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CHAPTER 1

INTRODUCTION TO THE SOVIET-AMERICAN EXPEDITION TO THE SEYCHELLES ISLANDS

BY

E. A. TITLYANOV, M. M. LITTLER AND D. S. LITTLER

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E.A. Titlyanov*, M.M. Littler and D.S. Littler****

BACKGROUND AND OBJECTIVES

The First Soviet-American Expedition in Marine Biology to the Seychelles Islands was organized by the Institute of Marine Biology, Far East Branch of the USSR Academy of Sciences, at the request of the Seychelles Government. The Republic of the Seychelles Islands sought information on the marine plant resources and productivity of benthic and planktonic communities of the Seychelles Bank. After discussing the program of work in the Department of Development of the Republic of the Seychelles Islands with the Deputy Minister, Mr. Selvine Jandron, the following research objectives were established for the expedition:

1) To study the benthic marine biota and fouling processes of the Seychelles Islands, which represents a poorly investigated region of the Indian Ocean.
2) To provide the first analyses of the species composition of algal communities for several remote island groups (Farquhar Atoll, Cöetivy Atoll, Cosmoledo Atoll, Amirantes Group) and to supplement previous knowledge on the algae of Aldabra Atoll, Mahé Island and Praslin Island.
3) To study the distribution of autotrophic organisms over the various reef systems and determine the depth ranges of algae, seagrasses and corals.
4) To evaluate the common algal and seagrass resources in the area of study, particularly species of commercial interest.
5) To estimate the production potential of the major producers of organic matter on Seychelles reefs; i.e., benthic macroalgae, seagrasses, reef building corals and phytoplankton.
6) To assess the prevalent environmental parameters of the various island groups studied: e.g., optical characteristics of the water, seawater temperatures, nutrient contents, oxygen levels, pH and current velocities.
7) To investigate the adaptations of photosynthetic organisms to light, nutrients, temperature and water motion.
8) To study nitrogen and phosphorus metabolism in macrophytes and nitrogen cycling in bottom sediments on island coasts, lagoons, channels and reef-flats.

Proceeding from the above objectives, the First USSR-USA Expedition in Marine Biology to the Seychelles Islands was complex with 62 specialists from various disciplines

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* Institute of Marine Biology, Far East Branch, USSR Academy of Sciences, Vladivostok, 690032, USSR

** Department of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560

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participating: 55 from the USSR, 6 from the USA and 1 from Vietnam. The expedition had its own logo (see cover page) with the letters "SAV," which suggested the international character of the expedition: Soviet-American-Vietnamese.

The expedition took place aboard the R/V Akademik A. Nesmeyanov from 14 December 1988 to 11 April 1989. The route of the expedition was as follows (Fig. 1): the ship departed Vladivostok 14 December 1988 and via Singapore arrived at the Port of Victoria 9 January 1989. The research on the Seychelles Islands was conducted from 9 January 1989 to 16 March 1989. From 17 March 1989 to 11 April 1989, the expedition transited back to Vladivostok (again via Singapore). Altogether, the expedition examined 11 Seychelles island groups, including the Amirantes Group, Cöetivy Atoll, Farquhar Atoll, Aldabra Atoll, Astove Atoll, Cosmoledo Atoll, Providence, Mahé, Praslin, La Digue, Desroches, African Banks and St. Joseph Atoll.

PARTICIPANTS

The administrative members of the expedition included the following: the Head of the Expedition - Prof. E.A. Titlyanov, marine algal and coral physiologist; the Assistant Science Heads - Dr. Y.Y. Latypov, coral taxonomist and ecologist, and Dr. P.V. Kolmakov, specialist in carbon metabolism of algae; the Assistant Head of Transport - Captain Oleynik S.D.; the Scientific Secretary of the expedition - Dr. T.A. Terekhova, specialist in lipid metabolism of marine organisms.

The expedition was organized into the following research groups:

1) The Taxonomic Group (under the direction of Dr. A. Kalugina-Gutnik from the Institute of South Seas Biology, Sevastopol), which conducted taxonomic and biocoenological studies of algae and seagrasses;

2) The Biological Communities Group (led by Dr. Y.Y. Latypov and Dr. N.I. Selin, Institute of Marine Biology, Far East Branch, USSR Academy of Sciences, Vladivostok), which assessed vertical and horizontal distributional patterns;

3) The Productivity Group (Dr. M.V. Propp, Institute of Marine Biology), which evaluated primary production of plankton and studied nitrification processes in sediments;

4) The Algal and Coral Physiology Group (Prof. E.A. Titlyanov, Institute of Marine Biology), which investigated light and temperature dependence of photosynthesis in algae, seagrasses and reef-building corals, including adaptations of plants to major environmental factors;

5) The Radioisotope Group (Dr. K.Y. Bil', Institute of Soil and Photosynthesis, USSR Academy of Sciences, Puschino, Moscow), which studied potential photosynthetic capacities of autotrophic plants, their apparent photosynthesis under natural conditions and mechanisms of carbon metabolism;

6) The Hydrology Group (Dr. A.V. Novozhilov, Institute of Marine Biology, and Dr. E.A. Chernova, Pacific Institute of Geography, Far East Branch), which investigated currents, turbulence, temperature and transparency of waters at different depths and estimated major biogenic elements and metals in seawater;

7) The Biochemistry Group (Dr. N.A. Latyshev), which estimated the content of biologically active lipids in marine algae and soft corals.

