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Features of formation of reefs and macrobenthos communities in the An Thoi archipelago the Gulf of Thailand (South China Sea)

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ABSTRACT

Macrobenthos communities studied on fringing reefs of the AnThoj archipelago using SCUBA-diving equipment. The islands are located in the turbid and highly eutrophic waters of the eastern Gulf of Thailand. We researched species composition and settlements densities and biomasses in common species of algae, coelenterates, mollusks and echinoderms, as well as the degree of substrate coverage by macrophytes and coral. Clear vertical zonation identified in the change of the various communities in macrobenthos. The dominance of massive *Porites* on almost all reefs of the Gulf of Thailand is due to their ability to survive in stressful for many corals. They predominate over other scleractinian for the productivity of organic matter, the degree of substrate coverage and species diversity. They also constitute the reef skeleton and play a significant role of the expansion of its area in themuddy bottom of the Gulf of Thailand.

KEYWORDS

Coral;
Reef;
Macrobenthos;
Community;
AnThoi archipelago;
Vietnam.

INTRODUCTION

Most of the reefs in Vietnam, as along the coast, the islands and the open sea, are similar in their morphological zonation, composition and structure of a community of other Indo-Pacific reefs. There are fringing mainland and island reefs, barrier and platform reefs and atolls[1-7]. They are characterized by well-defined morphological zonation (lagoon, reef flat and so on), a rich diversity of species of coral, usually dominated Acroporidae[8-12]. Reefs at the Tonkin Gulf, because of their specific hydrological and abiotic conditions[13,14] differ in the structure of reefs and benthic communities. The AnThoi archipelago reefs have structural and morphological zoning and developed powerful reef deposits, common in structural reefs of the Indo- Pacific. They cover a thin crust of coral and seaweed boulder- boulder and rocky substrate, almost without changing the underwater geomorphological profile[15-17]. The mountainous An Thoi archipelago is situated in the eastern part of the Gulf of Tonkin (10°-10°30' N, 103°50-104°05'E) and includes 13 islands. The relief of the latter represented by relatively high plateaus bordered by steep abrasion denudational-collapsed slopes. The islands are built of sand, stone and conglomerates occurring within a monoclinal flat dipping complex and partially covered by quaternary sediments. A characteristic feature of the island relief is the steepness of its slopes, which well pronounced in the coastal zone and on submarine slopes. A ruined-rocky under-water relief has developed in connection with this geomorphological pattern. The submarine slopes represented by boulder-block deposits transforming with deeper depths into stony and gravel deposits, which, deeper down, replaced by sandy-corallogenic deposits with large amounts of organogenic detritus.

The islands of the archipelago are located in the coastal semiclosed part of the bay, which characterized by specific chemical and ecological conditions (see TABLE). First, there is a great concentration of dissolved suspended matter, reaching more than 100 mg/1, which is twice as great as around the Ca Thuik Islands and Charlotte Bank, in the open part of the South China Sea. The concentration of chlorophyll *a* in the waters around the islands is almost two times greater. Since the salinity in the open part of the South China Sea is more than 32 ‰, and the islands of An Thoi it ranges from 30.31to 31.26 ‰. Amount of suspended matter (turbidity) in the water near the islands of An Thoi almost twice the cores of such indicators at the entrance to the bay and the open sea. Not the best role for the formation of reefs and benthic communities and has a reduced amount of oxygen in the waters of the archipelago.

TABLE 1 : Surface water chemistry of some reefs of south vietnam

Area	Quantity of suspended solids, mg/l (turbidity)	Salinity,‰	O_2, ml/l	PO_4, µg/l	Porg, µg/l	Corg,µg/l	Shl, µg/l	The MOAT, mg/l
1	0.26	30.58	5.14	0.5	1.9	130	0.11	4.05
2	1.26	*30.95*	5.53	2.8	3.5	145	0.50	4.20
X	0.69	30.79	5.31	1.8	2.7	91	0.29	4.12
S	0.37	0.14	0.14	0.9	0.5	39	0.14	0.08
3	0.08	32.12	5.48	0.5	1.6	65	0.12	2.80
4	0.85	32.26	5.78	2.5	5.0	198	0.5	3.78
X	0.66	32.22	5,60	1.15	2.9	107	0.25	3.19
S	0.20	0.03	0.09	0.87	1.1	47	0.15	0.39
5	0.40	30.31	4.88	0.5	1.7	385	0.25	6.05
6	3.28	31.26	5.63	2,5	4.75	115	1.22	0.65
X	1.26	30.84	5.09	0.8	3.14	206	0.57	3.68
S	0.31	0.50	0.29	0.8	1.7	83	0.36	1.41

Note: 1-2 – Thochu Island, 3-4 – Con Dao Islands, 5-6 - AnThoi archipelago, X-mean value, S - standard deviation. Samples are taken at 24 stations

The above-listed peculiarities, combined with the presence of constant currents usually running in the same directions (clockwise in the rainy season and counter-clockwise in the dry season), make the environ-mental conditions very peculiar for corals.

MATERIALS AND METHODS

The composition and distribution of scleractinian and common macrobenthos species (about 400 species) and the community structure in each reef zone were studied using scuba equipment along seven transects located on six islands (Figure 1). We used generally accepted hydrobiological methods[18], including the technique of frames and transects[19]. The transects, each 200 m long, marked off by the meter, were located in open and closed bays, on capes, and along rocky, stony, and sandy coasts in order to include the greatest diversity of reef communities in the surveyed area. At every square meter along each transect, we counted branched, massive, encrusting, and funnel-shaped scleractinian colonies using a frame divided into 100 small squares10 cm^2. We also studied the degree of substrate coverage by corals and determined the density of common species of mollusks and echinoderms. In the aggregations of invertebrates, we recorded the settlement density and biomass of each species across an area of 10-30 m^2. On each transect section with a soft bottom; we collected seven samples using a bottom sampler Van-Wine (0.025 m^2)and recorded animals and plants through 2-

5 frames 1-10 m^2 in area. In the laboratory determined the species composition and quantity indicators of abundance of benthos (biomass and density of each species and systematic group, total biomass and abundance). A lot of large organisms determined to slash at the chemist's scales accurate to 10 mg, small-on torsion scales to within 1 mg. We drained the animal for 1 min on the filter paper before weighing. All data measured on area 1 m^2. Coefficients of species diversity corals were calculated by the formula: $H = -\Sigma [(n_i /N) \times (\ln n_i / N)]$, where H – Shannon Diversity Index, n_i - number of individuals belonging to i species, *N*–total number of individuals[20]. Level of similarity of different communities defined in terms of similarity[21] clustering Ward carried largest Jaccard index using the program Statistica 6.0.

