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BLUE-GREEN ALGAE (CYANOBACTERIA) OF THE OCEANIC COAST OF ALDABRA

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BLUE-GREEN ALGAE (CYANOBACTERIA) OF THE OCEANIC COAST OF ALDABRA

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ABSTRACT

An account is given of the blue-green algae of the oceanic coast of Aldabra, from the supralittoral to the sublittoral at 40 m depth. These algae are most conspicuous in the supralittoral and upper littoral. Here they form an almost complete cover on rocks, usually with both epilithic and endolithic layers, and on beachrock sometimes also a distinct chasmolithic layer some 3 to 5 mm inside the rock. Lower in the intertidal their distribution is patchy, though sometimes there occur visually conspicuous films of various Oscillatoriaceae or *Nodularia* on sediments or tiny colonies of *Calothrix crustacea* on rocks. Of all regions on the atoll with a dense photosynthetic cover, the uppermost 15 m of the sublittoral probably has the fewest obvious growths of blue-green algae, but these become more frequent at greater depths. Conspicuous blue-green algal populations below 15 m are all dominated by forms of *Lyngbya*. At one site, at a depth of 40 m, there occurred branched tubular structures made up of filaments of *L. sordida*, and closely associated with shrimps which apparently live inside the tubes. Although a similar association has been noted elsewhere in shallow tropical waters, this is the first record for deep waters.

INTRODUCTION

Observations made during the Phase VI Royal Society expedition to Aldabra Atoll, Indian Ocean, showed that blue-green algae (Cyanobacteria) are widespread and often very abundant. It was therefore decided to attempt to produce a comprehensive account of the types and roles of these organisms. Descriptions have since been made of these algae in terrestrial and freshwater environments (Whitton, 1971; Donaldson & Whitton, 1977) and the intertidal region of the lagoon (Potts & Whitton,

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in press). There has not so far been an opportunity to make a systematic study on the outside of the atoll, but many scattered observations have been included at the same time as other studies. They are brought together in the present paper to help complete the general picture of blue-green algae on this one atoll.

There is now a considerable literature on Aldabra. The volume edited by Westoll and Stoddart (1971) includes accounts of the shallow sublittoral marine vegetation (Price, 1971) and zonation of intertidal animals (Taylor, 1971). More recent data on geology are given by Braithwaite *et al.* (1973), and Braithwaite (1975), climate by Stoddart and Mole (1977) and intertidal animals by Hughes and Gamble (1977). Trudgill (1976) and Taylor and Way (1976) deal with aspects of marine erosion, including some comments on the role of endolithic algae. Data on pH and Eh given by Potts and Whitton (1979a) include environments on the oceanic coast, while Potts and Whitton (in press) describe a pink endolithic prokaryote in the supralittoral of an oceanic cliff. These authors also review the marine literature.

METHODS

Interpretation of zones on shore

The use of zonal terminology proved difficult, because many observations were made on single visits at a particular time. Taylor (1971) used the terminology of Lewis (1964), with littoral fringe, eulittoral and sublittoral zones. Potts and Whitton (in press) followed Womersley and Edmonds (1952) when describing the distribution of blue-green algae in the lagoon, with a supralittoral, upper, mid and lower littoral and sublittoral. In the present account we do not feel sufficiently confident of our interpretation of zonation to use one terminology and suggest the equivalents in other systems. We use the terms supralittoral, upper littoral and sublittoral where the zones appear to be equivalent to those described for the lagoon; in situations where there is a distinct barnacle zone (the upper limit of the eulittoral in Lewis's system), reference is also made to this.

Dates and locations

Observations on the blue-green algae of the atoll have been made during three periods: December 1968 — January 1969 by B.A.W.; November 1972 — June 1973 by B.A.W. (part) and A. Donaldson; November 1974 — June 1975 by B.A.W. (part) and M.P. Observations outside the reef ridge in deeper waters were made only during the first visit, on the western end of the north coast; materials were collected down to 40 m using SCUBA (diving). Detailed observations on endoliths in the supralittoral and upper littoral were made only during the third period. Brief general observations were included on the oceanic coast opposite the locations of the 13 transects studied in the lagoon (Potts & Whitton, in press). Visits were made also to the only area of mangrove forest outside the lagoon (Au Parc) and the most exposed coast, the eastern extremity of Point Houdoul.

Naming of blue-green algae

The methods used here for naming blue-green algae are the same as those described in detail by Potts and Whitton (in press). They involve the classical botanical approaches to allocating binomials by authors such as Frémy (1933) and le Campion-Alsumard (1969), with one important modification. Where species have been delimited in the past almost entirely on rather arbitrary size ranges, the records made here are based on standardized ranges *e.g.* cells > 2 ≤ 4 µm, > 4 ≤ 8 µm wide etc. In the floristic list, records are given first for the actual categories used, and then the most appropriate binomial added.