The American scientists included: Andrew Benson, Member of the U.S. National Academy of Sciences, Scripps Institution of Oceanography, La Jolla, specialist in carbon reduction metabolism and arsenic metabolism in plants; the group from the National Museum of Natural History, Smithsonian Institution, Washington, D.C. - Mark Littler, Senior Scientist, physiology and ecology of marine algae; Diane Littler, Research Associate, taxonomy and ecology of algae; Barrett Brooks, Scientific Assistant; Leonard Muscatine from the University of California, Los Angeles, physiology and cell biology of reef-building corals, and Phillip Dustan from the College of Charleston, specialist in coral adaptation to light.

Dr. Pham Van Huen from the Institute of Marine Research, SRV, Nhatrang, specialist in hydrochemistry of tropical waters, also participated in the expedition. In order to fulfill the goals of the extensive research program, the following specialists were included in the expedition as well: Dr. L.P. Perestenko, Institute of Botany, Leningrad, algal taxonomist; Prof. V.M. Gol'd, University of Krasnoyarsk, specialist in productivity of phytoplankton; Dr. T.R. Pärnik, Institute of Experimental Biology, Estonia, specialist in photosynthesis. The Chief Dive Officer was Y.P. Popov, a diver of USSR 1st class status. The Master of the ship was A.V. Gulyaev, a certified long voyage captain. Altogether, there were 62 scientists and 60 crew members aboard the R/V Akademik A. Nesmeyanov.

PRELIMINARY FINDINGS

During the expedition, the ship transited a total of 17,163 nautical miles. Out of a total of 116 days, research was conducted on station during 41 days, transitions took a total of 61 days, mooring at ports (Singapore, Victoria, Mombasa) required 14 days. The expedition studied 12 island groups of the Seychelles including Cöetivy Atoll, Farquhar Atoll, Aldabra Atoll, Desroches, Praslin, Mahé, La Digue, African Banks, St. Joseph Atoll, Providence, Cosmoledo Atoll and Astove Atoll. A total of 257 benthic stations were studied, 687 samples of phytobenthos were collected and analyzed, 479 of these were quantitative. The macrophytic standing stocks of 28 intertidal and 37 subtidal transects were assessed at depths ranging from 0 to 50 m. All hydrobiological and benthic investigations were carried out by snorkling and SCUBA diving. The first results of these investigations are presented in the following collection of works. This introductory chapter provides a general overview and highlights some of the main findings.

The total list of plants collected includes 8 seagrass species and 292 algal species (161 Rhodophyta, 92 Chlorophyta, 30 Phaeophyta and 9 Cyanophyta). Algae were most diverse and abundant on the high granitic islands of Mahé and Praslin, where 168 and 114 species, respectively, were collected (see Figs. 2-8). The high granitic islands (Mahé, Praslin and La Digue) also were rich in macroalgal communities dominated by *Sargassum* (Phaeophyta, Figs. 6 and 7), with fresh weight biomass ranging up to 8-10 $kg{\cdot}m^{-2}$. Agar containing algae, chiefly *Gracilaria crassa*, with a biomass of up to 3-6 $kg{\cdot}m^{-2}$, were also prominent on high islands (Fig. 8).

The species composition of algae on low calcareous islands was not as rich and ranged from 40 (Providence Group) to 119 (Aldabra Atoll) species per island group. In the floras of low carbonate islands, species of Rhodophyta (52-62%) and Chlorophyta (22-44%) predominated, whereas Phaeophyta were few (2-7%).

The marine vegetation of carbonate islands is dominated mainly by phytocoenoses of abundant seagrasses, with *Thalassodendron ciliatum* as the main community- (coenosis) forming species. Biomass estimates of seagrasses and algae of coral islands varied from 0.5 to 3.5 wet $kg{\cdot}m^{-2}$. According to expedition estimates, the marine plant stocks of Cöetivy, Farquhar and Desroches comprise 1,963,000, 195,100 and 16,600 tons of fresh mass, respectively. One hectar at Cöetivy contains, on average, 15 tons of fresh mass, compared with 19 t at Farquhar and 23 t at Desroches.

Collections of Octocorallia made on the expedition nearly doubled the published list of species known for the Seychelles Islands.

The species composition and distribution of corals, mollusks and sponges was investigated throughout intertidal and upper subtidal zones for 12 of the Seychelles island groups. The data obtained substantially increased the available knowledge of the biology of reef systems of this region and will be useful in planning fishery, mariculture and tourism activities.

