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CHOROLOGY

Reef-Building Corals and Reefs of Vietnam: 2. The Gulf of Tonkin

Yu. Ya. Latypov
Institute of Marine Biology FEB RAS, Vladivostok, 690041 Russia
e-mail: Itpv@stl.ru
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Abstract—This paper deals with the history and results of the studies of reefs and coral communities of the Gulf of Tonkin based on published and unpublished materials, including the author's. The state of the art in the study of reef-building scleractinian corals and reefs of this region is reported. The peculiar nature of the reefs studied is caused by the monsoon climate in the region ahd river runoff waters cooled to 16-18°C, silted to 100 g/m2 per day, and freshened to 28%e in the wintertime, i.e., conditions far from optimum for reef formation. The silting and eutrophication of the gulf waters resulted in a change in the composition and structure of the coral reef communities via the reduction or elimination of certain coral species. Instead of acroporids, typical for the majority of other reefs, reef communities of the Gulf of Tonkin are dominated by poritids and faviids, which form the framework of the reefs. These peculiarities make the reefs of the Gulf of Tonkin really unique.

Key words: the Gulf of Tonkin, reefs, reef-building corals, poritids.

The Gulf of Tonkin, called Bac Bo by the Vietnamese, cuts deep into the continent. In the west, it borders on the eastern Indo-Chinese coast; in the east, it borders on the western coast of Lai Chau Peninsula and Hai Nam Island (Fig. 1). The shallowness of the gulf and peculiarities of its bottom relief are of special importance. The depths of the gulf and adjacent parts of the South China Sea do not exceed 100 m. The northern part of the gulf is a shallow-water area confined with a 50-m isobath in the south. The western coast of the gulf borders on a wide water strip with a depth below 50 m. The bottom of the gulf is plain and is covered with soft ground dominated by silts and silty sands with shell fragments and organogenous matter. The central groove of the bottom, confined with 50- to 60-m isobaths, is covered with silty and clayey ground. Due to the shallowness of the gulf, the water is rapidly warmed up to 29-32°C in summer and cooled to 16°C in winter [2, 48].

A huge continental runoff occurring via numerous rivers flowing into the gulf plays an important role in its hydrological regime. Thus, the Krasnaya River alone brings into the gulf as much as 137 billion m^3 of fresh water and 116 million tons of suspended matter every year [41]. The river waters desalinate the water in the western and northwestern parts of the gulf to 26-3 \%c and form a constant runoff current with a salinity of 21 - 22%e, running along the western coast southward [2]. The continental runoff bears a huge amount of terrigenous matter, forming a thick covering over the bedrock and structures of the reef's origin. The daily amount of matter accumulated in the water column constitutes 25-60 g/m^2, while the daily amount of matter settling out onto the bottom varies between 16-100 g/m^2. In typhoons, these values increase tens of times [3, 11, 32].

The Gulf of Tonkin features regular daily tides up to 3-4 m in height and strong tidal currents with a speed of 1.5-2, and sometimes 3, knots.

In Northern Vietnam, in particular, in the Gulf of Tonkin, the year includes four seasons, which differ considerably in wind and precipitation regimes, as well as in water mass dynamics [4, 31].

In winter (October-March), a pronounced current of desalinated runoff waters is observed to run along the western coast southward. The uppermost part of the gulf is supplied with the warm and saline waters carried from the southeast (the South China Sea) through the central and eastern parts of the gulf. In the central part of the gulf, a cyclonic gyre comprising the zone of active water mixing is seen (Fig. 2a). In spring (May-April), the runoff current weakens and runs closer to the coast. The whole gulf is filled with the water carried from south, while local cold water moves downward to the bottom to form a bottom current running in the central groove southward (Fig. 2b). The summertime (June-August) is characterized by an anticyclonic circulation in the center of the northern shallowness and superficial south current of warmed waters. In this period, the river runoff increases and the bottom waters upwell in the southwestern part of the gulf and off the coasts of Hai Nam Island (Fig. 2c). In September, the hydrological regime changes to its winter state, yet the summer water circulation partly persists (Fig. 2d).

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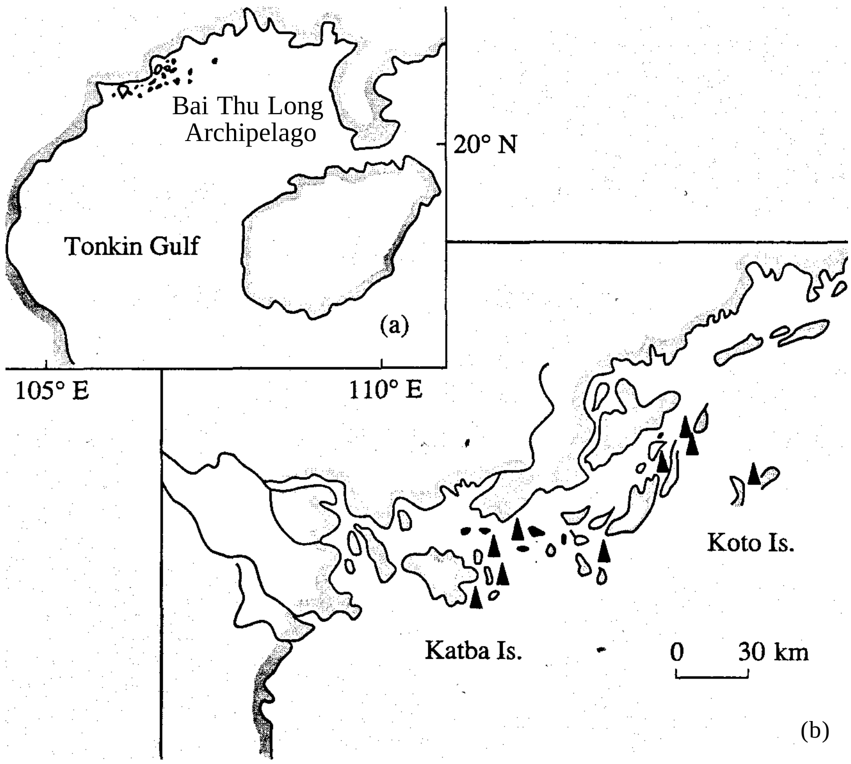

Fig. 1. Schematized map of the Gulf of Tonkin (a) and the areas surveyed (b), triangles.

