ISSN 1063-0740, Russian Journal of Marine Biology, 2013, Vol. 39, No. 6, pp. 413–419. © Pleiades Publishing, Ltd., 2013.
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Changes in the Species Composition of Benthic Macroalgal Communities of the Upper Subtidal Zone on a Coral Reef in Sanya Bay (Hainan Island, China) During 2009–2012

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Received January 24, 2013

Abstract—Investigations of macroalgae were carried out on a coral reef at the Luhuitou Peninsula in Sanya Bay (Hainan Island, China) in the upper subtidal zone at a depth of 0.5 to 4 m during the dry season (in April 2009 and 2012). In total, 130 species, varieties, and forms of marine macroalgae were found: 71 (54%) Rhodophyta, 33 (25%) Chlorophyta, and 26 (21%) Phaeophyceae. In terms of the number of species and the floristic composition of algae in the communities, the reef benthic flora in the subtidal zone of Sanya Bay, which is polluted by municipal waste waters and aquaculture wastes, was close to the flora of Indo-Pacific coral reefs situated in areas with low pollution. In 2009 and 2012, the algal turf communities differed both in the algal species diversity and in the composition of dominant species. These differences might be due to an annual periodicity of changes in vegetation: algal turf patches are detached from the hard substrate and a new algal community is formed at this location.

Keywords: macroalgae, subtidal, algal turf community, South China Sea, Hainan, pollution, long-term changes in flora

DOI: 10.1134/S1063074013060084

INTRODUCTION

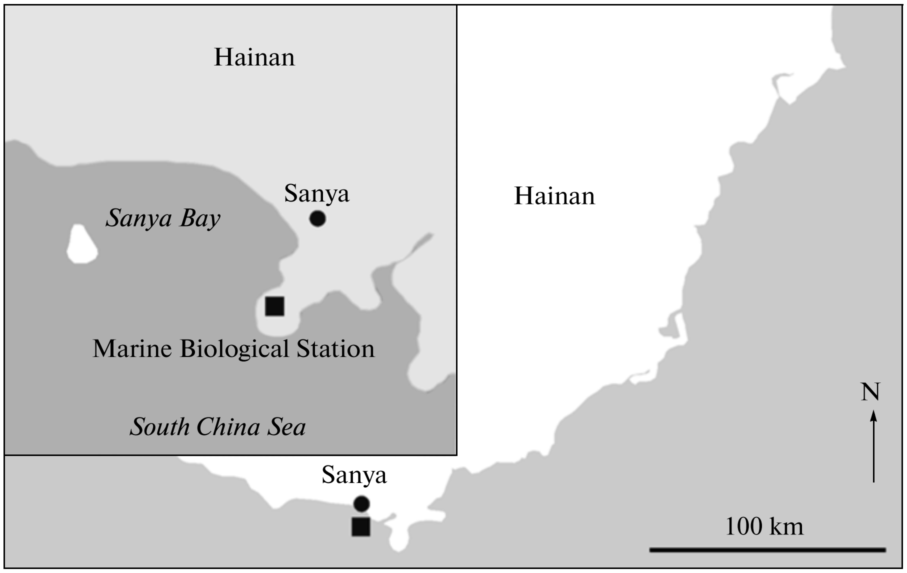
Hainan Island (China) is located in the subtropical zone of the South China Sea (18°10′–20°9′ N, 108°37′–111°1′ E). A Soviet naval expedition reported in 1958–1959 on a high diversity of fauna on the coral reefs of Hainan Island [1]; the rich diversity has fallen dramatically over the next 30 years [4, 15]. In the 1960–1990 period about 80% of the fringing reefs along the coast were destroyed or damaged by human activities [9, 16]. At present, the development of tourism and aquaculture has led to high eutrophication of shallow bays [10, 14]. Currently, the intensive and unsustainable exploitation of the Hainan coral reefs in the second half of the last century and eutrophication of coastal waters of the island have changed the species composition of the local marine flora. This situation is confirmed in the only paper on the long-term changes in the flora of green macroalgae (Chlorophyta) that occurred in the coastal waters of Hainan Island from 1935–1960 to 1990–1992 and in Sanya Bay from 1990–1992 to 2008–2009 [11].

The aim of this study is to compare the diversity of macroalgae from the orders Rhodophyta, Ochrophyta (Class Phaeophyceae), and Chlorophyta in the dry season (April 2009 and 2012) on the Luhuitou Peninsula coral reef in Sanya Bay.