The composition, distribution and patterns of fouling on ships and hydrotechical constructions were investigated and described near Mahé, Farquhar, Aldabra, Desroches and Praslin islands. The physical removal of fouling communities in the tropical waters of the Seychelles often led to very rapid refouling that was more extensive than the previous communities.

Using a fluorescence system of diagnosis, physiological and production characteristics of phytoplankton were studied at 52 shelf and 12 oceanic stations. Based on the data obtained, total phytoplankton production of the Seychelles Bank was evaluated.

Patterns of changes of nitrogen content were determined, which proved to be a major limiting element in sediments of the Seychelles. Considerable differences in the processes of nitrogen transformation were shown in sediments of high granitic islands (Figs. 2-8) versus low carbonate atolls (see Figs. 9-15), that are related to different concentrations of iron.

Light and temperature dependence of photosynthesis, pigment composition, morphology, anatomy and paths of photosynthetic carbon metabolism were studied in seagrasses, macroalgae and corals in reference to environmental conditions. It was shown that the seagrasses, macroalgal species and coral zooxanthellae investigated have characteristic C_3-photosynthesis. Macrophytic algae of the Seychelles Islands show a relatively great capacity for photosynthetic apparatus acclimation, but tend to have comparatively low levels of photosynthesis.

The intensity of photosynthesis and respiration was measured in respect to the exchange of nitrogen, phosphorus and dissolved organic matter in species of corals, algae, seagrasses and periphyton in reference to ecological factors in the region of study. The dependence between the intensity of photosynthetically active radiation, fluctuations in the content of biogenic elements and production efficiency of the reef ecosystem was documented. Some of the mutualistic interactions as well as nontrophic interactions between the more common species of animals and plants in the area were defined.

GEOLOGICAL HISTORY

As pointed out by Stoddart (1984a), the Seychelles are unique among the world's isolated islands in that some of them are of continental origin. The granitic group of islands (Mahé, Praslin, La Digue) are about 650 million years old and consitute a 'micro-continent' isolated by continental drift during the formation of the Indian Ocean. Thus, the granitic islands are biogeographically interesting in that they would be predicted to contain elements of a much older biota with links to India and Madagascar.

The low carbonate islands may be as old as the Eocene, having been built on now subsided volcanoes (Stoddart 1984a). All have been greatly modified by Pleistocene fluctuations in sea level and as a result their biotas are likely to be derived mainly by processes of long-distance dispersal.

MARINE BIOLOGICAL STUDIES

The 1964 International Indian Ocean Expedition provided the geological groundwork for future detailed studies of Seychelles reefs (Stoddart 1984a). The Sealark Expedition of 1899-1900 produced early inventory information, with about 120 macroalgal species collected by J. Stanley Gardiner (Gepp and Gepp 1908, Weber van Bosse 1913). More recently, Titlyanova and Butorin (1978) doubled the known records of macrophyte species from Mahé and Cöetivy Islands, and Aleem (1984) described the seagrass communities of Mahé, Latam, Aldabra, Comoro, Farquhar and Amirantes Islands. Especially noteworthy are the studies conducted through the Royal Society of London Research Station on Aldabra, which have been reviewed by Stoddart (1967, 1970). Price (1971) also reported on the sublittoral ecology of Aldabra, while Taylor (1968) and Taylor and Lewis (1970) treated some of the reef and seagrass invertebrate communities around Mahé. Research on Seychelles and other western Indian Ocean reefs has been reviewed by Stoddart and Younge (1970). Further specialized inventory studies on the marine biota have focused on Aldabra Atoll and are included in a special volume of the Bulletin of the Biological Society of Washington, edited by Kensley (1988). Despite their long history, biological knowledge of the reefs of the Seychelles remains at the inventory level. This lack of both synoptic and detailed information led us to turn our attention to the marine primary producers of this unusual island group.

CLIMATIC CONDITIONS

The Seychelles Islands are situated in the subequatorial climatic zone, which is characterized by a predominance of the equatorial air mass in summer (December-March) and different air masses in winter (June-September). Seasonal changes of wind direction occur with summer winds blowing from the equator (northwestern monsoon), whereas in winter, winds blow towards the equator (southeastern trade wind). Summers are humid and rainy, with unsteady winds and thunderstorms. Wind directions are as follows: from January to March - northwestern monsoon, recurrence 30-50%; from May to November - southeastern monsoon, recurrence 50-85%; from April to December, winds are unsteady, average monthly wind velocities are 2-6 $m \cdot sec^{-1}$ throughout most of the subequatorial zone.

