Indo-Pacific reefs.

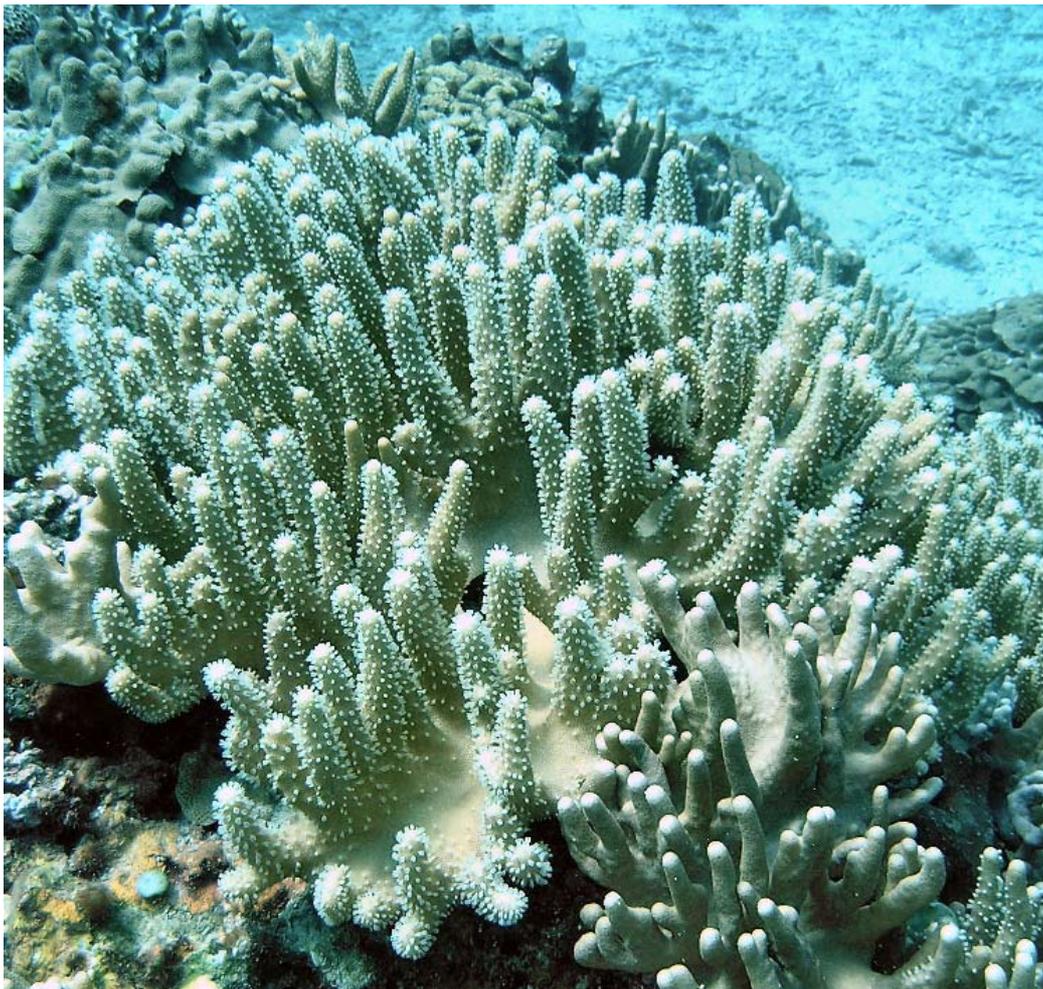


Figure 4. A mono-colony of the alcyonarian *Sarcophytum trocheliophorum*.

4. Acknowledgements

We are grateful to E. Kogan for translation of article into the English. Special thanks to Prof. James Crabbe for his valuable and constructive remarks to the manuscript of the article.

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