MATERIALS AND METHODS

The investigations were carried out on a coral reef at the Luhuitou Peninsula in Sanya Bay, opposite to the Marine Biological Station of the Institute of the South China Sea of the Chinese Academy of Sciences (see figure). The algae were collected in April 2009 and 2012 at a depth of 0.5 to 4 m. In the study area, the upper subtidal zone is presented by a sloping shore of the platform that spreads along the coastline, approximately 50 m in width from the border of the lower intertidal zone to a depth of about 4 m. The bottom substrate is built of a carbonate reef base, dead colonies of hermatypic corals, coral debris, shells, sand, and silt. The average levels of the main parameters of the environment during the study are shown in Table 1.

The marine plants were collected from substrates of all types, with a complete removal of algae: 10×10 cm^2 plots for algal turf communities and 25×25 cm^2 plots for communities of large algae. The study involved more than 100 sites of hard substrate and 20 sites of soft substrate. Each area was photographed before the algal sampling. Taxonomic identification of algae was carried out on fresh samples. The systematic order of species and author names (Table 2) are given according to AlgaeBase [2].



Scheme of the area of study: Coral reef of Luhuitou Peninsula in Sanya Bay (Hainan Island, South-China Sea, China).

The occurrence of representatives of various taxa on the bottom was estimated visually or via photos [12]. Species with a projective cover of the bottom from 10 to 30% were recorded as common and from 30% and above, as mass species. Species represented by only one to ten individuals in all samplings for the year were considered as species of rare occurrence. The dominant species of the community were determined by visual inspection as well. A community with more than 50% of the bottom surface occupied by algae of one (dominant) species was designated as mono-dominant, by two species, as bidominant, and by three to five species, as polydominant.

RESULTS

In total, 130 species, taxonomic varieties and forms (taxa) of marine macroalgae were found in April 2009 and 2012 in the subtidal zone on the coast of Luhuitou Peninsula: 71 red algae (54%), 33 green algae (25%), and 26 brown algae (21%) (Table 2). Thus, the 99 taxa found in April 2009 included 52 species of red algae (51%), 27 species of green algae (27%), and 20 species of brown algae (22%). Along the border with the lower intertidal zone, we observed a bidominant community of Sargassaceae, which was dominated by *Sargassum polycystum* and *S. ilicifolium*, densely overgrown with epiphytic red algae, *Acrochaetium* spp., *Centroceras clavulatum*, etc. Beyond the field of Sargassum spp., the hard substrates was occupied by a dense polydominant algal turf community (3–6 cm in height). This turf community was dominated by a mosaic of such species as *Amphiroa foliacea, Jania capillacea, Acanthophora muscoides, A. spicifera, Hypnea pannosa, H. valentiae, Tolypiocladia glomerulata* and *Gelidiella acerosa* (Rhodophyta – Rh); *Dictyota friabilis* (Phaeophyceae – Ph); and *Boodlea composita, Bryopsis pennata, Caulerpa serrulata*, and *Neomeris annulata* (Chlorophyta – Ch). The species *Padina australis* (Ph) formed a monodominant community, including *Padina minor*. Among dead coral heads and blocks, *Ceratodictyon spongiosum* (Rh) was of frequent occurrence on the sandy bottom. About 10% of the hard substrates were occupied by crusts of *Neoralfsia expansa* (Ph) and species of the genera *Peyssonnelia* and *Lithothamnion* (Rh). Among epiphytes, *Stylonema* alsidii, Erythrotrichia carnea, Acrochaetium *hypneae* and *Hydrolithon farinosum* (Rh) dominated.

In April 2012, in the upper subtidal zone of the Luhuitou Peninsula we identified 117 taxa, including

Table 1. Climatic characteristics of the study area (after: Li, 2011)

Time of measurement	SST, °C	SD	Precipitation, mm	DIN, μm	PO_4^{-3}, μm
February–April of 2009	24.2–26.8	63	28.3	4.8	0.40
February–April of 2012	24.4–26.9	60	30.3	4.5	0.36

(SST) surface seawater temperature; (SD) number of sunny days; (DIN) mean concentration of dissolved inorganic nitrogen and phosphorus (PO_4^{-3}).

