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STUDIES ON BLUE-GREEN ALGAE AND PHOTOSYNTHETIC
BACTERIA IN THE LAGOON OF ALDABRA ATOLL

by

Malcolm Potts (B.Sc. Dunelm)

A thesis submitted for the degree of Doctor of
Philosophy in the University of Durham, England

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Malcolm Patte

7.1.77

ABSTRACT

This thesis reports a study of the dominant communities of photosynthetic prokaryotes, growing in the intertidal zone of the lagoon of Aldabra Atoll, Indian Ocean. The work was carried out from November 1974 to June 1975. Physico-chemical and descriptive data collected from standard transects of the intertidal zone are presented, together with the Eh-pH ranges of various communities associated with lagoon sediments. A taxonomic checklist is given of species from marine and brackish habitats, with descriptions and notes on distribution and abundance.

More detailed studies were made on various communities of blue-green algae and photosynthetic bacteria. These included estimations of standing crop, the monitoring of physico-chemical parameters over 24 hour periods, and studies on the ability to fix nitrogen in situ as indicated by the acetylene reduction assay technique.

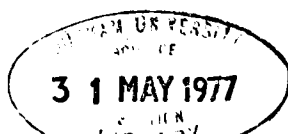
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List of symbols and abbreviations

A	= absorbance
A_{\max}	= maximum absorbance
Bchl <u>a</u>	= bacteriochlorophyll <u>a</u>
chl <u>a</u>	= chlorophyll <u>a</u>
C_2H_2	= acetylene
C_2H_4	= ethylene
cm	= centimetre
$^{\circ}C$	= degrees Celsius
g	= gram
h	= hour
l	= litre
m	= metre
M	= mole
mm	= millimetre
min	= minute
ml	= millilitre
mg	= milligram
nm	= nanometre
nM	= nanomole
μm	= micrometre
μg	= microgram
%	= percent
‰	= salinity
lx	= lux
s	= standard deviation

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1 INTRODUCTION

1.1 Marine photosynthetic prokaryotes

1.11 Ecology

Blue-green algae are widespread, and sometimes abundant, in most marine habitats except the colder parts of the open ocean (Fogg, 1973). On rocky shores a littoral fringe is characterized by the presence of blue-green algae and lichens, and of the latter, several genera contain blue-green algae as phycobionts e.g. Lichina with Calothrix (Fogg, 1973). A detailed account of the distribution of blue-green algae on rocky shores around the British Isles was given by Lewis (1964). He found the lower limit of the littoral fringe to be associated with the first appearance of barnacles, and at its upper part, the lichens Verrucaria, Caloplaca and ^{the brown alga} Pelvetia were characteristic. A vertical zonation of blue-green algae was shown by Little (1973) on sandstone shores near Millport, Isle of Cumbrae. Here Gloeocapsa crepidinum dominated the upper part of the supralittoral zone, while Nostoc entophytum increased in abundance towards the splash zone.

In limestone areas, endolithic blue-green algae are common in the eulittoral, as well as in the littoral fringe and sublittoral zone (Fogg, 1973). Along the Dalmatian coasts of the Adriatic Sea, Ercegović (1932) found a zonation of endolithic communities, the width of each zone being dependant on coastal slope and wave action. Le Campion-Alsumard (1969) also described well defined zones of endolithic blue-green algae on rocky shores in the region of Marseille, France.

She found shallow-boring and epilithic species such as Gloeocapsa deusta, Scopulonema hansgirgianum, Entophysalis granulosa and Placoma vesiculosa, growing in narrow zones in the upper intertidal and supralittoral. The deeper-boring species e.g. Plectonema terebrans, Mastigocoleus testarum, Kyrtuthrix dalmatica and Hyella tenuior, formed much wider zones in the lower intertidal. The distribution of endolithic species of blue-green algae in the intertidal zone is dependant on water supply, and along a diminishing gradient the general tendencies in algal growth are an overall reduction in average cell size and a reduction in depth of carbonate penetration (Golubić, 1975). Boring by endolithic filaments of these algae is an extracellular dissolution process, and has been described in Hormathonema sp. by Alexandersson (1975). This author discovered external organelles (1.0 x 10.0 µm) at the apices of perforating filaments, and suggested these structures to be involved in the process of chemical dissolution.

On the whole, eulittoral blue-green algae seem commoner in warmer waters (Fogg, 1973). Van den Hoek et al. (1971) comment that they are common along the shores of inner bays and lagoons of Curaçao, Netherlands Antilles, and list 31 species, amongst which are Calothrix crustacea, Hydrocoleus lyngbyaceus, Lyngbya aestuarii, Microcoleus chthonoplastes, Schizothrix calcicola and Aphanocapsa littoralis. Khan (1969), who studied intertidal rock pools at Oahu, Hawaii, recorded 17 species growing on both limestone and lava ; of the two substrata, lava appeared to support the greater number of

species.

The margins of shoal areas of lagoons support extensive, thick, vigorously growing blue-green algal mat communities (Conover, 1962). Laminated mats of algae were described by Kendall and Skipworth (1968) from protected intertidal and supralittoral flats of a highly saline lagoon, the Khar al Bazam, Abu Dhabi, southwest Persian Gulf. The largest algal flat ran parallel to the coast for 42 km, and had an average width of 2 km, with a thickness of some 30 cm. Park (1973) found 12 species to be common in algal mats of the Trucial Coast, Persian Gulf. Of these, Entophysalis magna and Microcoleus chthonoplastes were found to be responsible for the colonization and binding of new areas of intertidal sediments.

Within recent years increased attention has been given to the sediment binding and trapping abilities of intertidal mats, which form laminated sedimentary structures termed recent stromatolites (Golubić, 1973). At Andros Island, Bahamas, Monty (1965) described widespread stromatolites in the windward lagoon. These structures had a seasonal growth rate, which was fastest during July and August. Walter et al. (1973) found three distinct types of stromatolite in aragonite depositing lakes near the Coorong Lagoon, South Australia. The three forms, stratiform, globular and crenulate, were built entirely of bound sediment and species of filamentous blue-green algae. The shape of the globular stromatolites was shown to be due to the radial growth and movement of a species

of Schizothrix. Although stromatolites have been described mostly from areas in which the predominant sediments are carbonates, they may in certain locations trap and bind other sediment types. Gunatilaka (1975) described laminated mats of Microcoleus chthonoplastes and Schizothrix sp. from mangrove mudflats in the Mannar Lagoon, Sri Lanka, and Schwarz et al. (1975) have reported on the occurrence of quartz-sand stromatolites of Microcoleus sp. in the Bay Saint-Jean (Cape Timiris), Mauritania, West Africa. In both these situations the mats lacked the cementation afforded by carbonate sediments in other stromatolite environments. Lamination is a feature shared by all recent stromatolites, with alternating layers of sediment and organic material, and there are various opinions on the significance of the lamellae. Gebelein (1969) considered them to be the result of an algal growth cycle, whereas Logan et al. (1964) attributed them to sedimentation. Recently, Park (1976) has pointed out that although algal growth follows a diurnal pattern, sedimentation is far less regular or predictable, and any computations on the calendar role of stromatolites should be viewed with suspicion.

The taxonomic interpretation of marine blue-green algae, particularly endolithic species, varies considerably between authors. The lack of experimental data on marine forms which characterize algal mats, and the ecological significance of recent stromatolites, are considered by Golubić (1973) to be valid reasons for treating these marine blue-green algae as separate taxa from freshwater forms. Some experimental

evidence for this view has recently been given by Stam and Holleman (1975). These authors isolated species of Phormidium from marine and freshwater habitats, and found the marine forms to have a greater halotolerance, and less morphological variability than those from freshwater. However, Drouet (1963, 1973) felt the considerable morphological and ecological variability of species of blue-green algae, to be simply a reflection of the ability of these organisms to produce a wide range of morphological and ecological variations on the basis of one genotype. In his revision of the families Oscillatoriaceae and Nostocaceae, Drouet (1963, 1973) made no distinction between marine and freshwater taxa. These conflicting views illustrate one of the problems met with in the taxonomy of marine species of blue-green algae. A more detailed account of the taxonomy is given in section 1.4.