The Gulf of Tonkin contains over 3000 islands, some 2000 of which are situated in its northern part, in Ha Long Bay. As a result of century-long erosion processes, the islands feature bizarre relief, in particular, numerous bights cutting deep into an island, grottoes, and caves, which display diverse biotic conditions, under which, the formation of coral reefs and coral reef communities can occur. The coastal zone is strongly jagged featuring steep slopes and plenty of crashed rocks and blocks. The underwater relief is formed by slightly inclined short platforms with alternating terraces at the depths of 3, 6, 9, and 11 m and numerous solid rock residuals cut with abrasions. The morphological profiles of the reefs are determined mainly by the geomorphology of the underwater slope and, to a lesser degree, carbonate deposits of the reef's origin [8, 34].

The first data on the fauna of the Gulf of Tonkin with a reference to several scleractinian and gorgonian coral species were obtained by an expedition aboard the RV "De Lanessan" [40]. In the late 1930s, some investigations were undertaken by Dawydoff in Ha Long Bay. The results were included in Dawydoff's list of bottom invertebrates of Indochina [23]. The list and general remarks on the distribution of separate animal groups gave one a clear insight into the peculiarities of the Vietnamese fauna. However, Dawydoff's report, as well as that by Serene, contained limited data on the corals of the Gulf of Tonkin, namely, as few as some 20 generic and specific names from different cnidarian groups.

In 1958, a joint Chinese-Soviet expedition worked on Hai Nam Island. That work resulted in new data on the taxonomical composition of reef-building corals and virtually the first data on the reefs of the Gulf of Tonkin [16]. Naumov *et al.* mainly focused on studying the reefs in the littoral zone of the northern and southern coasts. They established 37 scleractinian taxa of the generic and specific level and elucidated the peculiarities of their distribution. According to their data, the distribution of corals in the Gulf of Tonkin reefs is characterized by a distinct zonality, which is hardly comparable with that off Jamaica and Marshall Island. The suppression of the reefs studied was attributed to their proximity to the northern boundary of the coral reef distribution area. The researchers concluded that the coral reefs off Hai Nam Island comprise two types. The first one, so-called tidal coastal reefs, feature two belts, the inner and outer ones. The corals within the inner belt develop mostly into massive colonies—adaptive forms resistant to tidal action. The second type, so-called reefs of closed bights and lagoons, is characterized by a branched shape of corals and the absence of zones or belts.

Naumov *et al.* only studied two nearshore reef zones, lagoon and reef flat; however, they managed to distinguish certain classifiable features of the reef geo-