Table 2. Species composition, occurrence and abundance of macroalgae on the coral reef of Luhuitou peninsula in Sanya Bay

Algal species	April 2009	April 2012	Algal species	April 2009	April 2012
Division Rhodophyta			*H. farinosum* (J.V. Lamouroux) D. Penrose & Y.M. Chamberlain	E+++	E+
Order Stylonematales			*Jania adhaerens* J.V. Lamouroux	E+	E+
Family Stylonemataceae			*J. capillacea* Harvey	+++,	E+, +
Stylonema alsidii (Zanardini) K.M. Drew	E+	E+++	*J. pumila* J.V. Lamouroux	+	+
Chroodactylon ornatum (C. Agardh) Basson	E+	E+	*J. ungulata* f. *brevior* (Yendo) Yendo	–	E+
Order Erythropeltidales			*Pneophyllum fragile* Kützing	E+++	E+
Family Erythrotrichiaceae			Family Hapalidiaceae		
Erythrotrichia carnea (Dillwyn) J. Agardh	E+++	E+++	*Lithothamnion* sp.	+	+
Sahlingia subintegra (Rosenvinge) Kornmann	E+	E+	**Order Gigartinales**		
Order Acrochaetiales			Family Cystocloniaceae		
Family Acrochaetiaceae			*Hypnea esperi* Bory de Saint-Vincent	–	E+
Acrochaetium hypneae (Børgesen) Børgesen	E+++	E+	*H. pannosa* J. Agardh	+++	+++
A. robustum Børgesen	–	E+	*H. spinella* (C. Agardh) Kützing	–	E+
A. microscopicum (Nägeli ex Kützing) Nägeli in Nägeli & Cramer	+E	E+++	*H. valentiae* (Turner) Montagne	+++	+++
Order Colaconematales			**Order Rhodymeniales**		
Family Colaconemataceae			Family Champiaceae		
Colaconema gracile (Børgesen) Ateweberhan & Prud'homme van Reine	–	E++	*Champia parvula* (C. Agardh) Harvey	E+	E+
Order Nemaliales			*C. vieillardii* Kützing	–	E+
Family Galaxauraceae			Family Lomentariaceae		
Tricleocarpa fragilis (Linnaeus) Huisman & R.A. Townsend	–	++	*Ceratodictyon intricatum* (C. Agardh) R.E. Norris	+	E+
Actinotrichia fragilis (Forsskål) Børgesen	+	++	*C. spongiosum* Zanardini	++	++
Family Liagoraceae			*Lomentaria corallicola* Børgesen	–	+
Liagora ceranoides J.V. Lamouroux	+	+	**Order Gracilariales**		
Order Gelidiales			Family Gracilariaceae		
Family Gelidiaceae			*Gracilaria salicornia* (C. Agardh) E.Y. Dawson	+	+
Gelidium pusillum (Stackhouse) Le Jolis	–	+	*G. tenuistipitata* var. *liui* Zhang & Xia	+	–
Family Gelidiellaceae			*Hydropuntia eucheumatoides* (Harvey) Gurgel & Fredericq	+	++
Gelidiella acerosa (Forsskål) Feldmann & G. Hamel	++	+	**Order Ceramiales**		
Parviphycus adnatus (E.Y. Dawson) B. Santelices	–	+	Family Ceramiaceae		
P. pannosus (Feldmann) G. Furnari	–	+	*Centroceras clavulatum* (C. Agardh) Montagne	+	+++
Order Halymeniales			*C. minutum* Y. Yamada	–	E+
Family Halymeniaceae			*Ceramium cimbricum* H.E. Petersen in Rosenvinge	E+	E+
Halymenia maculata J. Agardh	+	++	*C. cingulatum* Weber-van Bosse	–	E+
Grateloupia filicina (J.V. Lamouroux) C. Agardh	+	+	*C. comptum* Børgesen	E+++	–
Order Peyssonneliales			*C. borneense* Weber-van Bosse	E+	–
Family Peyssonneliaceae			*C. tenerrimum* (G. Martens) Okamura	E+++	E+
Peyssonnelia conchicola Piccone & Grunow in Piccone	++	++	*Corallophila kleiwegii* Weber-van Bosse	E+++	E+
P. inamoena Pilger	–	+	*Gayliella flaccida* (Harvey ex Kützing) T.O. Cho & L.J. McIvor in Cho et al.	E+++	+++, E+++
P. rubra (Greville) J. Agardh	++	++	Family Rhodomelaceae		
Order Corallinales			*Acanthophora muscoides* (Linnaeus) Bory de Saint-Vincent	+++	+++
Family Corallinaceae			*Acanthophora spicifera* (M. Vahl) Børgesen	++	+
Amphiroa foliacea J.V. Lamouroux	+++	++	*Herposiphonia secunda* (C. Agardh) Ambronn	+	E+, +
A. fragilissima (Linnaeus) J.V. Lamouroux	+	++	*H. secunda* f. *tenella* (C. Agardh) M.J. Wynne	+	++
Hydrolithon boreale (Foslie) Y.M. Chamberlain	+E	E+	*Leveillea jungermannioides* (K. Hering & G. Martens) Harvey	+E	E+