Increased rainfall and terrigenous runoff due to greater adiabatic cooling of monsoonal winds on the rainforested high granitic islands (Procter 1984; Walsh 1984) should result in an increase in organically-derived nutrient availability (Littler et al. 1992) in nearshore waters. Nutrient input into low island systems is mainly from normal oceanic water throughput, presumed episodic upwelling and nitrogen fixation. Some of the low carbonate islands receive considerable enrichment from terrestrial erosion of both modern and fossil guano deposits. Winter is somewhat cooler than summer, less rainy, with steady moderate winds. The average monthly humidity is more than 70% in the hottest period of the year (December-April) when air temperatures reach 26-29°C.

Average monthly cloud cover in the open ocean and on islands varies from 3 to 7 percent within a year, recurrence of clear sky conditions ranges from 10 to 30% within a year, however from May to November in the western region of the zone it increases to 40-60%. On high islands, the average monthly number of clear days during the year is 1-3, the total yearly amount of precipitation is 1500-2700 mm and, on the windward slopes of high granitic islands, rainfall may exceed 3000-3500 mm. The greatest amount of precipitation occurs from December to March, 183-482 mm per month, and the number of rainy days varies from 11 to 22 during each month.

The hydrological regime of the Seychelles Islands is characterized by high water temperatures with small seasonal and yearly fluctuations (27-31°C), a predominance of waves 1-2 m in height, a salinity range of 34.5 to 35.5%, small fluctuations in tidal level and well-developed systems of constant currents (Taylor and Lewis 1970). Inter-trade wind countercurrent conditions, observed from November to March between approximately 3° and 8° S and running from west to east with an average rate of 0.5 knots and stability of 25-50%, play an important role in the formation of the dominant current regime of the area.

GEOMORPHIC CHARACTERISTICS

The detailed geomorphology of Seychelles island groups, including all those visited by the expedition, has been characterized in Stoddart (1984b). The Seychelles Islands and Seychelles-Mascarene depression represent a micro-continent, which was formed from the ancient continent Gondwana about 130 million years ago (Johnson et al. 1976). According to their geomorphology, the islands are subdivided into high granitic groups (e.g., Mahé and Praslin, Figs. 2-5), low calcareous groups (e.g., Desroches and Alfons) and slightly higher carbonate groups (e.g., Aldabra, Cosmoledo and Astove, Figs. 9-12). Granitic islands are formed of gneiss granites (Figs. 2-4), have steep shores and, as a rule, are fringed with shallow borders of carbonate sand (Figs. 5 and 6). Low calcareous islands do not rise more than 2-3 m above sea level (Fig. 12) and are composed of bioplastic sand and coral rubble (Fig. 11) transported from reef-flats by storms. Deposits of phosphorites are observed on some low islands (described as "guano," Baker 1963, Fig. 12). Higher limestone islands rise up to 8 m above sea level (Fig. 9). Aldabra, Cosmoledo and Astove are atolls with a well-developed central lagoon.

In the example of Aldabra Atoll, three types of geomorphological forms of relief are present, which are connected with their lithological features and external erosive processes (Stoddart 1984, Braithwaite 1984). Intensive aerial decay and washing away of reef surfaces have led to formation of a specific surface with highly irregular sharp edges and knife-like projections (Fig. 10), the so-called champignon surface. Other surficial forms (e.g., platin, smooth, hard surfaces) were probably formed from the bottom of ancient lagoons. The third type of relief, called pavement, may have been formed from submarine erosion of ancient reefs.

Modern reef formation is closely connected with the geological history of the various islands, their geomorphology and ongoing erosive processes, which determine the conditions of present sedimentation. There are three kinds of reefs in the Seychelles islands: fringing, platform and atolls (Stoddart, 1984b). Fringing reefs (Figs. 5 and 6) are formed on the coastlines of the granitic islands of the Seychelles Bank and are most extensive on Mahé and Praslin islands. These reefs extend as uneven belts from 500-750 m in width along the southeastern coast of Mahé, whereas along Mahé's northwestern coasts these belts reach 1500 m in width and have deep (up to 15 m) transverse channels. The degree of irregularity and jaggedness of reefs are connected with the erosive history of pleistocene reefs and the absence of strong wave action (Lewis, 1969). At Praslin, the fringing reef reaches more than 2850 m in width (Fig. 6), although in the most narrow places it is only 380 m wide. The high islands occur on a granitic base where blocks of reef rock rising up to 9 m above sea level (Figs. 2-4) consist of fragments of granite combined with carbonate shells, coral rubble, coral sand and remains of calcareous algae.

Platform reefs are found on some of the low islands (not more than 2-3 m in height above sea level) and are formed by calcareous detritus deposits transported from reef flats (Figs. 10 and 11). Such reefs can extend over large or small portions of an island system (Cöetivy - 37%, Desroches - 68%, Providence - 20%).