Photosynthetic bacteria often occur in close association with blue-green algae, usually as a well defined layer beneath algal mats. Conover (1962) described a pink layer of Chromatium 15 mm below the surface of mats of Lyngbya confervoides, in intertidal habitats of Texas lagoons. The pH through the mat dropped from 7.5 at the surface to 6.2 in the Chromatium layer, and Eh values dropped from +400 mV in the water above the mats to 0.0 mV in the sediment below the pink layer. Doemel and Brock (1976) showed sulphate reduction to occur only in the lower layers of benthic mats, growing in siliceous thermal pools, Yellowstone National Park. The reduction was associated with a coloured layer of photosynthetic

bacteria. A profile of sulphate concentration through these mats, showed low concentrations in the lower levels, and relatively high values at the mat surface.

Photosynthetic bacteria differ from blue-green algae in their photosynthetic metabolism (Pfennig & Trüper, 1974), photosynthesis occurring under anaerobic conditions with no liberation of oxygen, and requiring external electron donors such as reduced sulphur species (Scher et al., 1963). In shallow aquatic habitats where there is a high concentration of sulphides, they often become visually conspicuous as bright coloured films, and may cause wide expanses of water to appear red (Genovese, 1960). Cviic (1955, 1960) showed the phenomena of "de l'eau rouge", in a submerged limestone bay on the northwest side of the Adriatic island of Mljet, to be due to Rhodopseudomonas sp. In the Black Sea, Kriss (1959) found photosynthetic bacteria associated with a zone of hydrogen sulphide, at a depth of 2000 m.

1.12 Physiology

Fogg (1973) commented on the comparatively few studies of marine forms, and within recent years there has been increased interest in certain aspects of their physiology, particularly nitrogen fixation (Stewart, 1973). In coastal environments of Scotland, Stewart (1967) demonstrated in situ nitrogen fixation by communities of Calothrix scopulorum. He found seasonal variations in the fixation rates, which were attributed to temperature changes, and desiccation of the communities during the summer months. The mean fixation rate

was estimated as $2.5 \text{ g N m}^{-2} \text{ a}^{-1}$, representing about 41% of the mean total nitrogen present. The acetylene reduction technique was used by Carpenter (1973), to measure in situ nitrogen fixation by Trichodesmium thiebautii in the southwest Sargasso Sea. This planktonic species fixed nitrogen at a rate which would have allowed only an average of one cell division every 47 days ($0.044 \text{ } \mu\text{g N colony}^{-1} \text{ day}^{-1}$). Nitrogen fixation was also found associated with Trichodesmium erythraeum and Richelia intracellularis, in the central North Pacific Ocean (Mague et al., 1974). These authors found that acetylene reduction was constant for only two hours in vitro, after which activity was lost. From the tropics, Wiebe et al. (1975) have demonstrated in situ nitrogen fixation by communities of Calothrix crustacea, in intertidal environments of Eniwetok Atoll, Pacific. The highest rate found was $55 \text{ nM N}_2 \text{ fixed h}^{-1} \text{ cm}^{-2}$, yet considerable time was required for the communities to reduce acetylene at linear rates under the natural light regime. Also at Eniwetok Atoll, Mague and Holm-Hansen (1975) have reported acetylene reduction by intertidal communities of Hormothamnion sp. and Nostoc sp. They suggested that the rates found parallel the ambient light intensity, and could have supplied up to $11 \text{ } \mu\text{g N cm}^{-2} \text{ day}^{-1}$ to the coral reef ecosystem. Recently, Webb et al. (1975) found positive fixation rates by communities of Hormothamnion sp. and Rivularia sp., in the nearshore lee of islands at Eniwetok. Rates ranged from 0 to $390 \text{ nM N fixed m}^{-2} \text{ sec}^{-1}$, and dark rates were 5 - 10% of the light rates.

The majority of studies on nitrogen fixation in photosynthetic bacteria, have been carried out under laboratory conditions. Smith et al. (1973) purified the molybdenum-iron protein of the nitrogenase in a species of Chromatium, and in a nitrogen limited culture of Rhodospirillum rubrum, Munson and Burris (1969) were able to demonstrate rates of 2 nM C₂H₄ produced min⁻¹ mg⁻¹ dry weight. Kobayashi and Mohammad (1971) showed that Rhodopseudomonas capsulatus, growing in symbiotic association with heterotrophic bacteria, was able to use pyruvic acid excreted by the heterotrophs to fix nitrogen under aerobic conditions. From the tropics, Trüper and Jannasch (1968) described Chromatium buderii growing in estuarine saltflats and salt marshes of the Galapagos Islands, but were unable to demonstrate nitrogenase activity in this species under laboratory conditions.

The chance to visit Aldabra Atoll in 1974 appeared an excellent opportunity to study marine communities of photosynthetic prokaryotes, within intertidal environments of the lagoon. The present chapter introduces various aspects of the geology and geography of Aldabra Atoll and the lagoon, intended as a background to more detailed descriptions given elsewhere in the thesis. Further information on geomorphology, geography and other studies carried out at Aldabra, are given in The Report Of The Royal Society Expedition To Aldabra 1967-68 (Westoll & Stoddart, 1971). Stoddart (1967), and Peters and Lionnet (1973), have summarised much of the literature relevant to Aldabra and other western Indian Ocean atolls.

1.2 Aldabra Atoll

1.21 Geography and climate

Aldabra Atoll is situated in the extreme southwest corner of the Indian Ocean ($9^{\circ} 24' S$, $46^{\circ} 20' E$). The land rim has a circumference of 96 km, varying between 0.25 and 5.0 km in width, and enclosing the lagoon. Passes break the land rim at four points, connecting the lagoon with the sea, and separating the principal land masses of Île Picard, Île Malabar, Île Polymnie and Grande Terre (Fig. 4.1). These form a more or less flattened oval shape, orientated along an east-west axis, with a maximum width of 14.5 km and maximum length of 34 km.

Farrow (1971) has discussed the climate of Aldabra in detail. The atoll experiences two climatic seasons, each approximately six months in duration, the wet season or WNW monsoon lasting from around December to April, and the dry season coinciding with the southeast trade winds which blow from May to November. Summer maximum temperatures average $32^{\circ}C$ and winter minima average $22^{\circ}C$, although much higher temperatures are experienced within the lagoon in summer.

1.22 Geomorphology of the land rim

Abbott (1893) and Fryer (1910a, 1910b, 1910c) commented on the most obvious features of the geomorphology, whilst the recent study of Braithwaite et al. (1973), discussed the geological history of Aldabra in detail.

The land is composed mainly of coral limestone, with guano-derived calcium phosphate in several areas. Drops in sea level have resulted in the cutting of two terraces, one at

8 m and the other at 4 m. The four islands are totally flat, excepting several large sand dunes along the seaward coast of Grande Terre. Natural pits up to 3 m in depth are common around the land rim, and often connect with the sea.

The exposed limestone has three recognizable morphological forms, termed champignon, pavé, and platin (Stoddart et al., 1971). The first has been formed by erosion and solution, and the surface is honeycombed and pitted, with razor sharp edges and small pinnacles. The second form is rounded and quite smooth with slight relief, and the third, the 'platin' type, completely flat. This last form is typical of the land rim in the southeast corner of the atoll (Fig.4.12).

The sheltered north coast has deeply undercut cliffs and sheltered beaches, contrasting with the more exposed south coast which receives the full force of the southeast trades. Here cliffs have been cut back with the wave action, and slope back to dunes and wind-blown sand deposits.

1.23 Flora

The importance and unique nature of the flora and fauna was discussed in detail by many authors (Peterson, 1968 ; Fosberg, 1967 ; Gaymer, 1966), when it was thought that the building of an air-base on the island was imminent. A complete list of those higher plants and eukaryotic algae referred to in the thesis, is given in Section 2.110, and it is the purpose of this section, to simply point out the main vegetation types on the atoll. Fosberg (1971) gave a detailed account of the vegetation, using the IBP-Fosberg

classification, however it is useful to summarise only the main vegetation types as first noted by Fryer (1910b). An extra category on marine angiosperms is included, due to their importance in this study.