RESULTS

Rocks in the supralittoral and upper littoral

Blue-green algae are present on almost all rock surfaces in the supralittoral and the upper part of the littoral. The nearer a true terrestrial environment, the more frequent is *Tolypothrix byssoidea*, the thinner any continuous endolith layer and the more scattered any true chasmolithic growths. Below the zone of *T. byssoidea*, but above the barnacle zone, the surface of most rocks may appear steel-blue, grey or almost black. The paler colours are due to *Hyella balani*, which grows both at the surface and endolithically. A bright green layer of chasmoliths is sometimes present, composed of forms resembling *Pleurocapsa*. In the same zone (below *Tolypothrix byssoidea* and above barnacles) *Scytonema* sp. forms small olive-green tufts in depressions in the champignon; it was found at every location studied, usually with many epiphytes *e.g. Xenococcus* spp., *Dermocarpa* spp. Slightly lower down the shore *Calothrix* and *Rivularia* are widespread on the north coast, and *Isactis* and *Rivularia* on the south coast.

Areas of beachrock on Île Picard (near the settlement) were studied more intensively. The rock is smooth, rounded and slopes towards the sea at an angle of about 10-15°. It has a blue-grey colour due to *Hyella balani*, and when fractured, a chasmolithic layer about 2 mm thick is visible at a depth of about 3-5 mm. Cells resembling *Pleurocapsa* and fungal hyphae are also present. In small cracks and crevices slightly further down the shore, but still holding water after the tide has receded, accumulated sand supports thin films of *Lyngbya martensiana* and *Schizothrix calcicola*, with some *Nodularia harveyana*. On passing down the shore from the blue-grey rocks, the colour changes to brown at about the level that barnacles appear. The brown colour is due to the sheaths of *Calothrix crustacea* and *C. contarenii*, which form a thin epilithic layer over *Hyella balani*.

After a period of particularly high tides and stormy seas, an extensive area of supralittoral beachrock became exposed due to the removal of sand deposits several metres thick which had been present for at least six months (and probably longer). The newly exposed rock appeared pale yellow, lacking the characteristic steel-blue colour of adjacent rocks. Examination of the surface of the beachrock showed no obvious blue-green algal communities. Patches of pale blue were

just discernable after 5 days, while the whole rock had light steel-blue colour within 2 weeks. Visually the rock was indistinguishable from other rocks after 5 weeks, but the green chasmolithic layer had not yet appeared.

Several species were recorded only in particular parts of the atoll, although this may well be simply a consequence of insufficient sampling elsewhere. *Scytonema endolithicum* grows in the upper supralittoral of Île Picard. The closely appressed filaments bore as much as 1200 µm into the rock; the cells are bright blue-green and the sheaths yellow-brown. When chips of rock with this alga were placed on agar (high $CaCO_3$ — seawater medium), filaments also developed above the surface, growing vertically, in small tufts, and reaching heights of 1000 — 2000 µm. At Dune d'Messe, inspection of black rocks showed that lichens are frequent higher up, while the endoliths *Brachytrichia* sp. and *Solentia stratosa* become more frequent lower down. A zone of lighter coloured rocks below these black rocks showed *Mastigocoleus testarum* to be the dominant endolith here. Rocks elsewhere on the south coast (*e.g.* Dune Jean Louis) showed a similar vertical colour zonation, with a blue-black zone above a paler one. *Brachytrichia* sp., *Solentia stratosa* and *Mastigocoleus testarum,* but apparently not *Scytonema endolithicum,* are all widespread on cliffs of the lagoon shore.

Reef-flat and reef-ridge on Île Picard

In general it appears that the longer rocks are covered by water each tidal cycle, the less conspicuous are the blue-green algae; however small areas of *Lyngbya* or colonies of *Calothrix crustacea* are not uncommon both in the area of the reef-flat and on the reef-ridge. Occasional patches of blue-green algae occur on the sediments between the shore and reef-ridge on Île Picard. These consist usually either of *Nodularia* or mixed populations of *Lyngbya* and other Oscillatoriaceae. Blue-green algal patches are apparently most frequent on sediments near the research station, in the same region that pink colourations due to phototrophic bacteria occur at some spring tides (Potts & Whitton, 1979b; in press). The Oscillatoriaceae here include *Spirulina*.

Sublittoral

Visually obvious growths of blue-green algae are only occasional, or even rare, in the upper 10 m, but become slightly more frequent at greater depths (down to 45 m, the maximum depth surveyed). The great majority of samples consist largely or entirely of *Lyngbya*, apart from the endolith *Plectonema terebrans* and occasional epiphytes, but *Calothrix* films also accur in the upper 10 m. *Lyngbya* trichomes show a wide range of widths, from about 5 to 40 µm, with no easy separation into distinct species, though many fall into the size range of *L. sordida* (14 — 31 µm). Conspicuous growths of the broadest forms (*L. majuscula*) were found only down to 20 m. Trichomes range in colour from green through olive to pink. Down to about 20 m examples occur of all colours, but by 40 m all are pink. Some of the best developed growths of *L. sordida* at 40 m were found to cover the surface of a sponge, itself red in colour (when viewed in daylight). A particularly

interesting population of *L. sordida* was found at this depth off Île Malabar, not far from Passe Gionnet. The alga formed branched structures attached at various points to dead coral and a dead clam; in at least some cases the alga formed distinct tubes. This population was closely associated with several shrimps, which apparently live inside the alga structure.