Table 2. (End)

Algal species	April 2009	April 2012	Algal species	April 2009	April 2012
Neosiphonia ferulacea (Suhr ex J. Agardh) S.M. Guimarães & M.T. Fujii in Guimarães et al.	+E	E+	**Order Dictyotales** Family Dictyotaceae		
N. howei (Hollenberg) Skelton & G.R. South	–	E+	*Canistrocarpus cervicornis* (Kützing) De Paula & De Clerck in De Clerck et al.	+	+
N. sphaerocarpa (Børgesen) M.S. Kim & I.K. Lee	–	E+	*Dictyota bartayresiana* J.V. Lamouroux	++	++
N. tongatensis (Harvey ex Kützing) M.S. Kim & I.K. Lee	–	E+	*D. friabilis* Setchell	++	E+, ++
Polysiphonia japonica var. *savatieri* (Hariot) Yoon	E+++	E+	*D. implexa* (Desfontaines) J.V. Lamouroux	+	–
P. scopulorum var. *villum* (J. Agardh) Hollenberg	–	E+	*Lobophora variegata* (J.V. Lamouroux) Womersley ex Oliveira	+	++
Palisada papillosa (C. Agardh) K.W. Nam [Laurencia papillosa (C. Agardh) Greville Chondrophycus papillosus (C. Agardh) D.J. Garbary & J.T. Harper]	+	+	*Padina australis* Hauck	+	+++
Tolypiocladia glomerulata (C. Agardh) F. Schmitz	+++, E+	+	*P. minor* Yamada	++	++
Chondria repens Børgesen	–	E+	**Order Fucales**		
Family Wrangeliaceae			Family Sargassaceae		
Anotrichium tenue (C. Agardh) Nägeli	+E	E+	*Sargassum ilicifolium* (Turner) C. Agardh	+++	+
Griffithsia metcalfii C.K. Tseng	+	+	*S. sanyaense* Tseng & Lu	++	+++
G. heteromorpha Kützing	+	–	*S. polycystum* (C. Agardh)	+++	+++
Wrangelia argus (Montagne) Montagne	+	E+, ++	*Sargassum* sp.	++	++
Family Spyridiaceae			*Turbinaria ornata* (Turner) J. Agardh	++	++
Spyridia filamentosa (Wulfen) Harvey in Hooker	++	+++	Division Chlorophyta		
Class PHAEOPHYCEAE			**Order Chlorococcales**		
Order Ectocarpales			Family Chlorochytriaceae		
Family Acinetosporaceae			*Chlorochytrium cohnii* E.P. Wright	–	E+
Hincksia conifera (Børgesen) I.A. Abbott	–	E+	**Order Ulotrichales**		
Feldmannia mitchelliae (Harvey) H.-S. Kim	+E	E+	Family Ulotrichaceae		
Kuetzingiella elachistaeformis (Heydrich) M. Balakrishnan & Kinkar	–	E+	*Ulothrix implexa* (Kützing) Kützing	++	–
			Order Ulvales		
Family Scytosiphonaceae			Family Ulvellaceae		
Rosenvingea intricata (J. Agardh) Børgesen	+	++	*Acrochaete geniculata* (N.L. Garder) O'Kelly	+En	–
Colpomenia sinuosa (Mertens ex Roth) Derbès & Solier in Castagne	++	+++	*A. leptochaete* (Huber) R. Nielsen	+En	–
Chnoospora implexa J. Agardh	–	++	*A. viridis* (Reinke) R. Nielsen	+En	+En
Hydroclathrus clathratus (C. Agardh) M.A. Howe	++	+, E+	*Pringsheimiella scutata* (Reinke) Marchewianka	E++	E+
Hydroclathrus tenuis C.K. Tseng & Lu	+	++	*Ulvella lens* P.L. Crouan & H.M. Crouan	+E	E++
Family Chordariaceae			Family Ulvaceae		
Myrionema strangulans Greville	–	E+	*Ulva clathrata* (Roth) C. Agardh	–	E+
Family Pylaiellaceae			*U. flexuosa* Wulfen	–	E+
Pylaiella tidalis (Linnaeus) Kjellman	–	E+	*U. prolifera* O.F. Müller	+	+
Order Sphacelariales			**Order Cladophorales**		
Family Sphacelariaceae			Family Cladophoraceae		
Sphacelaria novae-hollandiae Sonder	+	E+	*Chaetomorpha gracilis* Kützing	+	+
S. rigidula Kützing	–	E+++	*C. linum* (O.F. Müller) Kützing	+	+
S. tribuloides Meneghini	E+++	E+	*Cladophora laetevirens* (Dillwyn) Kützing	+E	E+
Order Ralfsiales			*C. vagabunda* (Linnaeus) Hoek	–	E+
Family Neoralfsiaceae			*Rhizoclonium riparium* var. *implexum* (Dillwyn) Rosenvinge	+E	
Neoralfsia expansa (J. Agardh) P.-E. Lim & H. Kawai ex Kraft	+	++	Family Anadyomenceae		