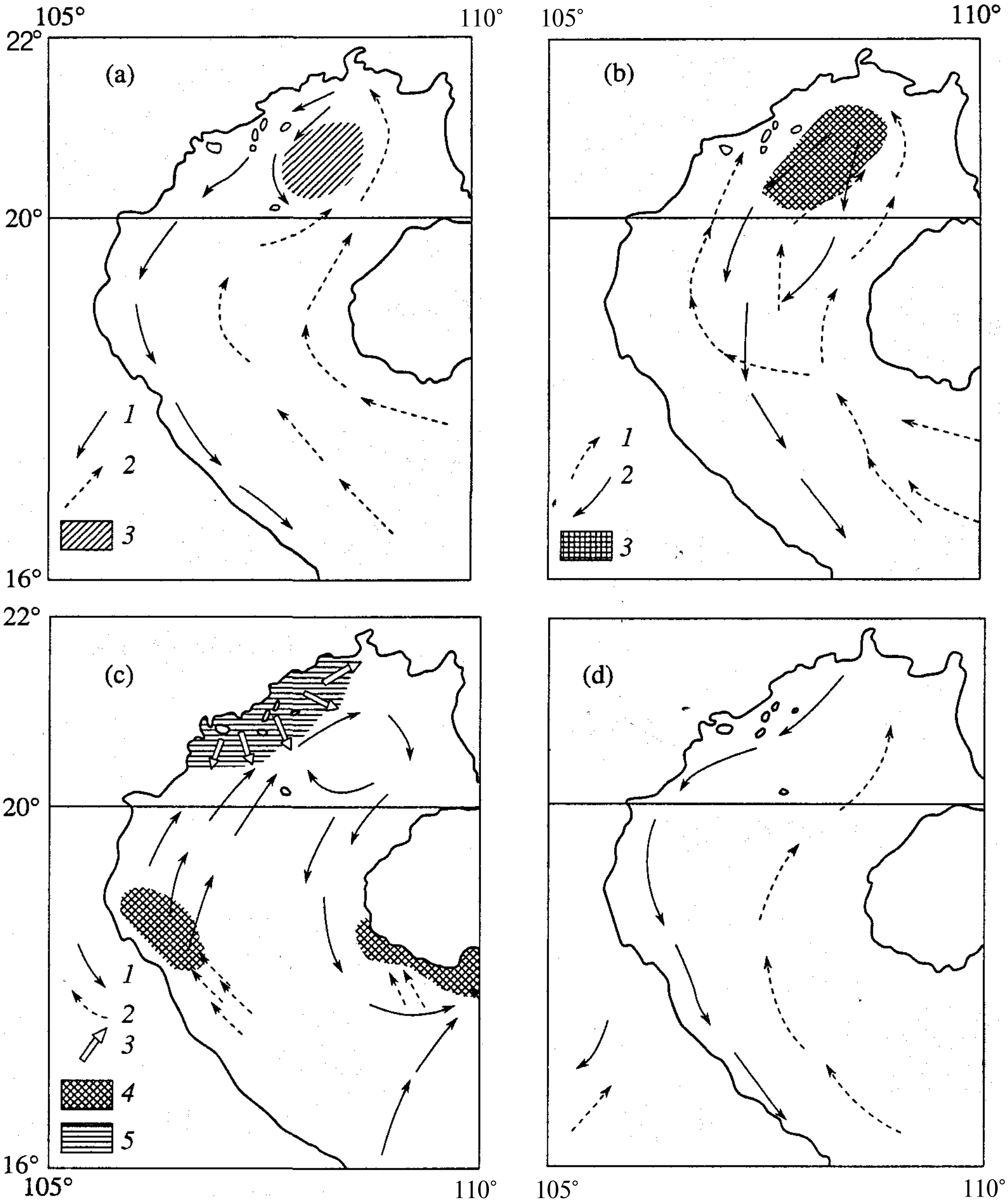

Fig. 2. Diagram of seasonal water circulation (from [4]). a—winter: *1*—cold desalinated current, 2—warm, less desalinated current, *3*—area of the mixing of cold and warm currents; b—-spring: *1*—warm superficial current, 2—cold near-bottom current, *3*—area of downwelling; c—summer: *1*—direction of superficial currents, 2—upwelling, *3*—direction of desalinated currents, *4*—areas of upwelling, 5—area of desalination; d—autumn: *1*—rundown desalinated current, 2—near-bottom compensatory current.

morphology and to reveal two reef types [16]. Later on, these types were also reported for other reefs and were named structural and unstructured [7, 8, 34, 29, 46].

In 1960-1961, joint Vietnamese-Soviet expeditions were performed with the purpose of a complex study of the Gulf of Tonkin. A hydrobiological survey was conducted all over the gulf at 105 stations at a depth of 5-157 m, as well as several littoral areas of the Bai Tu Long Archipelago and Hai Nam Island. Based on these studies, a list of some 900 bottom invertebrates was composed. Its analysis, as well as the faunistic characterization of the region [1, 2], has retained its fundamental importance for the description of the demersal fauna and its environment in the South China Sea to the present time.

Since the survey was mainly restricted to soft ground areas, the reefs and reef corals of the gulf were scarcely studied. The lists of the demersal fauna comprised as few as 12 scleractinian names, most of which were generic ones. This allowed Gurianova to conclude that the sedentary coelenterate fauna of the Gulf of Tonkin cannot be compared to that of the South Vietnam and that "madrepore corals only form reefs off Hai Nam Island" [2].

Species composition of corals of the Gulf of Tonkin

Species	Western part	Ha Long Bay	Eastern Part
1. *Stylocoeniella quenteri* Basset-Smith, 1834	+	+	-
2. *Psammocora contigua* (Esper, 1797)	+	+	+
3. *P. profundacella* Gardiner, 1898	+	+	+
4. *P. superficialis* Gardiner, 1898	+	+	-
5. *P. nierstraszi* Van der Horst, 1922	+	-	+
6. *P. digitata* Edwards & Haime, 1851	+	+	-
7. *Stylophora pistillate* (Esper, 1897)	-	+	+
8. *Madracis kirbyi* Veron & Pichon, 1976	-	+	-
9. *Acropora robusta* (Dana, 1846)	+	+	+
10. *A. danai* (Edwards & Haime, 1860)	-	+	-
•11. *A. nobilis* (Dana, 1846)	+	+	+
12. A. *formosa* (Dana, 1846)	» +	+	+
13. A. *microphthalma* (Verrill, 1869)	+	+	- +
14. A. *valenciennesi* (Edwards & Haime, 1860)	+	+	-
15. A. *glauca* (Brook, 1891)	+	+	+
16. A. *grandis* (Brook, 1891)	+	+	-
17. A. *acuminata* (Verrill, 1864)	+	+	+
18. A. *aspera* (Dana, 1846)		+	+
19. A. *hyacinthus* (Dana, 1846)	''- +	+	+
20. A. *cytherea* (Dana, 1846)	+	+	+
21. A. *austera* (Dana, 1846)	+	+	+
22. A. *pulchra* (Brook, 1891)	+	+	+
23. A. *millepora* (Ehrenberg, 1834)	+	+	+
24. A. *selago* (Studer, 1878)	+	+	-
25. A. *yongei* Veron & Wallace, 1984	+	+	-
26. A. *bushyensis* Veron & Wallace, 1984	+	-	-
27. A. *lutkeni* Crossland, 1952	+	+	-
28. A. *humilis* (Dana, 1846)	+	+	+
29. A. *digitifera* (Dana, 1846)	+	+	+
30. A. *gemmifera* (Brook, 1891)	+	+	+
31. A. *divaricata* (Dana, 1846)	+	+	+
32. A. *samoensis* (Brook, 1891)	+	+	+
33. A. *cerealis* (Dana, 1846)	-	+	-
34. A. *nasuta* (Dana, 1846)	+	+	-
35. A. *lopires* (Brook, 1891)	-	-	+
36. A. *fiorida* (Dana, 1846)	-	+	-
37. A. *sarmentosa* (Brook, 1846)	-	+	+
38. *Astreopora ocellata* Bernard, 1896	+	+	-
39. A. *myriophthalma* (Lamarck, 1816)	+	+	+
40. *Montipora tuberculosa* (Lamarck, 1816)	+	+	+
41. *M. monasterina* (Forskal, 1775)	-	+	-
42. *M. turtlensis* Veron & Wallace, 1984	+	+	+
43. *M. spongodes* Bernard, 1897	+	+	+
44. *M. undata* Bernard, 1897	+	+	-
45. *M. venosa* (Ehrenberg, 1834)	' +	+	+
46. *M. danae* (Edwards & Haime, 1860)	+	+	-
47. *M. turgescens* Bernard, 1897	+	+	+

Table. (Contd.)