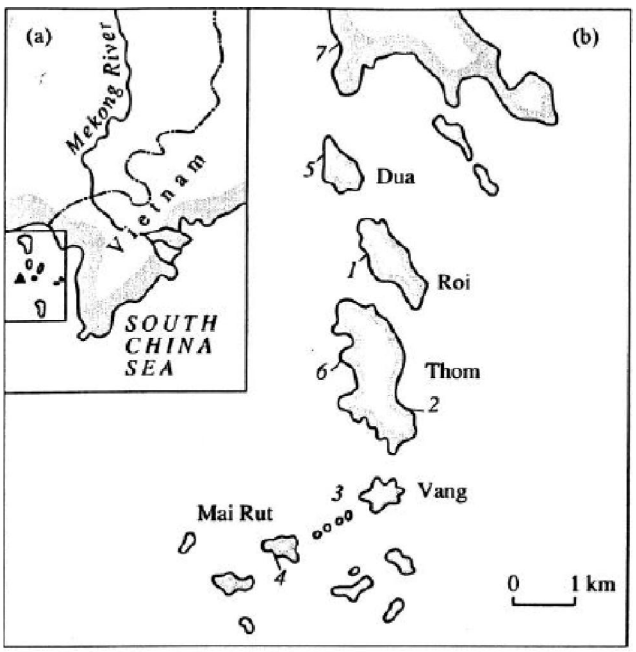

Figure 1 : Schematized map of (a) the An Thoi archipelago and (b) the location of transects *1-7* along its coasts

RESULTS

Zoning of communities

The reefs of the An Thoiarchipelago show no structural-morphological zonation and have developed reef deposits common to the structural reefs of the Indo-West Pacific. They form a thin crust covering the boulder-block and rocky substrates, which barely affect the submarine geomorphological profile. However, the composition and structure of bottom communities show noticeable vertical zonation. In coastal shallows, an algal-coral zone develops with a rather high density of large macrobenthos. It occupies depths down to 1.5-2 m and only rarely extends for more than 50 m. The algal-coral zone gives way to a zone dominated by coral settlements, Scleractinian dominate along steep boulder-block coasts, whereas Alcyonarian dominate along rocky shores. This zone extends for 40-100 m, at depths of 2 to 12 m. At the base of the reef slope and on the pre-reef platform, a zone of spotty gorgonarian-scleractinian populations arises. The geomorphological pattern of the shoreline and submarine slopes and distribution of corals and associated macrobenthos allowed us to distinguish two groups of reefs within the surveyed area: reefs of boulder-block coasts either closed or screened against per-manent wave action (transects 1-3,7; Figure 2) and reefs of rocky, more open coasts (transects 4-6; Figure 3). The species composition of the coral and macrobenthos varied on different reefs from 278 to 324 species. 29 species either dominated or appeared permanently in certain zones: the sponge *Petrosia testudinaria*; the corals *Sarcophyton trocheliophorum, Lobophytum pauciflorum, Juncella fragilis, Acropora cytherea, A. millepora, Montipora hispida, M. aequituberculata, Porites lobata, P. cylindrica, Goniopora djiboutiensis, Galaxea fascicularis, Pavona decussata, Platygyra daedalea, Diploastrea heliopora, Turbinaria peltata, T. mesenterina*, and *Millepora platyphylla;* the mollusks *Beguina semiorbiculata* and *Area ventricosa*; the echinoderms *Holothuria edulis, Stichopus variegatus, Bohadschia graejfei, Diadema setosum*, and *Linckia laevigata*; the polychaete *Spirobranchus giganteus;* the macrophytes *Turbinaria decurrens, Caulerpa racemosa*, and *Padina australis.* The constant occurrence of the same dominating species of coral or their groups together with a certain composition of macrobenthos within the same reef zones, allowed us to distinguish several characteristic communities. Below, we will discuss their composition, structure, and some peculiarities of their development.

Reefs of boulder-block coast

A community of *Acropora cytherea + Millepora platyphylla* subdominated in the intertidal zone by the alga *Turbinaria decurrens* (with a biomass of up to

10487 g/m^2) develops in the coastal area. Among other algae, *Padina australis*, *Caulerpa microphyza*, and patches of the sea grass *Thalassia hemprichii* occur the most often. With a mean density of 724 spec/m^2 and biomass of 3694 g/m^2, macrophytes may provide up to 70% of the projective coverage of the substrate. Colonies of the dominating species of scleractinian *Acropora*, and the hydroid *Millepora* reach 2 m in diameter. Other corals are most often represented in this community by *A. millepora*, *A. robusta*, *Pavona decussata*, *Porites lutea*, *P. lobata*, *Pocillopora verrucosa* and *Hydnophora exesa*. Altogether, 25-30 species of scleractinian are found in this community and cover up to 60% of the substrate surface.