- a) mangrove
- b) Pemphis acidula bush
- c) open bush
- d) shore zone
- e) marine angiosperms

Mangroves form an almost continuous fringe around the coasts of the lagoon, and are the dominant vegetation between the tide marks. Their distribution was first described by Macnae (1971), and they are referred to in more detail in Section 4.16.

A dense low scrub of Pemphis acidula Forst. covers much of the land rim, and forms an impenetrable barrier to movements in certain areas. In the southeast part of Grande Terre, a much more open bush type is found associated with the platin limestone.

Shoreline vegetation extends along much of the seaward coast and is representative of many oceanic islands in the tropics. On Aldabra, Suriana maritima L., Scaevola taccada (Gaertn.) Roxb., and Tournefortia argentea L.f. are common species.

Meadows of marine angiosperms grow at the level of low water both inside and outside the atoll, and are particularly abundant in the vicinity of passes, where they are associated

with the deposits of coarse sediments found in these areas.

1.3 The lagoon

1.31 Geomorphology

The lagoon occupies an area of 184 km², approximately 32 km² of which is mangrove forest. Along its east-west axis the lagoon is 29 km in length, and averages 6.5 km in width (Fig. 4.1). As can be seen in Table 1.1, in comparison with other atolls of a similar size, the lagoon is relatively large.

Table 1.1 Lagoon area in relation to atoll size, selected data from Wiens (1962)

atoll	length (km)	width (km)	lagoon area (km ²)
Arno	36.0	15.5	19.0
Ngulu	29.9	18.4	0.5
compared with the data for Aldabra:			
Aldabra	29.0	6.5	174

At low spring tides a large area becomes dry, the rock base being exposed. A large percentage of the present lagoon area was at one time land, the remnants of the ancient lagoon floor being the numerous flat-topped, champignon (mushroom-shaped) islets, scattered throughout the lagoon (Fig. 4.7). For its greater part the floor is very flat, with a slightly depressed area in the centre (Fryer, 1910b). Along its southern margin the floor is heavily pitted, and there are many sediment-filled depressions, ranging from several centimetres diameter to within excess of a metre. In the West, subterranean passages are thought to connect the lagoon with the sea.

Erosion has been responsible for the formation of four

passes, connecting the lagoon with the sea (Fig. 4.1). These are Grande Passe (c 20 m deep), Passe Houareau (c 15 m), Passe Gionnet (c 9 m), and the western complex of Passe Mili, the major passes of which are Passe du Bois (c 8 m) and Passe Femme (c 4 m). The importance of the passes in determining conditions within the lagoon is discussed further in Section 1.32.

Away from the passes lagoon sediments are relatively shallow, the deepest fine sediments being white carbonate silts of less than one metre depth, found at Bras Anse du Bois on the south coast (Farrow, 1971). These deposits are extremely shallow when compared with other atolls where carbonate sediments are accumulating, e.g. Weber and Woodhead (1972) described deep fine-grained carbonate sediments from Tarawa Atoll in the Gilbert Islands, and Emery et al. (1954) discussed many deep sediments from Bikini and nearby atolls in the Pacific. In many atoll lagoons sediments are derived from calcareous algae and bird droppings. For instance, at Funafuti Atoll in the Pacific, Halimeda deposits of 20 - 25 m depth were recorded by Davis (1928), and Friederici (1910) noted guano deposits of 8 m in the lagoon of Nian Atoll, also in the Pacific. Again, Aldabra differs in not having any deposits of significant depth, eventhough Halimeda grows within the lagoon and large bird colonies are found in several parts of the atoll. Fryer (1910c), considered the majority of sediments in the lagoon of Aldabra, to be a consequence of lagoon erosion. The deeper silts are associated with the sheltered lagoon shores,

this being consistent with that found for most atoll lagoons (Wiens, 1962). Fine white carbonate silts are typical of the south coasts, and brown gelatinous mangrove silts of the north and east coasts. Coarsest sediments are found in the general area of passes, where they typically form beaches. An extensive sandflat is formed between the islet of Île d'Esprit and the mangrove sandbank of Îles Moustique, a similar situation occurring at the eastern lagoon islet of Île Michel. Live corals are associated mainly with the passes, and have been described by Barnes et al. (1971).

The shores of the lagoon are for the most part undercut limestone, with a much smaller vertical amplitude than that of the seaward coast (0.25 - 3.0 m). The shores of Grande Terre slope towards the lagoon, and undercutting is virtually absent, however rock hummocks are common. Highest amplitudes are found along the northern perimeter of the lagoon, and many limestone residuals are visible close to the shore.

1.32 Tides and the tidal cycle

Tides delimit the intertidal, and as such the tidal cycle (and resulting movement of water), is the most important factor influencing the communities growing within this zone. For coral atolls, the number and depth of passes, as well as the area and depth of the lagoon itself can effect movements of water with each tide. Wiens (1962) summarised the depths of lagoons in relation to atoll size for many atolls in the Marshall and Caroline Islands of the Pacific, and a selection of his data is shown in Table 1.2. As can be seen, in comparison

with other atolls of a similar size, the lagoon is extremely shallow, with a maximum depth of only 5 m at the highest spring tides (Farrow & Brander, 1971).

Table 1.2 Lagoon depth in relation to atoll size, selected data from Wiens (1962)

atoll	length (km)	width (km)	max. lagoon depth (m)
Bikini	38.0	22.0	64.0
Ebon	12.0	11.0	36.0
Eniwetok	35.0	29.0	76.0
Jaluit	49.0	29.0	54.0
Ngulu	31.0	18.0	84.0
Rongelap	58.0	32.0	68.0
Rongerik	15.0	14.0	56.0
compared with the data for Aldabra:			
Aldabra	29.0	6.5	5.0

Tides at Aldabra are influenced markedly by the Moçambique Channel, and as a result Aldabra possesses a large tidal range, one of the largest known from an oceanic island, with a mean spring-tide range of 2.74 m (Farrow & Brander, 1971). This is in contrast to a range of 0.5m for the majority of atolls in the Pacific (Wiens, 1962), and 0.7 to 1.7 m for Indian Ocean atolls (Farrow & Brander, 1962).

The shallow nature of the lagoon, and the large tidal range have pronounced affects on water movements within the lagoon. Fryer (1910b) noted the extent to which it could become landlocked, the passes being inadequate to allow tides to flow evenly, inside and outside the atoll. The tidal range within the lagoon is very much reduced, a fact which is in

agreement with the observations of von Arx (1954), at the atolls of Bikini and Rongelap in the Pacific. He stated that "while the ocean rises and falls as a simple harmonic oscillator, the lagoon surface, because of the restrictions of passes to water flow, probably oscillates through a slightly smaller amplitude than the ocean surface". Time lag in tides thus occurs lagoonwards, and because of its shallowness, this lag is greatest at low water than at high (Farrow & Brander, 1971). A lag of up to four hours may prevail at the top of creeks in the eastern parts of the lagoon. A situation occurs at low neap tides where the lagoon is virtually tideless, with very small drops in water levels, and an ebb of 9.5 h in every 12 (Farrow & Brander, 1971). Towards the onset of spring tides more and more water enters the lagoon, and due to the size of the channels this gradually builds up inside the lagoon, so that at low water of springs a 'ponding effect' is responsible for a depth of 0.3 m of water covering most platforms. This situation never arises in most atoll lagoons due to their open nature, or large number of passes, e.g. Rongelap Atoll has nine passes and Bikini Atoll is connected to the sea by eight passes, with average depths of 60 m.

Extreme low water is therefore associated with neap tides and not springs, a fact to be borne in mind when making all definitions of the intertidal zone. Taylor (1971) gave the view that a central body of water in the lagoon was never or rarely renewed, simply moving to and fro with the tides.

Tides at Aldabra are computed from Admiralty Tidal

Predictions for Kilindini (African East Coast, 4° 04' S, 39° 39' E). High and low water are approximately six hours apart outside the atoll, but as can be seen from the above discussion this may vary within the lagoon.