Species	Western part	Ha Long Bay	Eastern Part
48. *M. caliculata* (Dana, 1846)	+	+	+
49. *M. hispida* (Dana, 1846)	+	+	-
50. *M. australiensis* Bernard, 1897	+	+	-
51. *M. informis* Bernard, 1897	+	+	-
52. *M. aequituberculata* Bernard, 1897	+	+	+
53. *M. digitata* (Dana, 1846)	+	+	-
54. *M. nodosa* (Dana, 1846)	+	+	-
55. *Povona cactus* (Forskal, 1775)	+	+	+
56. *P. clavus* (Dana, 1846)	+	+	+
57. *P. decussata* (Dana, 1846)	+	+	+
58. *P. explanulata* (Lamarck, 1816)	+	+	-
59. *Leptoseris mycetoseroides* Wells, 1954	+	+	—
60. *L. hawaiiensis* Vaughan, 1918	+	+	-
61. *Pachyseris rugosa* (Lamarck, 1851)	-	+	+
62. *P. speciosa* (Dana, 1846)	+	+	-
63. *Pseudosiderastrea tayamaiYabe* & Sug., 1936	+	+	+
64. *Coscinarea columna* (Dana, 1846)	+	+	+
65. *Fungia fungites* (Linnaeus, 1758)	+	+	+
66. *F. corona* Doderlein, 1901	—	+	-
67. *F. granulosa* Klunzinger, 1879	+	+	—
68. *F. danai* Edwards & Haime, 1851	+	+	—
69. *F. valida* Verrill, 1864	—	+	—
70. *Halomitra pileus* (Linnaeus, 1758)	+	+	+
71. *Herpolita Umax* (Houttuyn, 1772)	-	+	-
72. *Sandalolitha robusta* (Quelch, 1884)	+		+
73. *S. dentata* Quelch, 1884	-	+	—
74. *Polyphyllia talpina* (Lamarck, 1801)	-	—	+
75. *Lithophyllon undulatum* Rehberg, 1892	+	+	+
76. *L. mokai* Hoeksema, 1989	-	+	—
77. *L. bistomatum* Latypov, 1995	-	+	+
78. *Podobacia Crustacea* (Pallas, 1766)	+	+	+
79. *Porites lobata* Dana, 1846	+	+	+
80. *P. solida* (Forskal, 1775)	+	+	+
81. .P *murrayensis* Vaughan, 1918	+	+	-
82. *P. australiensis* Vaughan, 1918	+	+	+
83. *P. lutea* Edwards & Haime, 1858	+	+	+
84. *P. stephensoni* Crossland, 1952	+	+	+
85. *P. densa* Vaughan, 1918	+	-	+
86. *P. rus* (Forskal, 1775)	+	+	+
87. *P. mayeri* Vaughan, 1918	+	+	+
88. *P. limosa* Dana, 1846	—	-	+
89. *P. lichen* Dana, 1846	+	—	+
90. *P. mordax* Dana, 1846	+	+	-
91. *Goniopora stokesi* Edwards & Haime, 1851	+	+	+
92. *G. lobata* Edwards & Haime, 1860	+	+	+
93. *G. columna* Dana, 1846	+	+	+
94. *G. djiboutiensis* Vaughan, 1907	+	+	+

Table. (Contd.)