The atolls of the Seychelles usually include a number of islands of various sizes forming an irregular ring with several passages into a shallow central lagoon (Fig. 9). The largest lagoon occurs at Farquhar Atoll (14.6 km diam). As a rule, lagoons have underwater deltas, channels and inner breakwaters (edge or crest of a reef) formed by karst erosion of an ancient reef. The width of "rings" of atoll reefs ranges from 80 to 3250 m. The outer windward margins are usually wider than the leeward borders. Atolls of Aldabra, Cosmoledo and Astove are formed on elevated ancient reefs. The shallow lagoons of such reefs are infilled with sand, silts and stony coral deposits. Living corals (Figs. 13 and 14) reach their maximal development in the channels at the outlets of lagoons. The outer reef intertidal zones are represented by stony benches and platform regions of old reefs. The subtidal zones are formed by erosive halcyon reef coral deposits and the slopes are made up of coral and *Halimeda* sands, often dominated by the seagrass *Thalassodendron ciliatum* (Fig. 15).

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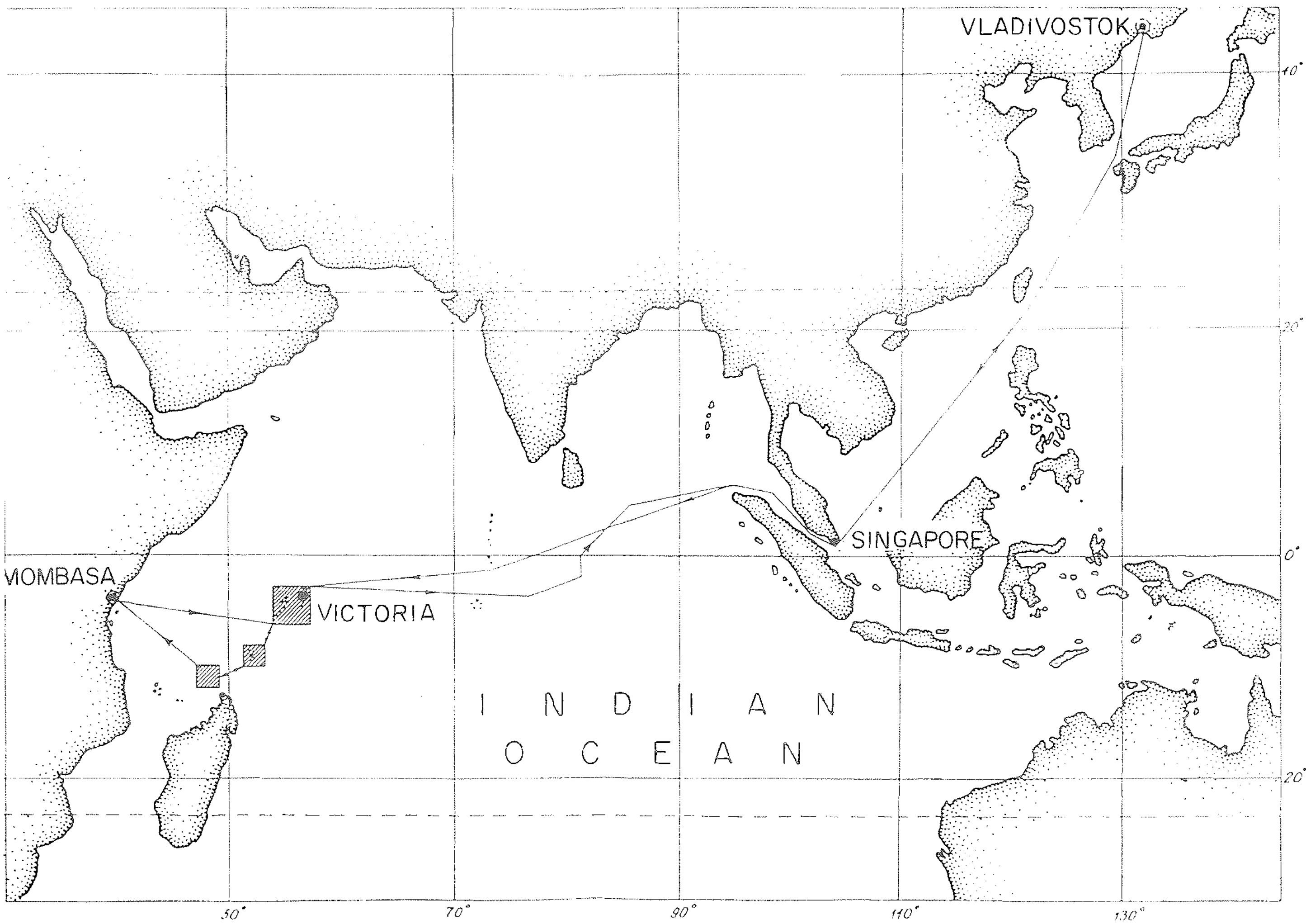

Fig. 1. Cruise Track of the USSR-USA Expedition in Marine Biology. Large blocked area indicates Seychelles granitic islands, small blocks indicate calcareous island groups.