Table 2. (Contd.)

Algal species	April		Algal species	April	
	2009	2012		2009	2012
Anadyomene wrightii Harvey ex J.E. Gray	+	+	*B. sphaerica* (Zanardini) Solms-Laubach	+	+
Order Siphonocladales			*Neomeris annulata* Dickie	++	++
Family Boodleaceae			Family Polyphysaceae		
Cladophoropsis membranacea (Hofman Bang ex C. Agardh) Børgesen	+	+	*Parvocaulis clavatus* (Yamada) S. Berger, U. Fettweiss, S. Gleissberg, L.B. Liddle, U. Richter, H. Sawitzky & G.C. Zuccarello	–	+
Boodlea composita (Harvey) F. Brand	++	+	*P. exiguus* (Solms-Laubach) S. Berger, U. Fettweiss, S. Gleissberg, L.B. Liddle, U. Richter, H. Sawitzky & G.C. Zuccarello	+	–
Phyllodictyon anastomosans (Harvey) Kraft & M.J. Wynne	+	+	*P. parvulus* (Solms-Laubach) S. Berger, U. Fettweiss, S. Gleissberg, L.B. Liddle, U. Richter, H. Sawitzky & G.C. Zuccarello	+	+
Family Siphonocladaceae			**Order Bryopsidales**		
Dictyosphaeria cavernosa (Forsskål) Børgesen	–	++	Family Bryopsidaceae		
Family Valoniaceae			*Bryopsis pennata* J.V. Lamouroux	++	++
Valonia ventricosa J. Agardh	+	+	Family Caulerpaceae		
Order Dasycladales			*Caulerpa racemosa* (Forsskål) J. Agardh	+	++
Family Dasycladaceae			*C. serrulata* (Forsskål) J. Agardh	++	+
Bornetella nitida Munier-Chalmas ex Sonder in Mueller	+	++	*Caulerpella ambigua* (Okamura) Prud'Homme van Reine & Lokhorst	+	–
B. oligospora Solms-Laubach	+	–	*Udotea javensis* Montagne	++	–

(E) epiphyte; (En) endophyte; (+) rare; (+ +) common; (+ + +) found in great numbers; (–) not found.

67 species of red algae (58%), 25 species of green algae (21%), and 25 species of brown algae (21%). The hard substrate was occupied by a bidominant community of the brown algae *Sargassum polycystum* and *S. sanyaense*, as well as a polydominant mosaic community of an algal turf. Sargassum spp. were thickly covered with epiphytic algae, *E. carnea, Chroodactylon ornatum, Acrochaetium robustum* (Rh), etc. The polydominant community of algal turf was dominated by long-living species of red algae, *A. muscoides, H. pannosa, H. valentiae, and Spyridia filamentosa* and ephemeral species *C. clavulatum* and *Gayliella flaccida* (Rh). Along the border with the lower intertidal zone, single dead coral blocks were occupied by a monodiminant community of *P. australis*. The hard substrate was occupied as well by the calcareous crust-like algae *Peyssonnelia conchicola, P. rubra, Lithothamnion* sp. (Rh), and *Neoralfsia expansa* (Ph). *S. alsidii*, and *E. carnea* (Rh) dominated among the epiphytic algae.