1.33 Intertidal environments

Basic terminology used in the description of rocky coast environments was first given by Stephenson and Stephenson (1949), and there are many studies of the zonation of blue-green algae, within the intertidal zone of rocky shores in temperate regions (1.11). Taylor (1971) recognized three distinct zones on seaward shores of Aldabra, and these may be briefly summarised here.

a) The littoral fringe ; characterized by the presence of Littorina sp., blue-green algae and lichens. The zone extends from, at its lower level, the first appearance of barnacles to the upper limit of Littorina at the top.

b) The eulittoral ('intertidal') ; extending from the first appearance of barnacles, to the lower limit and the occurrence of corals, marine angiosperms and Sargassum sp.

c) The sublittoral ('infralittoral') ; characterized by corals, marine angiosperms, Sargassum sp. and Turbinaria sp. Delimitation of the intertidal zone within the lagoon is discussed in detail in Section 4.12.

Lagoon intertidal environments have been classified for many atolls in terms of their characteristic sediments, e.g. the study of the lagoon at Onotoa Atoll, Pacific (Banner & Randall, 1952 ; Cloud, 1952), and at the atolls of Bikini,

Rongelap, Eniwetok and Rongerik (Emery et al., 1954). Farrow (1971) recognised three types of lagoon platform in Aldabra Lagoon, as distinguished by their crustacean burrows; sandflats, carbonate mudflats and mangrove mudflats.

1.331 Sandflats

The coarser sediments of the lagoon are found in the vicinity of passes e.g. Passe Gionnet, where beaches are typically formed. Wiens (1962) considered the sandflat to be the most extensive habitat on lagoon reefs. In Aldabra Lagoon a sandflat stretches for over one kilometre between the mangrove colonising bank of Îles Moustique, to Île d'Esprit and Île Sylvestre. This has formed at the confluence of strong tidal currents, and a large area is exposed at the lowest neap tides.

1.332 Carbonate mudflats

Shores along the southern part of the lagoon coast are the most protected within the lagoon, and it is here that the deepest sediments are accumulating. The sediments are fine calcareous silts which form mudflats, sometimes in excess of 400 m, sloping gently towards the central part of the lagoon. Weber and Woodhead (1972) described carbonate mudflats at Tarawa Atoll, Gilbert Islands, and Chave (1962) has summarised the processes of carbonate sedimentation, in many different marine environments.

1.333 Mangrove mudflats

Mangrove muds and silts are the predominant sediments along the relatively exposed northern coastline, and in the

eastern and southeastern parts of the lagoon. Along the northern perimeter of the lagoon, the shores of Île Malabar are covered by a greater depth of water than the south coast, and the intertidal zone is reduced, averaging ≈ 200 m. The largest area of mangrove mudflat is in the eastern lagoon at Cinq Cases, with an intertidal zone, in places exceeding one kilometre. Due to the numerous tidal depressions, exposed limestone and 'ponding' of water in creeks, the zone is not as clearly defined as elsewhere. Mangrove mudflats are common at many atolls, usually in the shallow water of lagoons, and Fosberg (1953) has discussed this environment for many atolls in the Central Pacific.

1.4 Taxonomy of blue-green algae

A brief mention was made in Section 1.11 of some of the problems encountered in the taxonomy of blue-green algae. The present section summarises the different approaches taken by various authors to the identification of species.

The starting points of nomenclature for filamentous blue-green algae are Bornet and Flahault (1886, 1888) and Gomont (1892); none have been designated for coccoid forms. Desikachary (1973) proposed that Lemmermann (1907) be declared as the starting point of the nomenclature for coccoid blue-green algae, whereas Stanier et al. (1971) argued that Nägeli (1849) should be used. Since the early works of Bornet and Thuret (1876), Gomont (1892), and Bornet and Flahault (1886), the classification of blue-green algae at all taxonomic levels has been essentially based on morphological characters. As a

result the taxonomy has followed a 'classical' trend, similar to that of other groups of algae and quite different to that of bacteria, even though the similarities of blue-green algae and bacteria were recognised by Cohn as early as 1853.

Classical taxonomy, with its underlying evolutionary assumptions, makes use of the monothetic principle of classification. All the characters of a subordinate taxa must necessarily be included in the definition of a superior taxon (Komárek, 1973). The standard texts of blue-green algal taxonomy use this principle e.g. Geitler (1932), Elenkin (1936, 1938, 1949) and Desikachary (1952).

Drouet and Daily (1956) and Drouet (1963, 1973) produced a new classification for the order Chroococcales and the families Oscillatoriaceae and Nostocaceae. They reduced the number of genera and species, together with other 'ecophenes', into synonymic lists with newly assigned generic names. An ecophene is defined by Davis and Heywood (1963) as "The reaction-types of the ecotypes called forth by the modificatory influences of extreme habitat factors", i.e. the characteristic phenotype produced in each particular locality. In the Hyellaceae, Drouet and Daily (1956) reduced the five genera with other 'ecophenes' into one species Entophysalis deusta. Nielsen (1973) however, has shown marked morphological differences between two marine species, Hyella balani and Gloeocapsa crepidinum, grown under identical laboratory conditions. Golubić (1969) has also observed consistent differences between two other species, Hormathonema paulocellulare and Hyella caespitosa, considered by Drouet and

Daily (1956) as growth forms of Entophysalis deusta. The extracellular pigment in Hormathonema paulocellulare is dark blue which turns red at $\text{pH} \leq 6$, in Hyella caespitosa it is yellow-brown turning green on treatment with acid. Both these species also show distinct boring patterns in carbonate substrates (Golubić, 1969).

The boring behaviour of endolithic marine blue-green algae has been used by Golubić and Le Campion-Alsumard (1973) as a taxonomic character. They showed significant differences in the boring patterns of Mastigocoleus testarum and Kyrtuthrix dalmatica. The course of penetration in Mastigocoleus testarum was arched to semicircular, in a horizontal and vertical direction. In Kyrtuthrix dalmatica it was predominantly perpendicular to the surface.

The improved isolation and purification techniques developed within recent years have helped greatly in making a more critical appraisal of conventional taxonomic methods, and one instance was given in Section 1.11. Many changes have been suggested in the taxonomy of blue-green algae, based on cultures and the study of 'type' material. These have been suggested because of the lack of distinguishing characters in many cases between the different taxa, and the presence of intermediate characters or forms (Desikachary, 1952). Stanier et al. (1971), after studying DNA base composition in axenic cultures of many species within the Chroococcales, showed the inadequacy of characterization by gross structural properties within this order. They demonstrated a certain degree of

consistency within the classification system as given by Geitler (1932), but not for that of Drouet and Daily (1956). Their findings led them to propose that "the blue-green algae must now be recognised as a major group of bacteria, distinguished from other photosynthetic bacteria by the nature of their pigment system and by their performance of aerobic photosynthesis". The views of Stanier et al. (1971) are now shared by an increasing number of workers who wish to encompass the taxonomy of blue-green algae within the 'International Code Of Nomenclature Of Bacteria' (1966). It should be noted that modern taxonomic methods using physiological and biochemical properties of organisms, such as DNA base composition, have been applied to only a few blue-green algae and at present cannot be applied to the determination of species in field populations.

Using a standard taxonomic text, such as that of Geitler (1932), problems arise when attempting to allocate suitable binomials to material collected from marine and brackish habitats. Marine forms are listed for only a few genera, and of these, many are poorly described. This is particularly true for the genera Scytonema and Schizothrix, several species of which represent significant components of algal mat communities, in intertidal habitats of many areas of the tropics (1.11). Only three out of 52 species of Scytonema, and two of over 70 species of Schizothrix, are described by Geitler (1932) as marine. However within the orders Chroococcales and Chamaesiphonales, the similarity in descriptions of marine and freshwater forms in a number of

genera, makes the validity of a distinction between freshwater and marine species questionable.