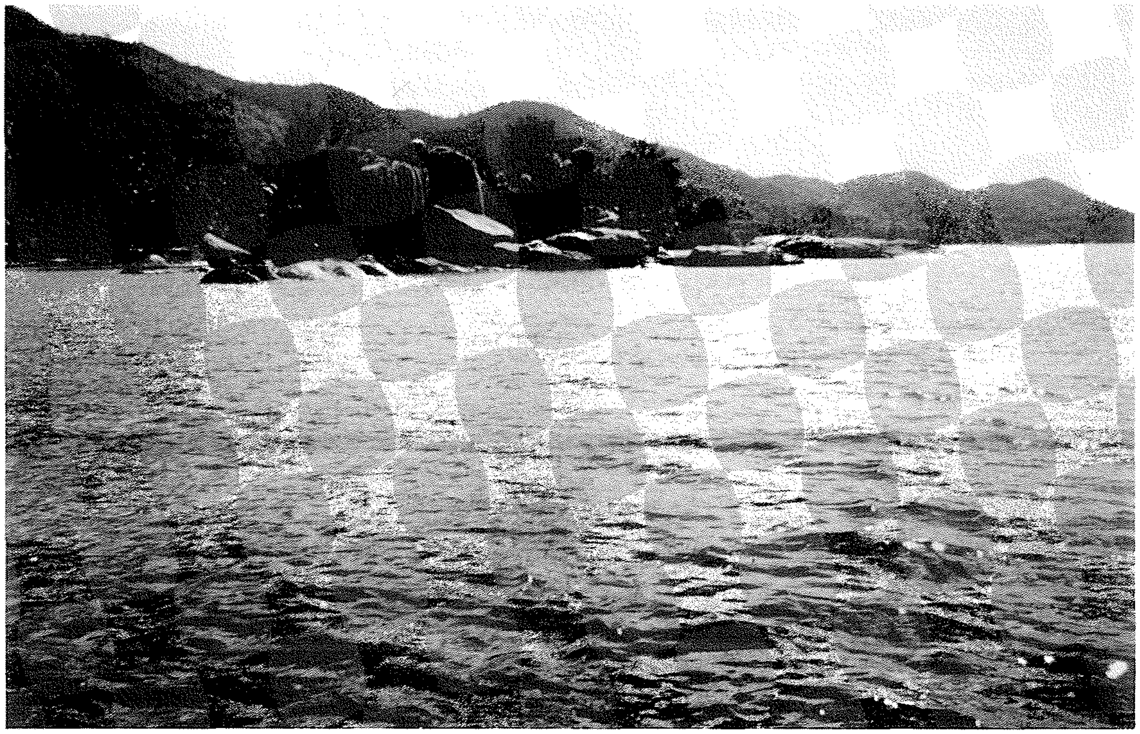

Fig. 2. Praslin Island showing the high topography and coastal granitic rock formations.

Fig. 3. Mahé Island showing the high topography and coastal granitic rock containing intertidal *Sargassum* communities.

Fig. 4. Granitic boulder on Mahé characteristic of Seychelles high islands.

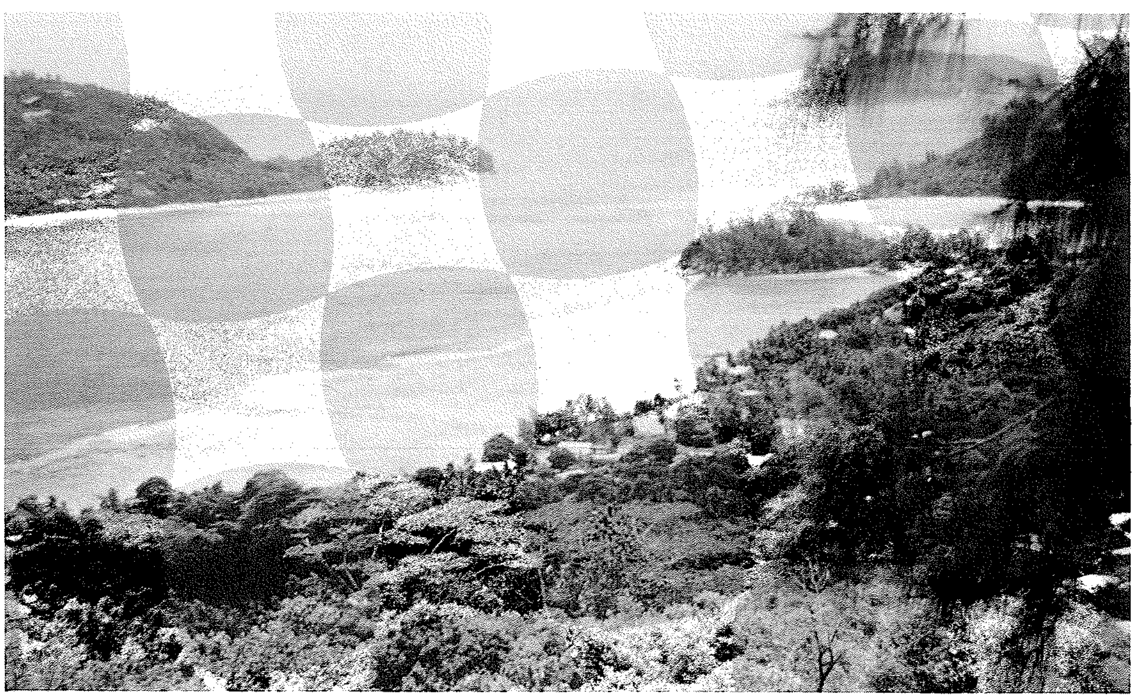

Fig. 5. Fringing reef on Mahé Island dominated by macroalgal communities.