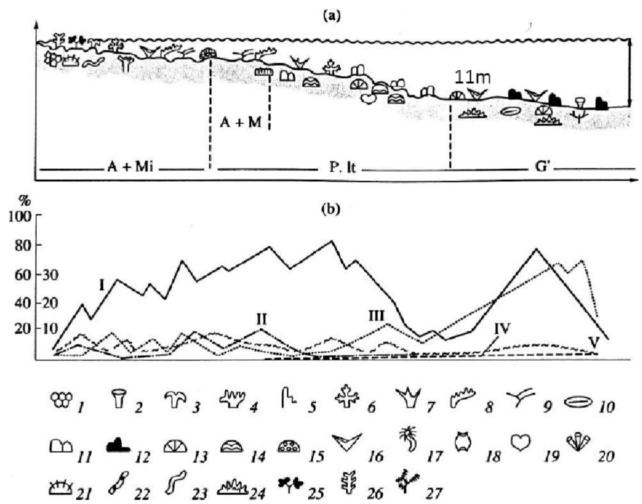

Figure 2 : Profile of a reef of boulder-block closed coasts with (a) the distribution of common macrobenthos species and (b) the degree of substrate coverage by corals and relationships between their colony shapes, transect. A+Mi- represents the community of *Acropora cytherea* + *Millepora platyphylla*; P.lt - represents the community of *Porites lutea*, A+M- represents the zone of*Acwpora*and *Montipora*; G- represents the zone of *Goniopora;* the abscissa represents the distance from the shoreline, m; the ordinate represents the degree of substrate coverage, %, to the left and number of colonies to the right. (I) Degree of substrate coverage by corals; (II) branching colonies; (III) massive colonies; (IV) encrusting colonies; (V) funnel-shaped colonies. (1) Crusts of zoanthides; (2) *Petrosia testudinaria;* (3) *Sarcophyton twcheliophorum*, (4) *Lobophytum pauciflorum*; (5) *Juncellaflagilis;* (6) *Pocillopora verrucosa*; (7) branched acropores; (8) *Acropora cytherea*; (9) funnel-shaped *Montipora*; (10) aggregations of fungiids; (11) *Porites*; (12) *Goniopora*; (13) *Favia* and *Favites;* (14) *Leptoria*, (15) *Diploastrea*; (16) *Turbinaria*; (17) *Spiwbranchus giganteus*; (18) *Cyprea arabica*; (19) *Arca ventricosa;* (20) *Lobophyllia;* (21) *Diadema setosum;* (22-24) different species of holothurians; (25) *Caulerpa racemosa*; (26) *Turbinaria decurrens;* (27) *Laurencia obtusa.*

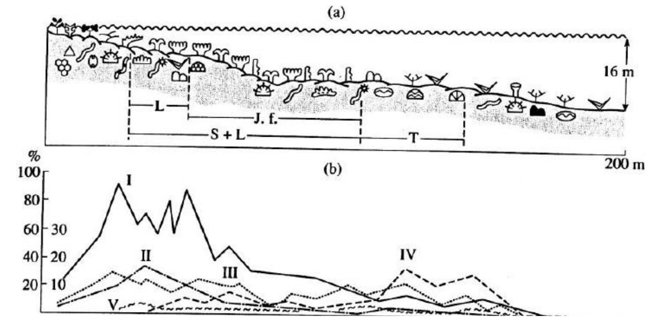

Figure 3 : Profile of a reef of rocky with (a) the distribution of common macrobenthos species and (b) the degree of substrate coverage by corals and relationship between their colony shapes, transect 5. S+L – represent the community of *Sarcophyton trocheliophorum* + *Lobophytum pauciflorum*; L–represent the facies of *L. pauciflorum*; J.f – represented the facies of *Juncella fragilis*; T – represented the zone of *Turbinaria peltata*. For other designation, see Figure 2

A significant role in the composition and structure of the community of *A. cytherea* + *M. platyphylla* and in the development of its overall biomass is played by numerous macrobenthos. These include the sea urchin *D. setosum*, with a density of up to 30 spec/m^2 and biomass of 2409 g/m^2; the holothurians *H. edulis* and *Stichopus chloronatus*, with settlement densities of no less than 0.5 spec/m^2; the sea stars *Culcita novaeguineae* and *L. laevigata*; and the mollusks *Cyprea arabica* (up to 5 spec/m^2) and *Trochus niloticus*.

Farther from the coast, the algal-coral community gives way to a straight coral community (mono- or two-species), which is explained by the increasing size and number of Poritidae colonies. On the western side of the islands, a community of *Porites lutea* develops, often covering the solid substrate, with colonies reaching 2 m high and 3-5 m in diameter in the seaward part of the reef (Figure 4). In the shallow portion of the *P. lutea* community one of the following Acroporidae species may be subdominant: *A. cytherea*, *A. hyacinthus*, *M. hispida*, or *M. aequituberculata*. The scleractinian *P. daedalea* and *P. verrucosa* and the hydroid *M. platyphylla*, with colonies reaching 1.5-2 m in diameter, are also constant components of the coral community. Patches of settlements of *Sarcophyton* and *Lobophytum* alcyonarian sometimes appear between the scleractinian. Th degree of substrate coverage by the corals reaches 60-100%.