The obvious problems in allocating suitable binomials to marine forms, have no doubt been instrumental in persuading many authors to adopt the taxonomic conventions of Drouet and Daily (1956) and Drouet (1963, 1973). In studies of intertidal rockpools at Oahu, Hawaii (1.11), Khan (1969) considered several of the forms he recorded as ecophenes of Lyngbya aestuarii and Entophysalis deusta. Van den Hoek et al. (1971) attributed the bluish colour of limestone in the upper intertidal zone of shores of Curaçao (1.11), to a Hyella 'phase' of Entophysalis deusta, and the characteristic blue colour of beach rock at Raroai Atoll, Pacific, was felt by Newhouse (1954) to be due to the discolouration of the sheath material of E. deusta. At Bermuda, Sharp (1969) used Drouet's classification (1963) to describe algal stromatolites in 31 different locations, allocating the name Schizothrix calcicola to all these structures.

Since the critical work of Stanier et al. (1971), an increasing number of workers have shown the classification system of Drouet and Daily (1956) and Daily (1963, 1973) to be a determinatively worthless one. In the present work, the 'Drouet classification' is totally rejected and is referred to only where comparisons are drawn. The taxonomic conventions of authors such as Geitler (1932), Frémy (1932) and Desikachary (1952) have been followed, supplemented by a computer-orientated recording system developed in Durham. Full details of this

system, together with the methods used in the allocation of binomials, are given in Section 3.11.

1.5 The project

The decision to study communities of photosynthetic prokaryotes within the intertidal zone of the lagoon was taken for several reasons. Blue-green algae were known to be abundant in sheltered intertidal habitats of several regions of the tropics, where communities often covered extensive areas (1.11). Of the studies on these communities, most were involved with the importance of algal mats as geological indicators in the fossil record (1.11), and it seemed that few workers had studied the ecology or physiology of the individual species. A number of authors commented on the distribution of blue-green algae in marine habitats of atolls (1.4), but adopted taxonomic conventions which are now known to be open to criticism (1.4).

Aldabra Atoll appeared highly suitable for a study of blue-green algae. The land rim was composed entirely of coral limestone, and the bulk of sediments within the lagoon were a result of erosion (1.31). As limestone substrata support communities of blue-green algae in many areas of the world (1.11), it seemed likely that these algae would be common and widespread within the lagoon. In addition, the high tidal range and shallow nature of the lagoon (1.32), produce an extensive intertidal zone sheltered from the sea outside the land rim, and the wave action caused by the south east trades (1.32). These conditions were known to lead to

extensive growths of blue-green algae in other areas of the tropics (1.11). Fogg's comment (1973) on the few studies of marine forms, strengthened the decision to study these communities. The association of photosynthetic bacteria with blue-green algae in various marine habitats, and the similarities between the two groups of organisms (1.11), suggested that they should be included in the studies within the lagoon. One aspect of the physiology of these organisms was chosen for study in more detail, and this was nitrogen fixation.

2 MATERIALS AND METHODS

2.1 Physical and chemical techniques used in situ

2.11 Measurement of light

A simple photographic light meter (model Weston Master IV, Sangamo Weston Ltd, Enfield, Mddx), was employed for all readings. This gave a numerical value on a 0 to 16 scale for each particular light intensity, and was calibrated against an EEL lightmaster/photometer (Evans Electroselenium Ltd, Essex) after return from Aldabra. It must therefore be stressed that the values of light intensity obtained in situ were only rough estimates of the actual values. However they are useful for making comparisons.

2.12 Measurement of temperature

The majority of temperature measurements were taken with two mercury thermometers, placed adjacent to one another. In practice these gave readings which differed by less than 0.1°C. A temperature reading was always taken simultaneously with pH and Eh readings (2.17), when waters and sediments were being studied. For more detailed studies on algal sediments, a thermocouple measuring device was used. This was a copper/constantan thermocouple wired through a 'Galvamp' galvanometer (Airmec Division Ltd). The wire probe had a surface area of only one square millimetre, and could therefore detect temperature changes within a very small area of mat. Distilled water was used as a reference, its temperature being measured with five mercury thermometers. Readings were taken at 15 min intervals over a 24 h period, and during the hottest

parts of the day, the galvanometer was protected with a white protective screen.

2.13 Measurement of relative humidity

Relative humidity was measured using a battery operated psychrometer (Atkins Technical Inc., Florida, U.S.A.), which gave wet and dry air temperatures. The 'gun' probe had an aperture of one centimetre and permitted readings to be taken from inaccessible points with a high degree of accuracy. Actual values of relative humidity were calculated from psychrometric tables (Marvin, 1973).

Readings were taken at heights of 0 cm, 1.0 cm, 10.0 cm, and 100 cm above microbial communities.

2.14 Analysis of water

Water samples were collected from 180 sites during the study period (November 1974 to June 1975).

Where deep enough a water sample was collected with a plastic beaker at 20 cm depth; if shallow (usually the situation), the sample was taken half-way between the surface and the bottom sediment. In some cases only a very thin film of water was present e.g. in the interstices of algal mats. Samples of these waters were removed using a pasteur pipette.

The sample (if sufficient) was immediately filtered through a No. 2 Sinta funnel (Gallenkamp, Stockton, England). The manufacturer quotes a pore size for this filter of 40 - 50 μm , but recent studies in Durham indicate the pores to effectively remove much smaller particles (J.P.C. Harding, pers. comm.). Nevertheless all that was required was that the

bulk of any algal standing crop should be removed, before storage or analysis. Part of the filtrate was collected in 30 ml plastic tubes, sealed with wax and stored at -10°C on return to the research station at Île Picard. The rest of the filtrate was analysed in situ.

Many of the methods used in the analysis of sea water, rely on the sample being analysed within a few hours of collection (Strickland & Parsons, 1968). This was not possible on Aldabra, where up to a week at a time was spent working away from the research station. For this reason 'Hach' water test kits (Hach Chemical Co., Iowa, U.S.A.), were used for the determination of ammonia, nitrate, nitrite and phosphate in solution, in situ. Each kit consisted of dry powdered reagents, packed in individual pre-measured polyethylene 'powder pillows'. Pillows contained the exact amount of reagent for one test, and this was added to a standard amount of the water sample (5 ml) in a glass tube. On mixing a colour reaction occurred, the intensity of which was compared with a colour comparator disc, and a concentration read. These kits were used extensively in the study of fresh waters, but there appeared to be few reports of their application in sea water before visiting the atoll. For this reason experiments were carried out to test their reliability in the analysis of brackish and sea waters, before visiting Aldabra, and also while working there.

In laboratory experiments, artificial sea water (ASP-2, Provasoli et al., 1958), and sea water collected from the Northumberland coast were compared in the 'Hach' tests for

ammonia and phosphate. No interference was detected (Table 2.1). Subsequent tests on Aldabra using lagoon waters, showed no evidence of interference in the test for nitrate or nitrite, when known concentrations of added nitrate and nitrite were estimated using the 'Hach' comparator discs (Table 2.2). However as analyses were carried out in situ, it became apparent that interference was influencing the 'Hach' analysis of O -phosphate. This was the least dependable of the analyses in samples of sea water.

2.15 Measurement of salinity

The concept of salinity is briefly discussed here and its relationship to chlorinity given, as it is only within recent years that the original calculation of salinity from chlorinity has been disputed (Perkins, 1974).

The salinity of the sea and brackish waters is defined as the total amount of dissolved inorganic salts, contained in one kilogramme of sea water or brackish water (Kemane & Schlieper, 1971). There is a fixed relationship between the salt content and the chloride content, so that salinity can be expressed as follows:

$$S = 1.80655 \times \text{chlorinity}$$

where chlorinity = g Cl kg⁻¹ sea water (Perkins, 1974).