DISCUSSION

In the upper subtidal zone of a coral reef in Sanya Bay, macroalgae settled mainly on hard substrates (the soft substrate was occupied by seagrass and communities of cyanobacteria). The average cover of the bottom was about 60% for macroalgae and 30% for hermatypic corals. The macroalgal communities were represented mainly by algal turf, as well as by crusts and large brown algae.

It was estimated from the published data [7, 11] and the results of our surveys that in the 1990s and in the last century and early in this century, along the coast of Hainan Island and neighboring small islets, 436 species, taxonomic varieties and forms of macroalgae and cyanobacteria were found and identified, including red algae, 250 taxa (60% of all species of macroalgae), 106 (25%) green algae, and 65 (15%) brown algae. Among the southern provinces of China, Hainan Island is the second in the richness of the flora only to Taiwan, where about 600 species of red, brown, and green algae were recorded [5, 17].

In 5 years of research (2008–2012) we collected 143 macroalgal species in the subtidal zone on the coast of the Luhuitou Peninsula, among which 79 were red (55%); 38, green (25%); and 26, brown algae (20%) [11 and unpublished data). Thus, in the richness and species composition, flora of the coral reef of Luhuitou Peninsula in Sanya Bay, which is heavily polluted with dissolved forms of inorganic nitrogen and phosphorus (Table 1) is nevertheless similar to the flora of coral reefs of the Indo-Pacific that are located in slightly polluted areas where the shares of red algae amounted to 50–60%; green algae, 20–30%; and brown algae, 10–20% [3, 5, 8, 13, 17]. This comparison indicates that the marine flora of Sanya Bay, in spite of the strong contamination of the water, has not undergone any dramatic changes, i.e., there are no records of macroalgal blooms, or an introduction of invasive species into the communities, nor a sharp shift towards the predominance of green algae.

From all known changes that occur at a high level of eutrophication in coral reef areas, we have observed only epiphytic overgrowth of larger forms of brown and red algae. Why haven't other signs of eutrophication appeared? One of possible causes of the absence of a negative effect of eutrophication on the flora of Sanya Bay could be the low availability of nutrients for sea plants in the subtidal zone owing to a dense overgrowth of their thalli by epiphytes and because of a sediment layer that constantly covers the algal thalli. It has been experimentally proven that dissolved inorganic matter that includes nitrogen and phosphorus is unavailable for most long-living species of macroalgae that inhabit Sanya Bay. The results of the investigation on determination of the molecular ratio of carbon to nitrogen in the tissues of algae from the bay have shown that the tissues of many algae were limited in nitrogen, although the concentrations of nitrogen compounds in the habitat were high [10].

Of 99 algal taxa found in April 2009, 85 species (65%) also occurred in 2012, and 9 species (7%) were found only in 2009. From 117 taxa found in 2012, 30 (23%) were not recorded in 2009. What was the cause of the appearance of 30 new algal species in 2012? Evidently, the objective reason for the increase in the species number is the development of epiphytes, which is observed in Sanya Bay on the background of a high level of eutrophication: of 30 algal species found in the area of the investigation for the first time in 2012, 24 species were epiphytes (Table 2).

The communities of the algal tuft in different years of observation differed not only in their species composition, but also in the composition of the dominant species. Thus, while *Acanthophora muscoides, Hypnea pannosa*, and *H. valentiae* dominated in the algal tuft in both 2009 and 2012, *Amphiroa foliacea, Jania capillacea* and *Tolypiocladia glomerulata* dominated only in 2009, and *Spyridia filamentosa* and the two ephemeral species *Gayliella flaccida* and *Centroceras clavulatum* dominated only in 2012. It is assumed that changes in the composition of both long-living and ephemeral dominant species in the communities of the algal turf of the upper subtidal zone in Sanya Bay occur each year, even under conditions of insignificant interannual fluctuations of the main climatic characteristics in the area (Table 1). The reasons for these changes are presently unknown and to clarify them further research is needed in order to study the succession of algal turf communities and seasonal changes in their composition and structure.