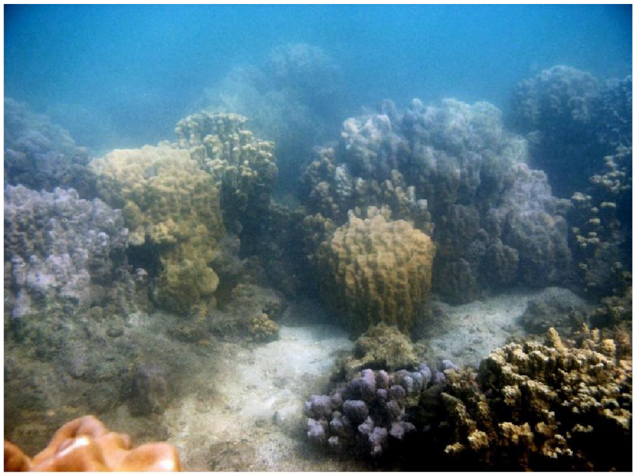

Figure 4 : A community of *Porites lutea*, transect 3, dept 3 m

The massive colonies of *Porites*, *Platygyra*, and *Cyphastrea* are inhabited by numerous bivalve mollusks and polychaetes. The mollusks include *A. ventricosa*, with a mean settlement density of 18.7 spec/m^2 and a biomass of 81.9 g/m^2, and *B. semiorbiculata*, with a density of 14.9 spec/m^2 and a biomass of 409.2 g/m^2. The settlement density of the polychaete *S. giganteus* reaches 100 spec/m^2 with a biomass of 148 g/m^2. The greatest settlement density among the macrobenthos was recorded for *A. ventricosa* (36 spec/m^2 and biomass of 1576.8 g/m^2) in colonies of *Cyphastreaserailia*, 140 m of the shoreline (transect 1) at Roi Island. The sea urchins *D. setosum* (3-5 spec/m^2), *Echinotrix diadema*, *E. calamaria* (0.5 spec/m^2 each), and *Toxopneuster pileolus* (0.3 spec/m^2) are common in the *P. lutea* community. The sea stars *L. laevigata*, *C. novaeguineae*, and *Echinaster lisonocus* and the mollusks *Tridacna crocea*, *Ustularca bicolorata*, and *Lopha cristagalli* also consistently appear in this community.

A community of *Goniopora djiboutiensis* spreads at the base of the reef slope and on the pre-reef platform. In this case, the dominating species provide a 40% substrate surface coverage (up to 75% in some patches), at densities of 20-40 colonies/m^2. In this community, the subdominants are the large *Favites abdita* and the *Sandalolitha robusta*, with colonies reaching 50-60 cm in diameter. Among the other scleractinian present, *Symphyllia radiata* and *Trachyphyllia geoffroyi* are the most common. The sponge *P. testudinaria* (1-2 colonies/m^2), the gorgonarians *Melithea*, *Subergorgia*, and *Juncella* (up to 10-15 colonies/m^2), and the holothurian *S. variegatus* (0.5 spec/m^2) are all constant components of the community. The spontagoid sea urchin *Brissus latecarinatus* distributed in the sand between the corals, and its settlements density and biomass reach 15.3 spec/m^2 and 18.5 g/m^2, respectively.

On the eastern side of the islands, the *P. lutea* community is less homogeneous. The overall domination of a single species of *Porites* rarely observed here. In the shallow water portion, an important role in the development of the community is played by the goniopores*G. djiboutiensis* and *G. lobata*, with settlement densities of up to 35 colonies/m^2 and sizes of 3.5 to 20 cm. In some areas, they provide up to 40% substrate coverage. A smaller, but rather noticeable role in the development of this part of the community is played by the corals *A. robusta*, *A. cytherea*, *P. verrucosa*, and *G. fascicularis* and the gorgonarian *J. fragilis*; the settlement density of the latter can reach 18 spec/m^2 at a biomass of 500 g/m^2. At greater depths, the numerous colonies of goniopores are replaced by large colonies of *P. lutea*, *P. lobata* (more than 2 m in diameter), *T. peltata*, and *T. mesenterina*, although they still appear the most frequently among other scleractinian. The colonies of *A. cytherea*, *A. florida*, and *A. millepora* increase in size. Constant coral components of the community include large colonies of scleractinian *P. daedalea* and *Leptoria phrygia*; the hydroids *M. platyphylla*, which reach 2 m in diameter; and the gorgonarian *J. fragilis*, which shows a settlement density of no less then 10 spec/m^2. Significant roles in the development of community composition, structure, and overall biomass are played by the sponge*P. testudinaria* sponges, which appear at every square meter and reach 1 m in height and 45 cm in diameter and the mollusks *A. ventricosa* (10.9 spec/m^2 and 455.6 g/m^2) and *B. semiorbiculata* (4.2 spec/m^2 and 141.1 g/m^2). The sea urchin *D. setosum*, the holothurians *S. variegatus* and *H. atra*, the sea star *C. novaeguineae*, and the bivalve mollusks *Tridacna squamosa* and *L. cristagalli* consistently appear between corals.

No clearly pronounced domination of any species of a coral or any other macrobenthos species observed on the pre-reef platform. These are mostly mosaic settlements, where the composition and density depend, to a significant degree, on the lithological component of the substrate. The latter varies from large pebbles (which arise from the island rock and from broken corals) to fine silted organogenic detritus and pure sand. There are most commonly settlements of solitary *T. geoffroyi* corals (0.35 spec/m^2, with a biomass of 16.6 g/m^2) and gorgonarians *Ctenocellia lira* (up to 10 spec/m^2) with *S. variegatus* and *H. edulis* holothurians (rarely more than 0.5 spec/m^2 at a biomass of 20 to 37 g/m^2). Constant components of the pre-reef platform settlements include the sponge *P. testudinaria*, the sea urchin *T pileolus*, and the mollusks *L cristagalli* and *Malleus malleus*. There are also single specimens of the gastropods *Cassis cornuta, Murex microphyllus, Terebra maculata, Pteria penguin,* and others (usually 15-20 species). These increase the species diversity and slightly elevate the total density and biomass of the community of the pre- reef platform, as do numerous polychaetes, amphipods, isopods, and other similar fauna in this zone. The total density of the latter may reach about 500 spec/m^2, while the biomass rarely exceeds 1.5 g/m^2.

Rocky coast reefs

A rich, multispecies coral-algal community develops in the coastal strip of reefs along rocky coasts. This is due to the great diversity of different terraces, crevices, grottoes, and conglomerations of rocks, which provide numerous differently oriented substrate surfaces at depths ranging from 0 to 3 m. The bulk of the community is composed of the alcyonarian *S. trocheliophorum* and large encrusting colonies of *A. cytherea* and *A. rvbusta*. The subdominants are the zoanthides *Zoanthus* sp. and the faviid *F. abdita*. Colonies of *G. fascicularis* and *H. exesa* may settle in patches, occupying up to one quarter of the total area of substrate coverage. About 30 species of scleractinian appear constantly. Combined with the alcyonarian, these provide 37-64% substrate surface coverage.