Fig. 6. Fringing reef on Praslin Island showing the expedition's intertidal taxonomic group approaching dark *Sargassum* communities toward the shoreline.

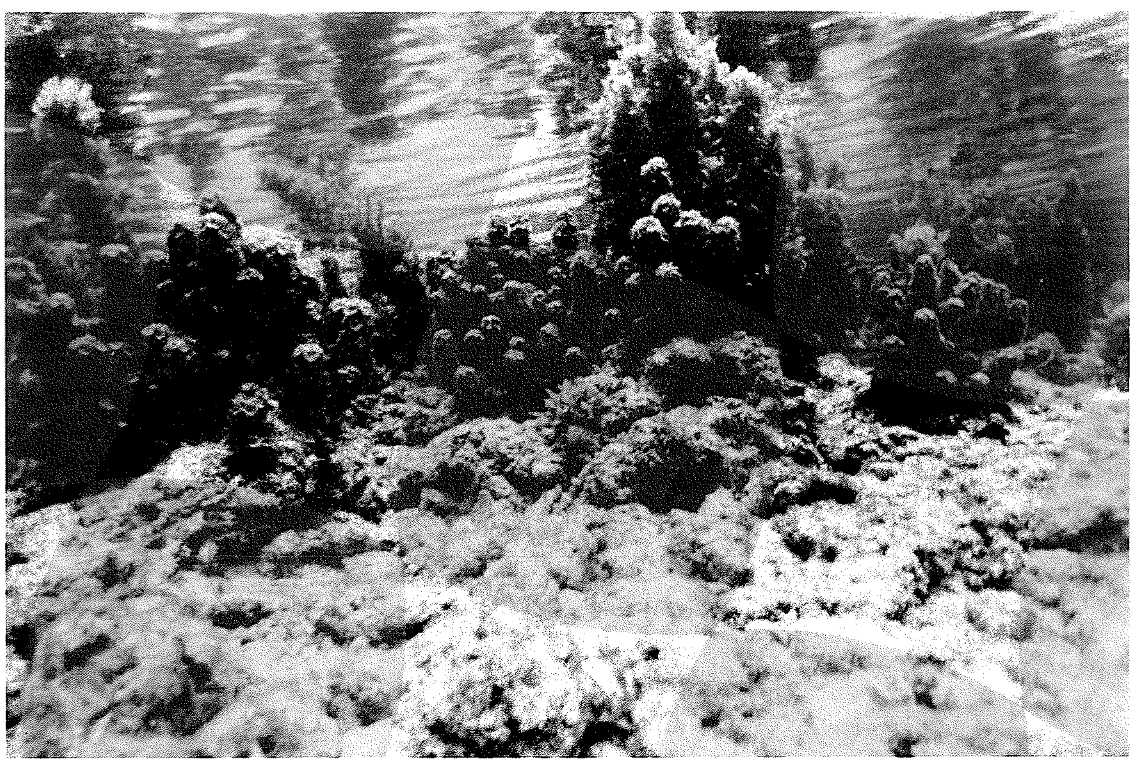

Fig. 7. Subtidal fringing reef macroalgal community dominated by the brown rockweeds *Sargassum* and *Turbinaria* characteristic of Seychelles high granitic islands.

Fig. 8. Intertidal community near Victoria Harbor, Mahé, dominated by large heads of the red alga *Gracilaria* growing on rubble.

Fig. 9. The outer reef platform of Astove Atoll showing seawater transport from the lagoon passage at low tide.

Fig. 10. Elevated and highly eroded fossil carbonate reef relief adjacent to the lagoon passage of Astove Atoll.

Fig. 11. Fragment of carbonate island substrate showing consolidated coral fragments and sediments.

Fig. 12. Pagode Island of the Cosmoledo Group with extensive guano build-up due to seabird rookeries.