Species	Western part	Ha Long Bay	Eastern Part
95. *G. stutchburyi* Wells, 1955	+	+	+
96. *G. tenuidens* Quelch, 1886	- \	+	-
97. *Alveopora allingi* Hoifmeister, 1925	+	+	+
98. *Barabattouia mirabilis Yabe &* Sugiyama, 1941	+	+	+
99. *Favia stelligera* (Dana, 1846)	+	+	+
100. *F.favus* (Forskal, 1755)	+	+	+
101. *F. speciosa* (Dana, 1846)	+	+	+
102. *F. pallid* (Dana, 1846)	+	+	+
103. *F. amicorum* (Edwards & Haime, 1850)	+	+	+
104. *F. matthai* Vaughan, 1907	+	+	+
105. *F. rotumana* (Gardiner, 1899)	+	+	-
106. *F. laxa* (Klunzinger, 1879)		+	+
107. *F. maxima* Veron & Pichon, 1977	+	+	+
108. *F. lizardensis* Veron & Pichon, 1977	+	+	+
109. *F. maritima* (Nemenzo, 1971)	+	+	+
110. *Favites chinensis* (Verrill, 1866)	+	+	+
111. £ *abdita* (Ellis & Solander, 1786)	+	+	+
112. *F.flexuosa* Dana, 1846		+	+
113. *F. complanata* (Ehrenberg, 1834)	• +	+	+
114. *F.pentagona* (Esper, 1795)	+	+	+
115. £ *halicora* (Ehrenberg, 1834)	+	+	+
116. *Goniastrea favulus* (Dana, 1846)		+	+
117. *G. retiformis* (Lamarck, 1816)	+	+	+
118. *G. aspera* (Verrill, 1865)	+	+	+
119. *G. pectinata* (Ehrenberg, 1834)	+	+	+
120. *G. palauensis* (Yabe, Sugiyama & Eguchi, 1936)	-	+	+
121. *Platygyra daedalia* (Ellis & Solander, 1786)	+	+	+
122. *P. lamellina* (Ehrenberg, 1834)	+	+	-
123. *P. sinensis* (Edward & Haime, 1849)	+	+	+
124. *P. pini* Chevalier, 1975	+	+	+
125. *Austmlogyra zelli* (Veron, Pichon & Best, 1977)	+	+	
126. *Oulophyllia crispa* (Lamarck, 1816)	+	+	+
127. *Hydnophora exesa* (Pallas, 1766)	+	+	+
128. H. microconos (Lamarck, 1816)	+	+	+
129. *Oulastreacrispata* (Lamarck, 1816)	+	+	+
130. *O. alta* Nemenzo, 1959	+	+	+
131. *Leptastrea purpurea* (Dana, 1846)	+	+	+
132. *L. transversa* Klunzinger, 1879	+	+	+
133. *L. pruniosa* Crossland, 1952	+	+	+
134. *L. bottae* (Edwards & Haime, 1849)	+	+	—
135. *L. bewickensis* Veron, Pichon & Best, 1977	-	+	-
136. *L. inaequalis* Klunzinger, 1879	-	+	- •
137. *Plesiastrea versipora* (Lamarck, 1816)	+	+	+
138. *Cyphastrea serailia* (Forskal, 1775)	+		+
139. *C. chalcidicum* (Forskal, 1775)	+	+	+
140. *C. microphthalma* (Lamarck, 1816)	+	+	+
141. *Montastrea curta* (Dana, 1846)	+	+	+

Table. (Contd.)

Species	Western part	Ha Long Bay	Eastern Part
142. *M. valensiennesi* Edward & Haime, 1849	+	+	+
143. *Echinopora lamellosa* (Esper, 1795)	+	+	+
144. *E. gemmacea* (Lamarck, 1816)	+	+	-
145. *Galaxea astreata* (Lamarck, 1816)	+	+	+
146. *G. fascicularis* (Linnaeus, 1797)	+	+	+
147. *Lobophyllia hemprichii* (Ehrenberg, 1834)	+	+	
148. *L. corymbosa* (Forskal, 1775)	+	+	-
149. *L costata* (Dana, 1846)	-	+	—
150. *L. hattai Yabe,* Sugiyama & Eguchi, 1936	+	+	+
151. *Lobophyllia* sp. 1	-	+	-
152. *Symphyllia recta* (Dana, 1846)	+	+	-
153. *S. radians* Edward & Haime, 1849		+	+
154. *S. valenciennessi* Edward & Haime, 1849	+	+	—
155. 5. *agaricia* Edward & Haime, 1849	+ -	+	—
156. *S. hassi* Pillai & Scheer, 1976	_ ·	+	-
157. *Echinophyllia aspera* (Ellis & Solander, 1786)	+	+	+
158. *E. echinata* (Saville-Kent, 1871)	+	+	+
159. *E. orphensis* Veron & Pichon, 1979	+	+	—
160. *Oxypora lacera* (Verill, 1864)		+	+
161. *Merulina ampliata* (Ellis & Solander, 1786)	+	+	+
162. *Mycedium elephantotus* (Pallas, 1766)	+	+	+
163. *Pectinia lactuca* (Pallas, 1766)	+	+	—
164. *P. paeonia* (Dana, 1846)	+	+	+
165. *Cynarina lacrymalis* (Edward & Haime, 1848)	+	+	—
166. *Turbinana peltata* (Esper, 1794)	+	+	+
167. *T.frondens* (Dana, 1846)	+	+	
168. *T. reniformis* Bernard, 1896	+	+	+
169. *T. mesenterina* (Lamarck, 1816)	+	+	+
170. *T. crater* (Pallas, 1766)	-	+	—
171. *T. radicalis* Bernard, 1896	—		
172. *T. stellulata* (Lamarck, 1816)	+	+	—
173. *T. bifrons* Bruggemann, 1877	+	+	+
174. *Dendrophyllia japonica* Rehberg, 1892	+	+	-
175. *D. sphaerica* Nemenzo, 1981	+	—	+
176. *D. cornigera* (Lamarck, 1816)	+	—	+
177. *D. aculeata* Latypov, 1990	+	+	+
178. *D. gracilis* Edward & Haime, 1848	+	+	
179. *D. horsti* Gardiner & Vaughan, 1939	+	+	+
180. *D. arbuscula* Van der Horst, 1922	—	—	+
181. *D. laboreli* Zibrowius & Brilo, 1984	—	—	+
182. *Tubastrea aurea* (Quoy & Gaimard, 1833)	+	+	+
183. *T. coccinea* (Ehrenberg, 1834)	-	+	+
184. *T. micranthus* (Ehrenberg, 1834)	+	+	+ •
185. *T. diaphana* (Dana, 1846)	-	+	+
186. *Balanophyllia cummingii* M.-E. & H., 1848	" +	+	+
187. *B. stimpsoni* Verrill, 1865	-	+	+
188. *Culicia stellata* Dana, 1846	+	+	+