In the intertidal zone of this community, an algal zone arises, dominated by the brown algae *T. decurrens, S. congkinhii, S. polycystum,* and *P. australis, C. microphyza* and *Amphiroa fragilissima* are present here, among other macrophytes. The former two species produce the greatest biomass, at 1737 and 1283 g/m^2, respectively. The face of the community, its composition, and its structure all depend, to a significant degree, on the large macrobenthos that are often present here. These include the holothurians *H. atra, H. edulis, S. variegates,* and *B. graeffei* (1.5-3 spec/m^2 each). The sea urchin *D. setosum* (up to 27 spec/m^2 at a biomass of 2438 g/m^2) and the cowry *C. arabica* (3-5 spec/m^2) are also numerous. The sea star *C. novaeguineae* and mollusk *T niloticus* appear consistently in the community.

Deeper down, at depths of 2 to 10 m and distances of 25-100 m from the shoreline, soft corals become dominant and a community of *Sarcophytum trocheliophorum* + *Lobophyton pauciflorum* develops. The alcyonarian make almost a solid carpet covering the horizontal areas of the rocky and block substrate and, on average, have high biomasses (12040 g/m^2 and 10330 g/m^2 for *S. trochelioporum* and *L. pauciflorum*, respectively). At 100% substrate coverage, these indices reach their maximum values of 37445 and 28620 g/m^2, respectively. Closer to the shoreline, the solid substrate coverage is more often made up of *L pauciflorum*, whereas, in the seaward part, it is mostly composed of *S. trocheliophorum*. In the central part of the community, there are areas dominated by *Sarcophytum* and subdominated by the gorgonarian *J. fragilis*, the latter having settlement densities of up to 15 spec/m^2 and a biomass of 556.3 g/m^2. A significant role in the development of the community of soft corals is played by scleractinian, which are represented by a few rather large colonies of *P. lobata, P. lutea, T peltata, D. heliopora, P. daedalea, L. phrygia,* and *Favia speciosa*. *A. cytherea, A. robusta, A. florida,* and the gorgonarians *Melithaea ochracea, Subergorgia suberosa,* and *Ellisella erythrea* are also found, with densities of no less then 2 spec/m^2.

Several macrobenthos are constant components of the community of *S. trocheliophorum* + *L. pauciflorum* community. These include the sea urchin *D. setosum* (5-7 spec/m^2); the holothurians and sea stars *H. edulis, S. variegates,* and C. *novaeguineae;* the mollusks *T. squamosa, A. ventricosa, B. semiorbiculata,* and *L. cristagalli*; and the polychaete S. *giganteus.*

At distances of more than 100-110 m off the shore-line, the amount and sizes of the boulder-block sub-strate decrease, and the community of soft corals is replaced by a multispecies coral community noticeably dominated by one or two species of scleractinian.

With a sharp increase in depth and reduction for material, the community of soft corals replaced by patches of monosettlements of *G. djiboutiensis* 3-5 m^2 in square. Between the latter are rare small colonies of other corals, such as *T. peltata, T. geoffroyi, Plerogyra sinuosa, Porites lichen, Leptastrea purpurea*, and *Psammocora superficial*. The sea urchins *D. setosum* (5-7 spec/m^2) and *T. pileolus* (0.75 spec/m^2) and the holothurians *S. variegatus* and *H. edulis* (3-5 spec/m^2) consistently appear among the corals. The organogenic detritus on the platform at the reef slope inhabited only by small, single corals *T. geoffroyi, G. djiboutiensis*, and *T. peltata* and echinoderms *H. edulis* and *T. pileolus*; the settlement density of the latter does not exceed 0.2-0.35 spec/m^2.

With gradually increasing depth and a reduction in size and amount of the boulder-block substrate, the community of *S. trocheliophorum + L pauciflorum* is replaced by a polyspecies coral community. It is dominated by the dendrophylliids *T. peltata* and *T. mesenterina* (up to 30% of substrate coverage and 60% of occurrence) and the *P. murrayensis* (10% of the coverage at 40% occurrence). The scleractinian *Stylophora pistillata, Acropora secale, L. phrygia, F. speciosa*$_t$ *F. abdita, G. fascicularis, Lobophylla hattai, Echinopora lamellosa*, etc. (19 species altogether) are represented by single colonies. A significant role in the development of the composition of this community is played by the sponge *P. testudinaria*; the gorgonarians *E. erythrea, M. ochracea, C. lira*, and *J. fragilis*; and the oyster *L cristagalli*, which are present at almost every square meter of the transect, with a density of 1.5 spec/m^2 and biomass of 125.6 g/m^2.

At a distance of more than 150-160 m from the shoreline, with the transformation of the boulder-block substrate into the pebble-detritus one, the coral settlements are formed only by single colonies of the scleractinian *T. peltata, Goniopora tenuidens, F. speciosa*, and *Tubastrea nigriscens*; the solitary fungiid *Fungia paumotensis*; and the gorgonarians *J.fragilis, Subergorgia tuberosa, M.ochracea, E. erithrea*, and *C. lira*. The latter noticeably dominates in terms of settlement density, at 3-5 spec/m^2. The bivalve mollusks *L. cristagalli* and *Pteria penguin* appear on every second gorgonarian.

DISCUSSION

In general, the coral fauna of the An Thoi archipelago and attendant macrobenthos have a high similarity with the composition of the rest of the macrobenthos Vietnam (Figure 5) and serves as a link between the Gulf of Thailand and other parts of the South China Sea,including the Gulf of Tonkin.