Readings of salinity were taken in situ using a National Institute of Oceanography portable salinometer. As the probe had a cylindrical shape of 72 cm³, readings could only be taken in relatively deep water, and a long cable proved cumbersome when travelling in the more inaccessible parts of the

Table 2.1 Comparison of the 'Hach' analyses for ammonia and phosphate, in ASP-2 and natural sea water (all values are in mg l⁻¹ and are the mean of three replicates, SW = sea water)

added NH ₄ -N	added PO ₄ -P	'Hach' readings from colour disc	
		NH ₄ -N ASP-2	PO ₄ -P ASP-2
0	250	0	252
3.0	50.0	3.0	303
4.5	30.0	4.4	332
5.25	15.0	5.1	348
5.4	7.5	5.2	356

Table 2.2 Accuracy of the 'Hach' test for nitrate in lagoon waters at Aldabra (all values are in mg l^{-1} and are the mean of three replicates)

added $\text{NO}_3\text{-N}$	'Hach' readings from colour disc
0	0
0.01	0.01
0.30	0.31
0.60	0.59
1.2	1.1
1.8	1.7
2.4	2.2

lagoon. The meter gave readings on a 0 to 38 ‰ scale. It was not always possible to obtain a reading of salinity in situ for all water samples, and subsequent salinities were estimated from tables of salinity (Strickland & Parsons, 1968), after chloride analysis of the samples (2.21).

2.16 Measurement of percentage dissolved oxygen

Measurements were taken with a Lakelands Instrument Co. portable meter, with accessory cable and Mackereth electrode. The probe was stored in a saturated solution of sodium sulphite when not in use to protect the electrode. Dissolved oxygen was read on either a 0 - 300 % or 0 - 150 % scale (assuming a barometric pressure of 764 mm). Readings were taken when there was sufficient water to cover the probe, which was lowered by the cable to approximately half way between the bottom and surface of the water being sampled.

2.17 Measurement of Eh and pH

The problems involved in the measurement of Eh and pH, and in the interpretation of results, have necessitated a somewhat detailed treatment of the methods used in the present study. It was also felt that a discussion of the theory should be included, to explain much of the methodology adopted. pH and Eh are very closely linked, and no attempt has been made to partition them in the following discussion.

Relative proton activity, $\text{pH} = -\log (\text{H}^+)$ and relative electron activity, $\text{pE} = -\log (\text{e}^-)$, are both used in the study of oxidation-reduction reactions in aquatic and terrestrial habitats (Stumm, 1966). Large positive values of pE (low

electron activity) represent strongly oxidising conditions, while small or negative values (high electron activity) correspond to strongly reducing conditions. pE is large and positive in strongly oxidising solutions (low electron activity), just as pH is high in strongly alkaline conditions (low proton activity), (Stumm, 1966). pE is therefore a measure of the free energy involved in a transfer of electrons. The energy gained in the transfer of one mole of electrons from an oxidant to H_2 , expressed in volts, is the redox potential (Eh), (Morris & Stumm, 1965). The importance of Eh as a parameter, is realised when one considers that biological processes are energy yielding systems which must involve a potential electron flow, for any given environmental condition (Borchardt, 1966). As 'redox potential' is a rather theoretical entity, the use of Eh is preferred in all discussions (M. Whitfield, pers. comm.).

Although the theoretical background of redox potential is well understood (Brown, 1933 ; Rivière, 1958 ; Morris & Stumm, 1965 ; Jones, 1966), the practicalities of measurement and quantitative interpretation of results are fraught with difficulties. Many workers have noted the problems associated with the measurement of Eh (Whitfield, 1969 ; Stumm, 1966), and these may be summarised as follows:

i) Electrodes disturb the environment; this may introduce air into the sample or allow gases to escape e.g. H_2S , CH_4 .

ii) A direct attack on the metal electrode by compounds such as sulphides e.g. S^{2-} , HS^- , H_2S , can set up an

irreversible potential. In the context of the present study it may be noted that sea water can have sulphate concentrations of up to 30 mM (Whitfield, 1971), and could therefore under suitable conditions give rise to high concentrations of sulphides. Extra care is therefore required, when studying marine habitats, to ensure the metal electrode is kept 'clean'.

iii) As redox potential depends on the ratio of oxidised to reduced species, and not their absolute concentration, it gives an indication of the level of activity in a system and not its extent. A solution superficially may appear to have a very low potential, however addition of a minute amount of oxidant can oxidise it completely. This fact should be considered in the light of two other problems associated with Eh measurements; micro-environments can differ widely in a system, and small amounts of various compounds, can be responsible for 'fixing' the potential (ii above), at the electrode surface. These compounds usually produce a highly reversible system, which is overall insignificant.

iv) The whole system being studied may be out of equilibrium. This obviously should be considered when widely differing results are obtained from points relatively close to one another.

v) Suspended matter and sediment particles in solution, and precipitation of sulphides at the electrode/sample junction can give rise to anomalous readings. Bates (1964) advocated the coating of pH electrodes with a thin layer of silicone to reduce these 'suspension effects'.

vi) No account of the potential within individual particles is taken when sediments (or sea water) are studied. This must also apply to suspensions of sediments.

vii) Reduced sediments when removed from their low potential environment, undergo marked changes when exposed to air. Readings from such sediments must therefore be viewed with caution.

As can be seen the problems associated with Eh measurements are considerable. Nevertheless, provided certain precautions are taken and a standard technique imposed, useful data may be obtained.

Ideally many electrodes are required when taking readings, to ensure reproducibility of results. In practice a minimum of two should be used. Even so, two electrodes adjacent to one another can give readings which differ by 10 to 30 mV, due to the platinum electrode being not truly inert (Whitfield, 1969). Large differences between the two should be viewed with suspicion, and the electrodes cleaned and recalibrated.

For cleaning, several workers advocate the use of chemicals; mainly strong acids such as chromic acid or chlorine-free nitric acid (slightly warm), (Callame, 1968 ; Jones, 1966). Others favour a mild abrasive e.g. emery paper (silicon carbide paper). In the field, the second method is the most practical, and should always be used when readings are being made at regular intervals. Where low Eh readings have been obtained, the probes should be cleaned by the former method. A combination

of the two is suggested.

Electrodes are calibrated before any set of readings are taken, and they should be checked at least twice during the measuring period. The commonest buffer used for redox probes is Zobell solution (0.003 M potassium ferrocyanide - 0.003 M potassium ferricyanide in 0.1 M potassium chloride solution) (Zobell, 1946). This solution has a potential equal to +430 mV, minus the potential of the reference electrode, which is +252 mV for 3 M KCl at 20°C. Brown (1933), showed 12 electrodes to agree to within 0.5 mV when calibrated in this solution. The calibration is simply checking the liquid junction at the reference electrode (Whitfield, 1972). Two electrodes can give consistent readings in a buffer, but differ by up to 50 mV in sediments, due to the different reactions occurring at the electrode surface. In Zobell solution, only the ferro-ferricyanide reaction occurs. A second buffer solution should always be used, as a check on the electrodes, and for this purpose a saturated solution of quinhydrone is often used, made up at a number of different pH values. The difference in readings between a set of buffers saturated with quinhydrone, must correspond to the pH difference x 58.1 mV (at 20°C) (Ingold, 1966). This is illustrated in Table 2.3.

In the present study, measurements of pH were taken in the field using a glass electrode (sinta plug, 450 E_o7) with a 1 M KCl reference electrode. A Pt-Ag/AgCl electrode with a reference electrode of 3 M KCl was used when taking Eh readings. Each electrode was used with separate Pye Unicam

model 293 portable meters, mounted in leather cases. Each of the cases were painted white to reduce solar heating, which could often have detrimental effects on the performance of the meters. The pH probes were calibrated in pH buffers made up at pH 4.0, 7.0 and 9.2 using 'soloid' buffer tablets (Burrough-Wellcome & Co.) in distilled water at 20°C. Initially in laboratory work buffers were made up at pH 7.0 and 8.0 using a solution of $\text{Na}_2\text{HPO}_4\text{-NaH}_2\text{PO}_4$ of 0.1 M strength (Bower & Bates, 1955). This was done to check the reliability of the buffer tablets. The platinum redox probes were calibrated each day with Zobell solution, and cleaned with emery paper and checked against quinhydrone buffers regularly in the field when measurements were being taken. They were usually left in chromic acid overnight, when very low potentials were encountered during field sampling.