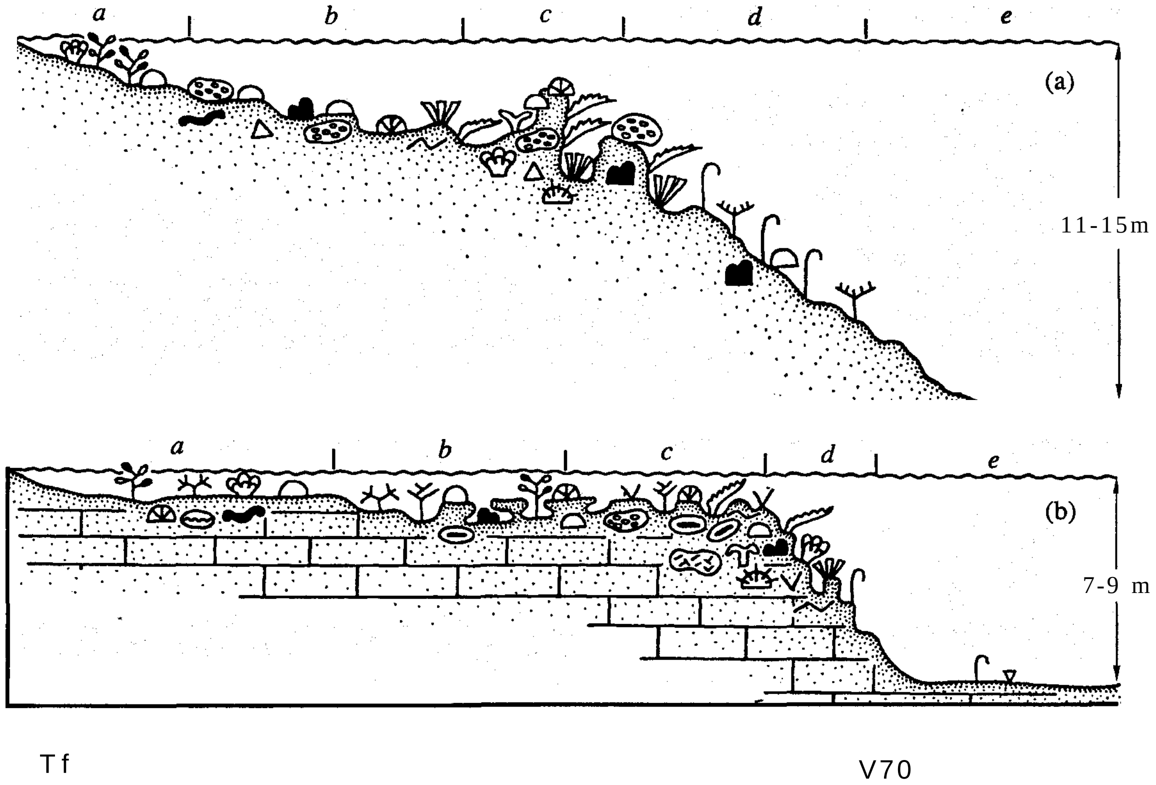

Fig. 4. Schematized profile of an unstructured (a) and structural (b) reefs, a: a—algal-coral zone, *b*—multispecific coral settlement zone, *c*—zone of predominance of one or two coral species, *d*—reef slope, e—pre-reef platform; b: *a*—nearshore channel, *b*—inner reef flat, *c*—outer reef flat, *d*—reef slope and pre-reef platform. 1-3—various algae; *4, 6*—poritids; 5, *20*—faviids; *9-11,13-16*—corals forming colonies of different shapes (branching, encmstung, funnel, and others); 7, *8,12, 21*—various mollusk and echinoderm species; *17-19*—gorgonarians and alcionarians.

onies play in the formation of the reef framework. These colonies are mainly formed of *Porites* species, occurring throughout the littoral to reef slope base zones. Different *Porites* species form large colonies up to 2.5 m in diameter and over 1 m in height or groups of colonies of different sizes with a coral density of 18-25 spec/m^2 and projective coverage of up to 80%. As a rule, *Porites* species predominate in the reef flat, especially in its inner part, and in the reef slope, where they often form microatolls [12,19,34]. Massive *Porites* are observed to predominate and form continuous settlements under similar conditions off Singapore and in the Gulf of Thailand, the Great Barrier Reef (Australia), and the eastern coast of Africa [27, 21, 38, 33, 39].

Another peculiarity of the studied reefs is the uniqueness of their morphological zonality and the way of the formation of the organogenous reef framework. The vertical zonality of the composition and structure of a reef community is strongly pronounced; however, typical reef zones such as lagoon, reef front, and reef flat are occasionally difficult to distinguish. Reefs featuring certain classifiable geomorphological elements are called structural [46], as distinct from developing reefs that lacking special structural features and are called coral communities or specialized settlements [29].

In the Gulf of Tonkin, two reef types occur—structural reefs with a distinct zonality and unstructured ones, too, with a distinct vertical zonality, appearing as the replacement of communities corresponding to those of structural reefs. In unstructured reefs, corallogenic deposits form a thin crust over the substrate, which hardly, if at all, changes its profile (Fig. 4). The composition and distribution of the corresponding reef communities enable two reef zones to be distinguished, the inner heterotrophic and outer autotrophic ones. The zones form a single ecosystem [17, 18] and closely resemble those of reefs with a distinct zonality [5, 6, 11]. For the above-described reefs, the term "encrusting reefs" was proposed as distinct from structural or developing reefs [8, 34]. Both encrusting and regular reefs occur all along the Vietnam coast, as well as other regions of reef formation [22, 26, 43]. Their development is determined by the monsoon climate, which is characterized by continuous silting and periodic desalination, resulting in the perishing of many coral settlements. On the whole, the favorable period lasts somewhat longer than the unfavorable one enabling constant recovery of the encrusting reefs.