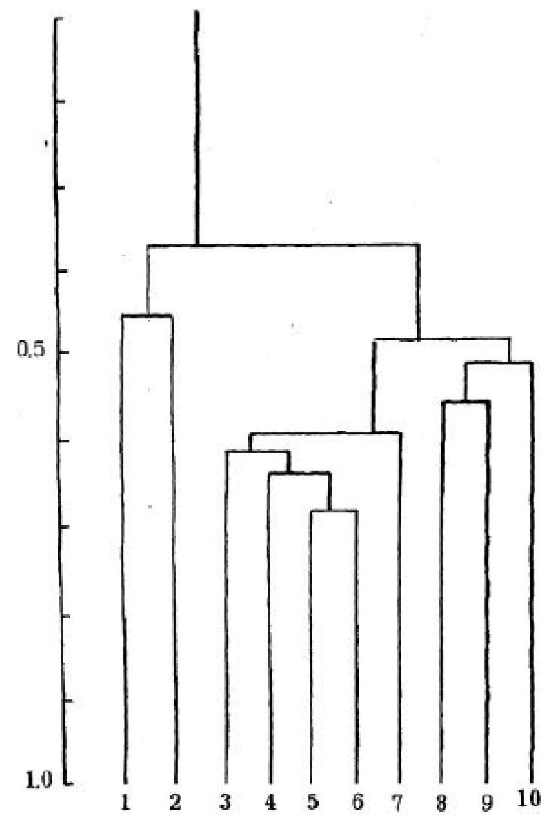

Figure 5 : Dendrogram of similarity in species composition scleractinian and macrobenthos the Gulf of Thailand and another regionof Vietnam. On axis of abscissa: 1 – BaiTu Long Archipelago (Gulf of Tonkin); 2 - Cu Lao Cham island; 3 - reefs of the Khanh Hoa Province; 4 - Ly Son Island; 5- Thu and CaThuik Islands; 6 - Con Dao Islands; 7 - Tho Chu Island; 8 - Namsu Islands; 9 - An Thoi Archipelago; 10 - Sihang Islands. The ordinate axis - correlation coefficient

The general pattern of benthic community development is similar throughout the reefs of the An Thoi archipelago. Mostly, these are communities of Poritidae or soft corals involving several biocenoses (zones, facies) that replace each other along the vertical and horizontal lines, with domination of certain species of scleractinian or their groups. The level of similarity of species compositions in different communities is rather great and ranges from 40-72%, somewhat decreasing, down to 19-46.7%, in soft-bottom communities. The degree of macrophyte similarity in algal-coral communities never falls below 22.6%. More than one third of the whole species composition of mollusk taxocene (38.3%) is common to all coral communities of the examined reefs. The greatest degree of similarity is shown among scleractinian, which have 64.8 to 72% of their species in common, due to the domination or the greatest frequency of occurrence of one and the same species groups in communities of different reefs. The major role in the development of the great similarity of corals is played by Poritidae, Acroporidae, Dendrophylliidae *Turbinaria*, and some species of Faviidae that occur almost everywhere.

The diversity of geomorphological conditions of the islands, constant water input from the open part of the South China Sea, steady monsoon winds, and great eutrophication provide a great diversity of rather specific conditions for the development of coral species diversity. In general, the species diversity of scleractinian in the surveyed area (160 species) is two times greater than in the innermost part of the Gulf of Siam and is comparable to the number of corals in other islands of the bay, namely Nam Su and Tho Chu islands. It is somewhat smaller than the coral diversity in the Con Dao and Thu (PhuQuy) islands of the open part of the South China Sea, although it is quite comparable to the latter[13,14,22].

The soft corals *Lobophytum*, *Sarcophyton*, and *Sinularia* make up settlements and even dominate on the windward sides of the examined reefs and also of other reefs of the South China Sea[12,23]. Many common features might also be retraced in the development of the coastal algal-coral community with large amounts of algae (*Turbinaria*, *Laurencia*, and *Sargassum)* and a large macrobenthos (mollusks, sea urchins, holothurians, etc.) and lagoon reef community in many regions[4,8,22,24-27].

At the same time, a changing and somewhat decreasing species diversity of acroporids is observed on the reefs of the An Thoi archipelago compared with those on the reefs of the open part of the South China Sea. The number of *Acropora* and *Montipora* species in the Con Dao and Thu islands and in the coastal reefs of South Vietnam is 1.5 times greater than in the observed reefs[22,28,29]. The decrease in species diversity via direct elimination of certain species and changes in the common structure of the reef community are usually related to silting and eutrophication of waters[30-34]. Eutrophication affects the composition and structure of coral communities via some biological processes. Among the latter are a greater capability to clear sediment, advantages in reproductive strategies or the rate of linear growth of colonies of some species against the colonies of other species, and resistance against predators

Coralum *Porites* are capable of secreting a strong bacterial envelope in polluted waters[35] and of beginning reproduction under conditions of great eutrophication 1- 2 months earlier than other corals and then producing larvae throughout the extended season of reproduction[36], They are also well adapted to deal with drying, overheating, and desalination[37,38]. All of these characteristics provide *Porites* with obvious advantages over other scleractinian under the stressful conditions of silted shallow waters. The domination of massive *Porites* (see Figure 4), which develop solid settlements in eutrophic or silted turbid waters, is characteristic of many reefs in the Indo-West Pacific and Atlantic[13,23,30,39-43].

Under conditions of great eutrophication, the increased concentration of biogens in the water may hamper the crystallization of $CaC0_3$[44], while, due to water turbidity and reduced illumination, the intensity of light-dependent calcification decreases[45]. Fast-growing corals, and, first of all, common species of the *Acropora* which usually perform calcification three times more intensely than massive porites[46] can, under such conditions, significantly reduce their rate of linear growth and be inferior to massive corals in the development of organic matter production on the reef.

The eutrophication of waters in the TonkinGulf and the related changes in abiotic and biotic factors, including those listed above; determine the specific composition and structure of reef-building scleractin-ian and the completely coral community.

The domination of massive porites throughout almost all reefs of the Gulf of Siam is due to the fact that these corals are capable not only of surviving under conditions that are stressful for many other corals, but also of dominating over other scleractinian in terms of organic matter productivity, degree of substrate cover-age, and species diversity[13,14,36].