According to our observations [Titlyanov and Titlyanova, unpublished data], the seasonal changes in the composition of dominant and accompanying species in the communities of the algal turf in the upper subtidal zone of Sanya Bay are determined mostly by the periodic character of annual changes in vegetation in the course of succession. The succession of new subtidal algal communities begins immediately when the substrate is free from old algal communities (i.e., after the algae are detached from the bottom and cast ashore); this event occurs in Sanya Bay from February to April annually.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project no. 12-04-01424 Physiological and Biochemical Mechanisms of Reactions of Benthic Autotrophic Organisms to Climatic and Anthropogenic Changes of the Environment: Ontogenetic Aspects).

REFERENCES

1. Guryanova, E.F., Marine zoological expedition to Hainan Island, *Vestn. Akad. Nauk SSSR*, 1959, no. 3, pp. 89–92.
2. Guiry, M.D. and Guiry, G.M., AlgaeBase. World-Wide Electronic Publication, National University of Ireland, Galway. http://www.algaebase.org. Accessed on June, 2012.
3. Huisman, J.M. and Borowitzka, M.A., Marine benthic flora of the Dampier Archipelago, Western Australia, *Proc. 11th Int. Mar. Biol. Workshop "The Marine Flora and Fauna of Dampier, Western Australia"*, 2003, vol. 2, pp. 291–344.
4. Hutchings, P.A. and Wu, B.L., Coral reefs of Hainan Island, South China Sea, *Mar. Pollut. Bull.*, 1987, vol. 18, pp. 25–26.
5. Lewis, J.E. and Norris, J.N., A history and annotated account of the benthic marine algae of Taiwan, *Smithson. Contrib. Mar. Sci.*, 1987, vol. 29, pp. 1–38.
6. Li, X.B., Identification of major factors influencing the composition, spatial and temporal variation of scleractinian coral community in Sanya, China, *Doctoral Dissertation*, Beijing: Chinese Academy of Sciences, 2011.
7. Liu, L., *Checklist of Marine Biota of China Sea*, Beijing: Sci. Book Service, 2008.
8. Silva, P.C., Basson, P.W., and Moe, R.L., Catalog of the benthic marine algae of the Philippines, *Smithson. Contrib. Mar. Sci.*, 1987, vol. 27, pp. 1–179.
9. Tadashi, K., Dai, C.F., Park, H.S., et al., Status of coral reefs in East and North Asia (China, Hong Kong, Taiwan, South Korea and Japan), *Status of Coral Reefs of the World, Global Coral Reef Monitoring Network*, Townsville, Australia, 2008, pp. 145–158.
10. Titlyanov, E.A., Kiyashko, S.I., Titlyanova, T.V., et al., Nitrogen sources to macroalgal growth in Sanya Bay (Hainan Island, China), *Curr. Dev. Oceanogr.*, 2011, vol. 2, no. 1, pp. 65–84.
11. Titlyanov, E.A., Titlyanova, T.V., Xia, B.M., and Bartsch, I., Checklist of marine benthic green algae (Chlorophyta) on Hainan, a subtropical island off the coast of China: comparisons between the 1930s and 1990–2009

reveal environmental changes, *Bot. Mar.*, 2011, vol. 54, pp. 523–535.

12. Titlyanov, E.A., Titlyanova, T.V., Yakovleva, I.M., et al., Regeneration of artificial injuries on scleractinian corals and coral/algal competition for newly formed substrate, *J. Exp. Mar. Biol. Ecol.*, 2005, vol. 323, pp. 27–42.
13. Tsuda, R.T., Checklist and bibliography of the marine benthic algae within Chuuk, Pohnpei, and Kosrae States, Federated States of Micronesia, *Pac. Biol. Surv. Bishop Museum*, 2006.
14. Zhang, G., Que, H., Liu, X., and Xu, H., Abalone mariculture in China, *J. Shellfish Res.,* 2004, vol. 23, pp. 947–950.
15. Zhang, Q., Shi, Q., Chen, G., et al., Status monitoring and health assessment of Luhuitou fringing reef of Sanya, Hainan, China, *Chin. Sci. Bull.*, 2006, vol. 51, pp. 81–88.
16. Zhang, Q., Xu, X.Z., and Long, X.M., A numerical study on internal tides in the northeast of the South China Sea, *J. Trop. Oceanol.*, 1996, vol. 14, pp. 15–23.
17. Zhang, S., The species distribution of the seaweeds in the coast of China seas, *Chin. Biodivers.*, 1996, vol. 4, pp. 139–144.

Translated by I. Barsegova