In the middle-late 1990s, the data available on the reefs of the Gulf of Tonkin were considerably extended due to joint studies by Vietnamese and Russian scientists and by researchers of the World Wildlife Foundation (WWF). In all, about 50 reefs were studied in the northern, central, and eastern parts of the gulf [3, 10, 11, 35, 47, 49]. The number of reef-building coral species was extended to 188 (see table). Several new coral species were discovered. To date, the state of the art in the study of reefs of the Gulf of Tonkin is quite comparable with that of the Australian, Indonesian, and Philippine reefs [13, 20, 45].

The studies resulted in a detailed description of the structure and composition of communities of structural and unstructured reefs. In each zone, dominant and subdominant coral and accompanying mass macrobenthos species were distinguished. In the nearshore zone of all reefs, an algal-coral community was found dominated by the red-brown sargassos, padins, and turbinaria algae. Rare corals formed small separate colonies in this zone. The reef flat zone of the structural reefs and corresponding zone of the unstructured reefs (Fig. 4) were characterized by monospecific settlements of acroporids and montiporids—major reef-building corals of the whole tropical zone of the World Ocean. In the reef flat, the composition of corals and the structure of coral communities were nearly the same as those of many Indo-Pacific reefs [10, 11, 47, 49].

The peculiar nature of the reefs of the Gulf of Tonkin is determined by the monsoon climate in the region and, in the wintertime, the effects of runoff waters carried into the gulf by large and small rivers. These waters are cooled to 16-18°C, silted to 100 g/m^2 per day, and freshened to 28‰. The reefs in the Gulf of Tonkin are thus exposed to conditions far from optimum for reef formation. However, the continuously arriving suspended matter does not settle out directly onto the coral settlements because of the huge integral water exchange and intense roiling [3, 11]. Water silting and eutrophication resulted in changes in the structure and composition of reef communities via the reduction or elimination of certain coral species [36]. As a result, instead of acroporids, typical for the majority of other reefs, the communities of the reefs of the Gulf of Tonkin are dominated by poritids and faviids, which form the framework of the reefs. These peculiarities make the reefs of the Gulf of Tonkin really unique.

The abundance of poritids was accounted for by their ability to secrete a firm mucous covering and start reproduction 1-2 months earlier than other coral species. These peculiarities favor their better adaptation to water eutrophication, overheating, and desalination under stressful conditions of silted shallow water [24, 25, 28, 42]. Massive colonies of poritids and faviids—one of major bioproducents under the local conditions—not only form the reef framework but also play a considerable role in the expansion of the reef area. Both biotic and abiotic factors cause the erosion of coral colonies, resulting in the passive colonization of vacant bottom areas by colony fragments. In the reef slope base zone, a new, now organogenesis, substrate is formed, which is subsequently inhabited by both corals and other phyto- and zoobenthos species. These factors are important for the Gulf of Tonkin, a shallow-water gulf with the predominance of soft ground and a limited availability of solid substrate off shore.

As compared to other reefs of Vietnam and many reefs of the Indo-Pacific, the reefs of the Gulf of Tonkin are characterized by a peculiar composition and structure of the reef communities. These reefs develop under complex hydrobiological conditions. In addition, they are situated in a populous area and constitute constant food and, as a result of increasing tourism, financial sources for the local people. Thus, they may be and must be used as a model in the research on the conservation and recovery of reefs subject to stressful conditions and anthropogenic contamination.

The peculiarities of the hydrological conditions of the Gulf of Tonkin and Gulf of Thailand cause then-coral species composition. On the one hand, the shallowness of both gulfs and high eutrophication and turbidity of their waters, caused by mainly clayey fractions, result in the similarity of their reefs and of the compositions of the reef communities to one another. On the other hand, the geographical remoteness of the two regions and the difference in their geomorphological conditions cause some differences in the composition of the coral communities of the gulfs. To date, members of the genera *Palauastrea* and *Caulastrea,* as well as *Acropora palifera,* common to most reefs, have been found in neither gulf. Members of the genera *Plerogyra* and *Physogyra* were not encountered in the Gulf of Tonkin, and members of *Pachyseris, Micedium,* and *Pectinia* have not been registered thus far in the innermost and nearshore parts of the Gulf of Thailand. However, some species of the latter three genera, as well as rarely occurring members of *Physogyra* and *Plerogyra* were found in the open parts of both gulfs, off Hai Nang and Tho Chu islands. It is noteworthy that the members of the genera distinguished for large polyp size—*Galaxea, Echinopora, Lobophyllia, Echinophyllia, Turbinaria, Podobacia, Lithophyllon, Fungia,* and *Goniopora*—were widespread in both gulfs. Most reef communities are dominated by numerous species of these genera, in particular, *Galaxea fascicularis, Goniopora stokesi, Echinopora lamellosa,* and *Lobophyllia hemprichii,* as well as by *A. cytherea, A. nobilis, 1. hispida, P. lobata,* and *P. cylindrica,* which are widespread in all Indo-Pacific reefs. The former species occupy as great an area as 60-80% of the substrate surface. Another feature shared by the two gulfs is the wide distribution of massive *Porites* colonies, forming vast monospecific settlements and exhibiting a huge diversity (not less than 10 species). As opposed to *Porites*, 5-7 *Pocillopora* species forming mass settlements in the majority of the Indo-Pacific reefs are extremely rare in the Gulf of Tonkin and Gulf of Thailand. No more than two species are to be found in the gulfs; the only exception are the reefs off Tho Chu and Hai Nam islands, situated in the open parts of the gulfs, where *Pocillopora* species are common.