The shallow nature of the Gulf of Siam and the fact that the hard rocky-block substrate limited by insufficient deposits in the narrow coastal strip impedes the enlargement of the reef area. Here, the massive porites, being among the major biogenic producers (100% occurrence at 40-100% coverage of substrate surface), not only form the framework of the reef, but also play a significant role in the expansion of the reef area. Tidal processes and the actions of many inhabitants of the *Porites* colonies (polychaetes, mollusks, and crustaceans) lead to erosion, which results in the passive colonization[47] of new bottom areas by broken portions of living *Porites* colonies. At the expense of the remnants of dead colonies, a new, now organogenic substrate develops and inhabited by porites, other corals, and different phyto- and zoobenthos. The intensity of biogenic production and the rate of erosion are indispensable conditions for the growth and formation of com-plete communities of reef-builders.

Despite the absence of the normal physiographic zonation and thick reef deposits, the reefs of the An Thoi archipelago show two clearly pronounced parts (which are usually characteristic of zonal structural reefs) with communities differing in composition and structure. The coastal (lagoon) portion of the reef consists primarily of a complex of heterotrophic organisms, polychaetes, bivalve and gastropod mollusks, different groups of echinoderms, etc. The zone of *Porites* domination, which is comparable to the reef fiat, and the reef slope are primarily inhabited by corals. The associated settlements of other macrobenthos are of pronounced subordinate importance. The lagoon part of the reef is mostly heterotrophic, while the reef flat and reef slope are both mostly autotrophic[48,49].

The reefs of the An Thoi archipelago, being located in specific conditions of the Gulf of Thailand, characterized by a great diversity of corals and associated macrobenthos and have a rather unique community composition and structure compared with the other reefs of Vietnam. All of these support the opinion that the reefs of the An Thoi archipelago must be preserved as an essential part of the reef ecosystem of the Vietnamese coast and the South China Sea as a whole, within a projected marine reserve area of Vietnam.

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REFERENCES

[1] Yu.Ya.Latypov; Community Structure of Scleractinian Reefs in the Baitylong Archipelago (South China Sea). Asian Marine Biology, **12**, 27-37 **(1995)**.

[2] Yu.Ya.Latypov; Macrobenthos Communities of AnThoi Archipelago of South China Sea. Russian Journal of Marine Biology, **26**, S25-S26 **(2000)**.

[3] Yu.Ya.Latypov; Scleractinian Corals and Reefs of Vietnam as a Part of the Pacific Reef Ecosystem. Open Journal of Marine Science, **1**, 50-68 **(2011)**.

[4] Yu.Ya.Latypov; Barrier and Platform Reefs of the Vietnamese Coast of the South China Sea. International Journal of Marine Science, **3**, 23-32 **(2013)**.

[5] S.T.Vo, G.Hodgson; Coral Reefs of Vietnam: Recruitment Limitation and Physical Forcing. Proceeding 8th International Coral Reef Symposium, **1**, 477–482 **(1997)**.

[6] J.E.N.Veron; Corals in Space and Time: The Biogeography and Evolution of the Scleractinia. Australian Institute of Marine Sciences, Townsville, 321 **(1995)**.

[7] N.H.Yet; Thánmphánloáihôcúngvàcáutrúc ran san hôDâoThuyênChài (QuânDâoTruòngSa).Tai nguyênvàmôitruongbiên.Hanoi, **l(4)**, 299–313 **(1997)**.

[8] Yu.Ya.Latypov, N.I.Selin; Coral Communities of Barrier Reefs of Vietnam. Russian Journal of Marine Biology, **34**, 143–150 **(2008)**.

[9] Yu.Ya.Latypov; Encrusting protected reef Hon Nai in Cam Ranh Bay in the South China Sea. Natural Science, **4**, 14-21 **(2012)**.

[10] J.E.N.Veron, G.Hodgson; Annotated Checklist of the Hermatypic Corals of the Philippines. Pacific Science, **43**, 234–287 **(1989)**.

[11] M.B.Best, B.W.Hoeksema, W.Moka *et al*.; Recent Scleractinian Corals Species Collected during the Snellius-II Expedition in Eastern Indonesia. NetherlandsJournal of SeaResearch, **23**, 107–115 **(1989)**.

[12] C.E.Dai; Patterns of Coral Distribution and Benthic Space Partitioning on the Fringing Reefs of Southern Taiwan. Marine Ecology, **14**, 185-204 **(1993)**.

[13] Yu.Ya.Latypov; Coral Communities of the Namsu Islands (Gulf of Siam, South China Sea). Marine Ecology Progress Series, **29**, 261-270 **(1986)**.

[14] K.Sakai, T.Yeemin, A.Svidvong *et al*.; Distribution and Community Structure of Hermatypic Corals in the Sichang Islands, Inner Part of the Gulf of Thailand. Galaxea, **5**, 27-74 **(1986)**.

[15] Yu.Ya.Latypov; Benthic Communities of Coral Reefs of Tho Chu Island (Gulf of Siam, South China Sea). BiologiaMorya, **25**, 201–208 **(1999)**.

[16] Yu.Ya.Latypov; Reef-building corals and reefs of Vietnam.1. The Gulf of Siam, Russian Journal of Marine Biology, **29**, S22-S33 **(2003)**.

[17] Yu.Ya.Latypov; Hermatypic corals and reefs of Vietnam.2. Gulf of Tonkin, Biol. Russian Journal of Marine Biology, **29**, S34-S45 **(2003)**.

[18] C.G.Petersen; The Animal Association on the Sea Bot-tom of the North Atlantic. Kobenhavn Berg Biological Station, **22**, 89-98 **(1971)**.

[19] Y.Loya, L.Slobodkin; The Coral Reefs of Elate (Gulf of Elate, Red Sea), Symposia of the Zoological Society of London, **28**, 117-140 **(1971)**.

[20] S.M.Mandaville; Benthic Macroinvertebrates in Freshwater – Taxa Tolerance Values, Metrics, and Protocols, Project H - 1.(Nova Scotia: Soil & Water Conservation Society of Metro Halifax) **(2002)**.