Table 2.3 Calibration of platinum electrodes using quinhydrone saturated buffers (Ingold, 1966)

buffer pH	potential of a Pt-Ag/ AgCl/3 M KCl electrode
7.02	+ 77 mV
4.00	+251 mV
9.20	- 51 mV

At each sample point pH, Eh and temperature were read by gently lowering the probes and thermometer into the sediment or water, vertical to the surface and as carefully as possible to avoid any disturbance. In practice it was found that a period of time was required (especially in sediments) for the redox probes to equilibriate, this usually occurring after two

to three minutes. Where possible, readings were taken at the surface, -10 mm, -20 mm, -40 mm, -60 mm, -100 mm and the deepest point (if deeper than 100 mm). Because of the shape of the probes and construction of the platinum and glass tips, it was possible to make accurate readings to within only 3 mm depth. When expressing results, the Eh value corrected to pH 7.0 has been included (Eh_7). This value is calculated assuming a change of one pH unit to be equivalent to a change of 58.1 mV (Ingold, 1966; Potts & Whitton, 1976a).

2.18 Collection and analysis of sediments

Surface sediments were collected with a small trowel, and then transferred to polythene bags open to the air. A spatula was used when sediment cover was particularly thin. Where it was felt that a particular area of sediment was of a homogenous nature, samples were collected at random from a number of different points and pooled for sieving purposes, but otherwise samples were collected from those areas which visibly differed from one another. The sediment associated with individual algal communities was obtained by breaking up the algal crusts or mats, and separating off the sediment.

Folk (1964) reviewed many of the techniques used in the analysis of sediments, and indicated sieving to be the most accurate for sands and coarse silts. As this has been the most widely used method for the analysis of these sediments since the initial work of Udden (1914), it was used in the present study. The scale of grade and class terms for clastic sediments as given by Wentworth (1922) i.e. 'The Wentworth Scale'

was adopted, and a set of four standard sieves to cover the range 2000 μm to 250 μm , were used in all analyses (Page, 1955). All sieves had brass mesh pores and were obtained from The Endecotts Filters Ltd, London. These fitted together in a vertical column over a collecting tray.

Table 2.4 Sieve sizes used in the analysis of sediments

mesh size	ϕ (phi no.)
2000 μm	-1.0
1000 μm	0.0
500 μm	+1.0
250 μm	+2.0

$\phi = -\log_2$ of the diameter (mm) as an exponent of the diameter for a geometrical scale (Pettijohn, 1975)

Approximately 150 g of sediment were used in each analysis, all sediment samples being dried at ambient air temperature before sieving. Sands were sieved dry by shaking and agitation of the column, while finer silts were washed through with water. The sediment left on each sieve after sieving was dried, weighed, and expressed as a percentage of the total initial weight. Results were presented in histogram form, with the weight of sediment per size category expressed as a percentage of the total sample weight (McBride, 1971).

2.19 Collection and preservation of samples

Apart from a systematic sampling of microbial communities concurrent with the transect programme (Chapter 4), an attempt was made to collect samples from as many sites as possible, with a view to producing a taxonomic checklist of marine Myxophyta at Aldabra. This involved several methods of sampling.

i) The collection of visually obvious communities associated

with sediments, rocks and water, within the lagoon intertidal zone (including tidal pools), not necessarily associated with transects. The seaward coast was also studied in a similar fashion, at points in line with transect areas.

ii) A procedure of more or less random sampling was adopted in transit between study areas e.g. the collection of plankton from within the lagoon.

iii) A detailed collection of samples from 1 cm^2 areas, where information on substratum microtopography, light intensity, coverage by water etc. was noted. A standard recording procedure was followed in the collection of this data, and was essentially based on the system at present in use for stream and river data (Whitton et al., unpublished data). A short summary may be included here.

On collecting a 1 cm^2 sample from an area of relatively uniform substrate, each particular category of information was coded as a number (Table 2.5). The sample was then split into four equal parts, one for taxonomic study and the other three for preservation in one or more of the following:

- i) 2 to 3 % formaldehyde in sea water
- ii) 2 to 3 % glutaraldehyde in sea water
- iii) 2 to 3 % formaldehyde/30 % alcohol in sea water
- iv) Iodine in KI solution

The larger rock and sediment samples were dried carefully in the shade, and sealed with a small amount of silica gel in plastic bags. Macro samples of algal mat were dried in a similar manner for storage.

Table 2.5 The coding of environmental data collected with
1 cm² samples

A. Physiognomic (for 1 cm² sample)

- 0 Not known
- 1 Film
- 2 Filaments over and parallel to the substratum but not attached
- 3 Filaments bound to or running through the substratum
- 4 Felt or mat, firm, often blistered, often lifting off as sheet
- 5 Felt or mat with wrinkled appearance
- 6 Felt or mat with erect filaments
- 7 Felt or mat with broken-up polygonal appearance

B. Proportion of representative area (living + non-living) contributed by the same photosynthetic forms as the sample

- 0 Not known
- 1 0.0 to 0.1 %
- 2 0.1 to 1.0 %
- 3 1.0 to 10.0 %
- 4 10.0 to 100 %

C. Thickness scale

- 0 Not known
- 1 Very thin
- 2 Thin
- 3 Moderate
- 4 Thick

D. Substratum

- 0 Not known
- 1 Metamorphosed limestone
- 2 Magnesian limestone
- 3 Other limestone
- 4 Chalk
- 5 Sandstone (coarse or medium) without lime can include conglomerate

Table 2.5 con.

- 6 Igneous rocks, or compacted limestone
- 7 Sandstone (coarse or medium), with detectable lime
can include conglomerate
- 8 Igneous rocks, or compacted sandstone, with
detectable lime
- 9 Not applicable
- 10 Shale
- 11 Cement and concrete
- 12 Brick
- 13 Wood
- 14 Peat
- 15 Plastic
- 16 Dead plants, species not recognizable, not peat
- 17 Iron

E. Substratum size

- 10 >4096 mm
- 20 256 to 4096 mm
- 30 64 to 256 mm
- 40 2 to 64 mm
- 50 62 to 2000 μ m
- 60 4 to 62 μ m
- 70 < 4 μ m

F. Substratum microtopography

- 0 Not known
- 1 Markedly emergent above average level
- 2 Plane
- 3 Hollows (+ or - round)
- 4 Crack across flow
- 5 Crack with flow
- 6 Channel (less than 50 mm wide, and at least 30 mm
deep)

G. Surface inclination

- 0 Not known
- 1 None
- 2 Just detectable visually to 10°
- 3 10 to 45°

Table 2.5 con.

- 4 45 to 85°
- 5 Approximately vertical
- 6 Lip

H. Surface aspect

- 0 Not known
- 1 Surface facing upstream
- 2 Surface facing downstream
- 3 Side
- 4 Underneath, or nearly so

I. Water depth at position of sample

- 0 Not known
- 1 Dry
- 2 Moist, or very thin film (2mm)
- 3 2 to 20 mm
- 4 20 to 100 mm
- 5 >100 mm

K. Exposure to light at actual sample point

- 0 Not known
- 1 More or less open through year
- 2 Moderate cover through year
- 3 Heavy shade through year
- 4 Moderate shade in summer
- 5 Heavy shade in summer

N.B. This a modified version of the recording system at present being used in Durham, and several categories with no particular relevance to Aldabra have been omitted.

When describing the abundance of particular species, the following categories were used:

- 0 absent
- 1 present
- 2 occasional
- 3 frequent
- 4 abundant
- 5 very abundant

2.110 Identification of species

A Cooke McArthur hand microscope (Vickers Instruments Ltd, England) was used to identify conspicuous communities in situ. Those samples returned to the research station, were examined using a dissecting microscope and transmitted light microscope (Wild). For each sample two slides were prepared, each with 22 x 44 mm coverslips, and each systematically scanned over its whole area. Where material was dry, it was soaked in sea water for five minutes before mounting. Rocks and sediments were studied for endolithic algae by treating each sample with 2 % HCl or Perényi solution Golubić et al. (1975), and then mounting in sea water.

The taxonomic conventions used in identifying species of blue-green algae were discussed in Section 1.4. All identifications of photosynthetic bacteria were made using Bergey's Manual (1974). The methods used in the allocation of binomials to photosynthetic prokaryotes, are discussed in detail in the following chapter.