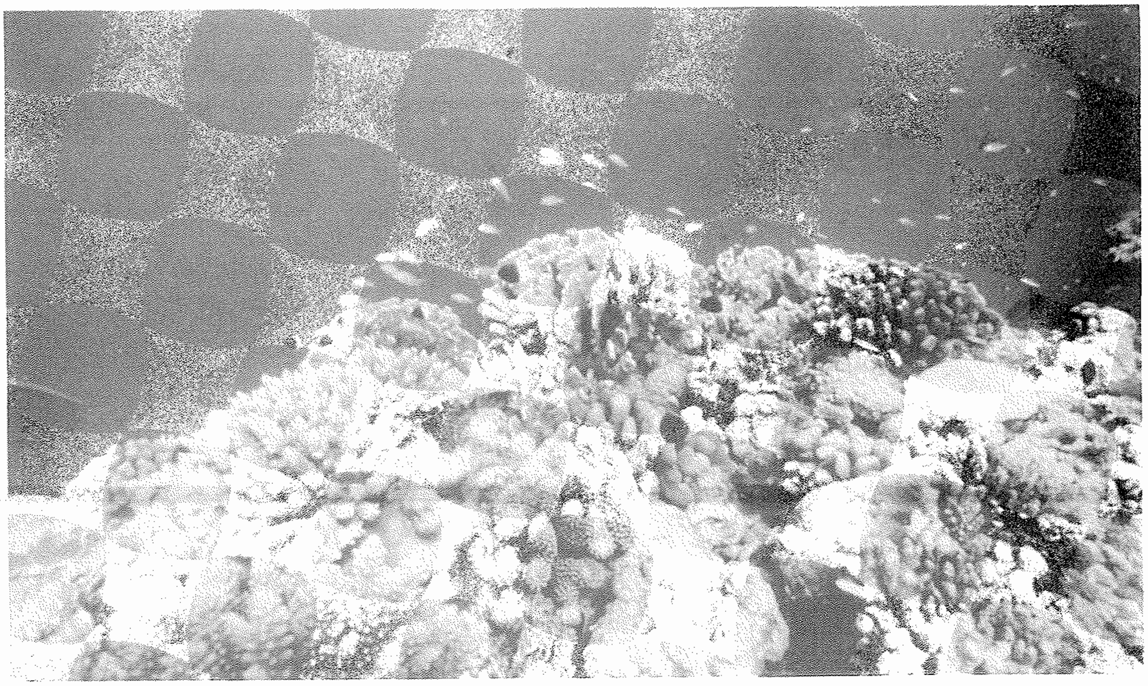

Fig. 13. Hermatypic coral community typical of Seychelles low carbonate islands (Cosmoledo Atoll).

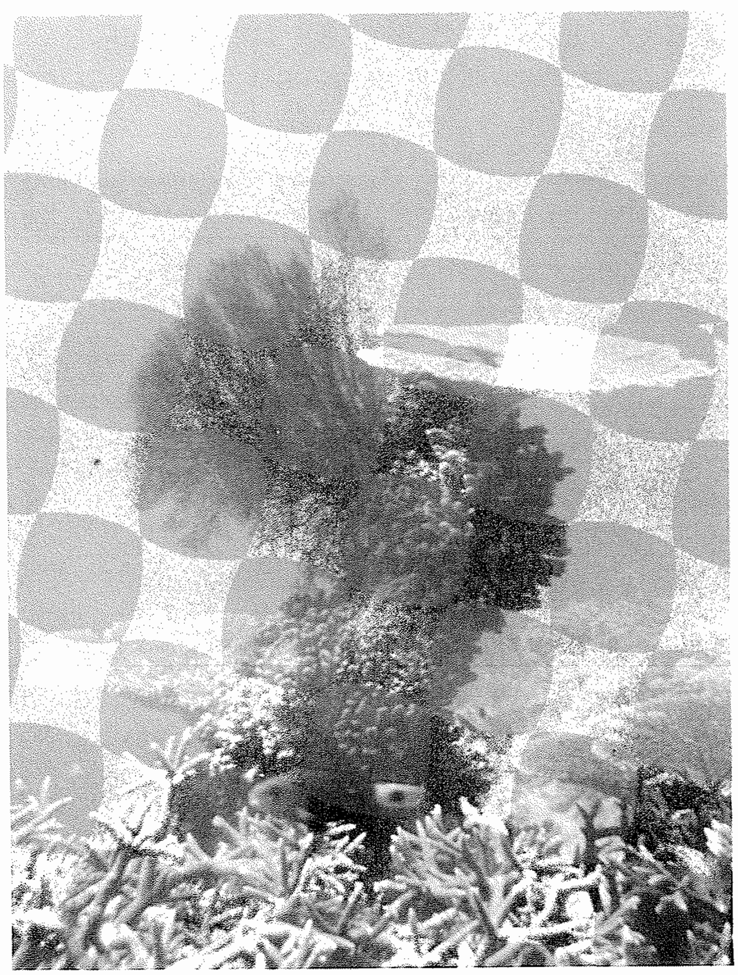

Fig. 14. Alcyonarian and stoney coral community characteristic of low carbonate atolls (Cöetivy Atoll).

Fig. 15. Subtidal *Thalassodendron ciliatum* characteristic of Seychelles soft-bottom habitats (25 m deep, African Banks).