[21] R.Serene; Inventaires des invertebras marine de l'Indochine, Institute of OceanographyIndochine, **30**, 3–83 **(1937)**.

[22] Yu.Ya.Latypov; Benthic Communities of Coral Reefs of Con Dao Islands of South China Sea. BiologiaMorya, **5–6**, 40–53 **(1993)**.

[23] Yu.Ya.Latypov; Reefs and Communities of Scleractin-ians of the Western Part of the BaiTu Long Archipelago (the South China Sea). BiologiaMorya, **1-2**, 17-26 **(1992)**.

[24] Y.Benayahu, Y.Loya; Space Partitioning by Stony Corals, Soft Corals, and Benthic Algae on the Coral Reefs on the Northern Gulf of Elate (Red Sea). Helgoland Wissenschaft Meeresuntersuchen, **30**, 362-382 **(1977)**.

[25] H.Mergner; Quantitative okologische AnalyseeinesRiffiagunenarealsbei Aqaba (Gulf von Aqaba, Rotes Meer). Helgoland Wissenschaft Meeresuntersuchen, **32**, 476-507 **(1979)**.

[26] S.Dollar; Wave Stress and Coral Community Structure in Hawaii. Coral Reefs, **1**, 71-81 **(1982)**.

[27] Yu.Ya.Latypov; Reefs and Communities of Scleractin-ians of Thu Island (South Vietnam).In Biologiyap ribrezhnykhvodV'etnama:Gid robiologicheskiei ssledovaniyal itoraliisublitorali Yuzhhogo V'etnama (Biology of Coastal Waters of Vietnam: Hydrobiological Investiga-tions of Intertidal and Subtidal Zones of South Vietnam), Vladivostok: DVO AkademiaNauk SSSR, (In Russian), 11-19 **(1988)**.

[28] Yu.Ya.Latypov; Scleractinian Corals of South Vietnam. BiologiaMorya, **5**, 12-19 **(1987)**.

[29] Yu.Ya.Latypov, N.I.Selin; Current status of coral reefs of islands in the Gulf of Siam and southern Vietnam. Russian Journal of Marine Biology, **37**, 255-262 **(2011)**.

[30] Y.Loya; Effects of Water Turbidity and Sedimentation on the Community Structure of Puerto Rican Corals. Bulletin Marine Science, **26**, 450-466 **(1976)**.

[31] T.Tomascik, F.Sander; Effect of Eutrophication on Reef-building Corals.2. Structure of Scleractinian Coral Communities on Fringing Reefs, Barbados, West Indies. Marine Biology, **94**, 53-75 **(1987)**.

[32] H.M.Gusman, J.Cortes; Coral Reef Community Structure at Cano Islands, Pacific Costa Rica. Marine Ecology, **10**, 23-24 **(1989)**.

[33] N.T.An; Biological Productivity of Vietnam Marine Waters.In Monographs on Vietnam Seas. Science Technology Publishing House, Ha Noi., 502–518 **(1994)**.

[34] K.E.Fabricius; Effects of irradiance, flow, and colony pigmentation on the temperature microenvironment around corals.Implications for coral bleaching? Limnology and Oceanography., **51**, 30–37 **(2006)**.

[35] H.W.Ducklow, R.Mitchell; Bacteria in Mucus Lay-ers on Living Corals, Limnology and Oceanography, **24**, 715-725 **(1979)**.

[36] T.Tomascik, F.Sander; Effect of Eutrophication on Reef-building Corals.3. Reproduction of the Reef-building Coral Porites porites.Marine Biology, **94**, 77-94 **(1987)**.

[37] H.Ditlev; Zonation of Corals (Scleractinia Coelenterata) on Intertidal Reef Flats at Ko Phuket, Eastern Indian Ocean. Marine Biology, **42**, 29-39 **(1978)**.

[38] P.F.Holthus, J.E.Maragos, C.W.Evans; Coral Reef Recovery Subsequent to the Freshwater Kill of 1965 in Kaneohe Bay, Hawaii. Pacific Science, **43**, 122-134 **(1989)**.

[39] P.W.Glynn; Ecology of a Caribbean Coral Reef. In The Pontes Reef Flat Biotope.Part 1.Meteorology and Hydrography. Marine Biology, **20**, 297-318 **(1973)**.

[40] H.G.H.Hamilton, W.H.Brackel; Structure and Coral Fauna of East African Reefs. Bulletin Marine Science, **34**, 248-266 **(1984)**.

[41] L.M.Chou, Y.H.Teoottt; An Ecological Study on the Progress Series, **23,** 79-84 **(1985)**.

[43] T.N.Khomenko; Distribution of Scleractinians Poritids on Reefs of the Bai Thu Long Archipelago of the Bay of Tonkin. BiologiaMorya, **3,** 11-19 **(1993)**.

[44] K.Simkiss; Phosphates as Crystal Poisons of Calcifica-tion. Biological Reviewsof the Cambridge Philosophical Society, **39**, 487-505 **(1964)**.

[45] R.E.Dodge; Growth Characteristics of Reef-Building Corals. Proceeding 4th Coral Reef Symposium, Manila, **2**, 241-248 **(1981)**.

[46] M.Huston; Variation in Coral Growth Rates with Depth at Discovery Bay, Jamaica. Coral Reefs, **4**, 19-25 **(1985)**.

[47] R.C.Highsmith; Passive Colonization and Asexual Col-ony Multiplication in the Massive Coral*Porites lutea*Milne Edwards and Haime. Journal Experimentalof Marine Biology and Ecology, **47**, 55-67 **(1980)**.

[48] J.A.Marsh; Preliminary Observation on the Produc-tivity of a Guam Reef Flat Community. Proceeding Second International Coral Reef Symposium, Brisbane, **1**, 139-145 **(1974)**.

[49] Yu.I.Sorokin; Ecosys-tems of Coral Reefs, Moscow: Nauka. (in Russin), **(1990)**.