LIST OF SPECIES

Durham computer number	Category used for records	Equivalent binomial, where applicable
010801	*Brachytrichia* sp.	
010918	*Calothrix contarenii* Bornet et Flahault	
010919	*C. crustacea* Thuret	
011560	*Chroococcus*, > 8 ≤ 16 µm, sheath not striated	*C. turicensis* (Nägeli) Hansgirg
018201	*Calmatella buaensis* Ercegović	
012005	*Dermocarpa leibleiniae* (Reinsch) Bornet et Thuret	
012006	*D. olivacea* (Reinsch) Tilden	
012008	*D. sphaerica* Setchell et Gardner	
012009	*D. minima* Geitler	
012050	*Dermocarpa* sp.	
012201	*Entophysalis granulosa* Kütz.	
013403	*Hormathonema violaceo-nigrum* Ercegović	
013604	*Hyella balani* Lehmann	
013605	*H. tenuior* Ercegović	
018750	*Isactis* sp.	
014204	*Lyngbya confervoides* Ag.	
014205	*L. digueti* Gomont	
014206	*L. epiphytica* Hieronymus	
014211	**L. martensiana* Menegh. ex Gomont	
014212	*L. norgardii* Wille	
014219	*L. majuscula* Harvey	
(014238)	*L. sordida* (Zanard.) Gom.	
014501	*Mastigocoleus testarum* Lagerheim	
014801	*Microcoleus chthonoplastes* Thuret ex Gomont	
014903	*Microcystis reinboldii* (Richter) Forti	
015101	*Nodularia harveyana* Thuret	
015103	*N. spurnigeria* Mertens	
015814	*Plectonema terebrans* Bornet et Flahault	
015932	*Pleurocapsa* > 4 ≤ 8 µm	*P. fuliginosa* Hauck
015933	*Pleurocapsa* > 8 ≤ 16 µm	*P. crepidinum* Collins
015934	*Pleurocapsa* > 16 µm	
016101	*Pseudanabaena catenata* Lauterborn	

Durham computer number	Category used for records	Equivalent binomial, where applicable
016572	*Rivularia* sp. D	
016602	*Schizothrix arenaria* (Berk.) Gomont	
016604	*S. calcicola* (Ag.) Gomont	
016732	*Scytonema endolithicum* Ercegović	
016754	*Scytonema* > 16 µm	*Scytonema* sp.
018602	*Solentia stratosa* Ercegović	
016901	*Spirulina subsalsa* Oersted	
016951	*S. subtilissima* Kütz.	
017602	*Tolypothrix byssoidea* (Berk.) Kirchner	
018401	*Trichodesmium erythraeum* Ehrenberg ex Gomont	
018402	*T. thiebautii* Gomont	
018052	*Xenococcus* > 2 ≤ 4 µm	*X. laysanensis* Lemmermann
018053	*Xenococcus* > 4 ≤ 6 µm	*X. kerneri* Hansgirg
018054	*Xenococcus* > 6 ≤ 8 µm	*X. schousboei* Thuret

**Lyngbya martensiana* may perhaps be a misidentification of *L. semiplena* Ag. The latter, in contrast to the former possesses a calyptra; *L. semiplena* has been reported elsewhere from marine environments much more often than *L. martensiana*.

DISCUSSION

Blue-green algae are equally abundant in the supralittoral of oceanic and lagoon shores of Aldabra, but there is a marked contrast in their behaviour further down the shore. On the oceanic side they become less frequent the longer surfaces are covered by water during each tidal cycle; this contrasts with the lagoon where large areas of the lower littoral are covered by mats of *Microcoleus chthonoplastes* (Potts & Whitton, in press).

Of all regions on the atoll with a dense photosynthetic cover, the uppermost 15 m of the sublittoral probably has fewer obvious growths of blue-green algae than any other. As ropes and buoys often developed *Lyngbya* tufts rapidly, it seems likely that the intensive grazing by animals is the main reason for the poor development of blue-green algae in the upper part of the coral zone. The importance of grazing by fish in suppressing algal growth on a shallow reef has been documented in some detail for Curaçao by Wanders (1977) and van den Hoek *et al.* (1978). Too few observations have been made of the sublittoral in the lagoon to compare it with the ocean.

Deeper in the ocean attached blue-green algae become slightly more frequent, in some cases being closely associated with a red sponge or with shrimps. The latter is apparently a similar association to that recorded by Cowles (1913) who summarized earlier data, Taylor (1950) for the Marshall Islands and Newhouse (1954) for Raroia. The previous

records are all from shallow waters, but otherwise the present association appears very similar. Cowles described the blue-green alga as *Plectonema*, but Newhouse identified his material as *Lyngbya sordida*, the same species as recognized for Aldabra.

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