On the whole, the species compositions of scleractinians of the two gulfs are quite comparable, both qualitatively and quantitatively. The gulfs share 71.7% of their total numbers of scleractinian species. The differences between the gulfs in coral species composition are apparently due to the inequality in the progress of their study.

Promoted in the conservation of reefs as an integral part of the natural complex, a component of the national wealth of Vietnam, and the property of mankind, the governing body of the National Center for Natural Science and Technology of Vietnam was informed that special attention should be given to the reefs of Bo Hung and Cong Do islands. The conservation and recovery of the high biodiversity of reef communities in these regions should be considered a first-priority task in the framework of creating reserves and conservation areas in the Gulf of Tonkin.

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In the 1980-1990s, intense systematic studies of the Gulf of Tonkin coral communities were performed in the course of joint expeditions by the Institute of Marine Biology (Far East Branch of the Russian Academy of Science) and Haiphong Institute of Oceanology (National Center for Natural Science and Technology of Vietnam). Over several years, eight expeditions were performed in which 61 reefs in different regions of the gulf were studied. In addition to studying the marine flora and fauna composition, geomorphological, ecological, and biochemical studies were performed addressing both the reef ecosystem as a whole and the structure of its constituent communities. The research efficiency was increased considerably due to using SCUBA diving. The results of these studies were published in a series of reports and scientific papers [10,14, 19, 30, 34, 35, 47, 49].

The first exploratory investigations of four coral reefs were performed in the northern part of the Bai Thu Long Archipelago using generally accepted techniques [37]. Along 6 transects, the extent of projective coverage of the substrate by corals was estimated and the ratio of massive, branched, and encrusting coral forms was calculated. The estimation of the former parameter was accompanied by the registration of predominant taxa at generic and specific level. Along each transect, bionomic zones and their boundaries were determined and qualitative collection of scleractinians was performed [14]. In all, 82 coral species were identified (see table) and their zonal distribution and structure of their communities were determined along each transect in relation with the degree of projective coverage and the predominance of certain coral species. One of the peculiarities of the reefs in the northern part of the Bai Thu Long Archipelago—development of massive and encrusting colonies—was revealed [12]. These reefs are partly formed by encrusting colonies of *Merulina, Podobacia, Echinophyllia*, and other species, which are present in all reef zones, whereas in most common reefs, the distribution of these species is limited to the reef slope base; the limited illumination conditions; and, as a rule, the silted substrates. The studied reefs also exhibited developed forms of other scleractinians, widespread all over the Indo-Pacific—*Psammocora, Coscinarea, Porites, Goniopora, Favia, Favites, Platygyra, Hydrophora,* and *Leptastrea.*

Another peculiarity of the reef community studied is the abundance and diversity of ahermatypic corals of the Dendrophylliidae family, most of which lack zooxanthelae. These corals make up one-fifth of the entire number of scleractinian species, while in the Indo-Pacific reefs, the proportion of dendrophylliids rarely exceeds 5-10% at a depth of 40 m [6]. At the same time, the reefs studied are characterized by a distinct vertical zonality and by the uniformity of the structure and composition of constituent benthic communities. The same reef zones are similar in the spectrum of benthic plants and animals, characterized by the distinct predominance of one or two species by biomass, the frequency

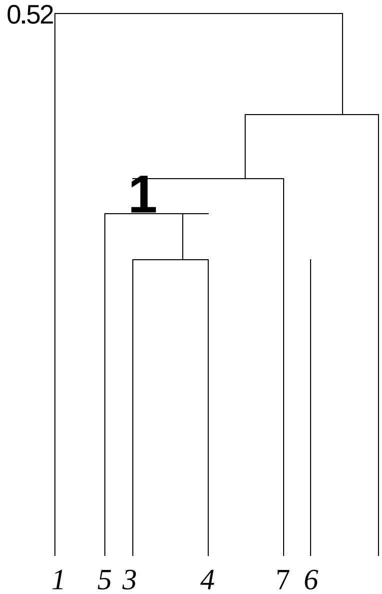

Fig. 3. Dendrogram of Jakkar similarity coefficient clusterization of coral species composition of different reefs of the South China Sea. *1-4*—Gulf of Tonkin, 5—Paracel Islands, 6—Gulf of Thailand and Con Dao, and 7—Thu islands.

of occurrence, or the projective coverage of the substrate. Thus, the reefs of the northern part of the Bai Thu Long Archipelago may be considered a stable ecosystem, adapted to low illumination conditions as a result of heavy water silting and eutrophication. The reef communities in this region are formed by both hermatypic corals, capable of surviving under low illumination conditions, and ahermatypic corals, whose distribution does not depend on the illumination level [14].

In 1984-1986, joint Russian-Vietnamese and independent Vietnamese expeditions occurred in the western part of the Bai Thu Long Archipelago. In these expeditions, the reefs of the archipelago's largest island, Katba Island, and the six islands closest to it were studied [8, 15, 30, 34, 48].

The data obtained allowed one to double the number of reef-building scleractinians. This is not only indicative of the high diversity of coral species in the region studied but also enables their faunistic comparison with the reefs of other parts of the South China Sea. The studied reefs and those of the other regions of Vietnam and the South China Sea have 55-65% common species. The coral faunas of the Gulf of Tonkin and the Gulf of Thailand share more than two-thirds of the species (Fig. 3). The high diversity of corals in these regions, as well as in the most of the Indo-Pacific reefs, is mainly due to the diversity of acroporids, comprising 28.5% of the coral species composition and forming monospecific settlements, often occupying a considerable proportion of the reef areas [7, 44].

As was mentioned above, one of the peculiarities of the Gulf of Tonkin reefs is the major role massive col-