Species of eukaryotic algae were identified tentatively using the text of Taylor (1960). Tables 2.6, 2.7, 2.8 and 2.9 list those higher plants, marine angiosperms, eukaryotic algae and colourless prokaryotes, made reference to in the thesis.

Table 2.6 Species of higher plants mentioned in the thesis

Acrostichum aureum L.
Avicennia marina (Forsk.) Vierh.
Bruguiera gymnorhiza (L.) Lam.
Casuarina equisetifolia L.
Ceriops tagal (Perr.) C. B. Rob.
Cocos nucifera L.
Cyperus ligularis L.
Euphorbia abbotii Baker
Ficus sp.
Lumnitzera racemosa Willd.
Pandanus tectorius Park.
Pemphis acidula Forst.
Rhizophora mucronata Lam.
Scaevola taccada (Gaertn.) Roxb.
Sclerodactylon macrostachyum (Benth.) Camus
Sonneratia alba J. Sm.
Sporobolus virginicus L.
Suriana maritima L.
Xylocarpus granatum Koen.

Table 2.7 Species of marine angiosperms mentioned in the thesis (den Hartog, 1970)

Cymodocea rotundata Ehrenb. & Hempr. ~~ex~~ Aschers

Halodule wrightii Aschers.

Halophila sp.

Syringodium isoetifolium (Aschers.) Dandy

Thalassia hemprichii (Ehrenb.) Aschers.

Thalassodendron ciliatum (Forsk.) den Hartog nov. comb.

Table 2.8 Species of eukaryotic algae mentioned in the thesis

Chlorophyta

Boodleopsis sp.

Cladophora spp.

Enteromorpha sp.

Halimeda spp.

Monostroma sp.

Rhizoclonium sp.

Ulva sp.

Phaeophyta

Sargassum sp.

Turbinaria sp.

Xanthophyta

Vaucheria spp.

Bacillariophyta

pennate diatoms

Rhodophyta

Bostrychia spp.

Gracilaria sp.

Heterosiphonia sp.

Spyridia filamentosa (Wolfen) Harvey

Table 2.9 Species of non-photosynthetic prokaryotes
mentioned in the thesis

Beggiatoa spp.

2.111 Analysis of standing crop

Studies on the standing crop of eight communities of blue-green algae were carried out at Île Picard. Communities were allocated a number between one and eight, prefixed by the letter C e.g C3, C7. A strategy for study was devised as follows:

i) A community was delimited subjectively, and an estimate of its area given. Notes on associated vegetation and land marks were taken so that it would be possible to identify and re-sample the community on any return visit.

ii) Where necessary an area was delimited and divided in two for sampling purposes. One half was sampled at one time, and the other at a later date if necessary.

iii) Where the community was obviously highly variable e.g. desiccated crusts over the surface of sediments, 20 random samples were taken together with four apparent maxima i.e. usually the densest part of a mat. Five random samples were collected where the community was apparently uniform.

iv) Each sample had a surface area of 100 cm^2 (10 cm square), selected by throwing a 100 cm^2 plate of wood in a random manner over a community. The area was cut out with a scalpel for mats, and included associated sediment.

Un-consolidated sand e.g. Hyella balani communities were sampled with a spatula to a depth of one centimetre.

v) Samples were dried immediately after collection (in the shade) and stored in polythene bags, for return to the U.K. and subsequent chlorophyll a analysis.

2.112 Studies on nitrogen fixation

In the present study, the acetylene reduction assay technique was used in the study of nitrogen fixation, by photosynthetic microbial communities at Aldabra. It was felt appropriate to first justify the use of this technique, before discussing the methods adopted.

Blue-green algae and photosynthetic bacteria are unique amongst photosynthetic organisms by virtue of their capacity to fix atmospheric nitrogen. This a consequence of the possession by these organisms of the enzyme nitrogenase. The properties and characteristics of nitrogenase have been studied by numerous authors (Smith & Evans, 1970 ; Stewart & Alexander, 1971 ; Stewart, 1973 ; Eady et al., 1975), and it has been shown that when reductant and ATP are available, the following compounds are reduced; N_2 , HCN, N_3^- , N_2O , C_2H_2 and isocyanides. Many methods exist for the determination and measurement of nitrogen fixation, these include nitrogen analysis, reduction of any one of the substrates above, and morphological/growth measurements. Only two methods have received increased attention within the last decade, these being the use of $^{15}N_2$ and C_2H_2 as substrates.

The acetylene-ethylene reduction assay has been widely implemented (Burris, 1975), since the findings of Schöllhorn and Burris (1966) and Dilworth (1966) (that acetylene is reduced to ethylene by nitrogenase), were used by Stewart et al. (1967), to demonstrate acetylene reduction by natural populations of blue-green algae. It was decided to use the

acetylene reduction assay technique in preference to $^{15}\text{N}_2$, in studies of lagoon communities of blue-green algae and photosynthetic bacteria. This decision was made because of the various facts concerning the two methods.

Basic facts associated with the use of the $^{15}\text{N}_2$ method are that it is expensive, insensitive to very low fixation rates, and the subsequent analyses are complex, and require extensive chemical procedures (Hardy et al., 1972). In contrast the acetylene-ethylene reduction assay is sensitive to very low activities of nitrogenase, the product of the assay (ethylene) can be easily and accurately determined using gas chromatography, and the equipment used for in situ studies is simple, portable and inexpensive. The importance of these points is realised when one considers the inaccessible nature of parts of the lagoon, the need for light and inexpensive apparatus, and the facility for storing samples safely and compactly for perhaps several months before analysis. In the context of storage of gas samples, non-sterile, non-silicone coated, 5 ml draw vacutainers (Becton & Dickinson Ltd) were used. Experiments carried out before visiting the atoll had shown no change in composition of gas mixtures of acetylene and ethylene, when analysed after 15 weeks of storage at 32°C (Table 2.10).

The general method used in situ was to select locally uniform areas of blue-green algal or photosynthetic bacterial communities, and to measure acetylene reduction by samples of the particular community, in the light and the dark. All assays

Table 2.10 Analysis of acetylene/ethylene gas mixtures stored in vacutainers over 15 weeks in the dark at 32°C (gas concentrations in nM ml⁻¹)

storage time (weeks)	n	C ₂ H ₂		C ₂ H ₄	
		\bar{x}	s	\bar{x}	s
0	5	42.9	2.89	2.81	0.224
6	5	42.9	2.89	3.07	0.141
15	5	47.9	1.91	2.71	0.300

commenced between 1000 and 1100 h, and lasted 60 min. The algal communities were not submerged by lagoon waters at the times of assay, but in all cases assays were conducted within a few hours of having been submerged by sea water, and had received no more than minor wetting by rain water since the previous submergence.

An attempt was made to consider the factors known to influence the reduction of acetylene (Hardy et al., 1973), when conducting the experiments. 7 ml glass serum bottles with perforated serum caps were used for all assays, and gases were removed or introduced through a rubber seal in the cap by syringe. Cores of alga and approximately 5 mm of associated sediment were introduced into the incubation bottles; in the case of communities with Hyella balani present, a slightly greater depth of sediment was used in order to make sure that all the algal cells in a vertical column were included. The algal core was disturbed as little as possible in the transfer, in order to minimize any environmental changes. However a slight compression and subsequent spreading out of the core was inevitable, due to the shape of the serum bottle. 1 ml of water (filtered rain water or sea water) was then added, the lid closed and the bottle pushed into the sediment such that the sample received a light regime similar to that of the surrounding community. A pre-incubation period of 10 min was allowed prior to the addition of the acetylene. 1 ml of acetylene gas (East African Oxygen Ltd) was then injected through the serum liner ($p_{C_2H_2} = 0.17 \text{ atm.}$), 1 ml of the

gas phase removed to equalize the pressure, and the bottles incubated for 60 min. Eight replicates were used in the light and eight in the dark for each experiment. For dark incubations the bottles were wrapped in aluminium foil.

At the end of the experimental period, gas samples were removed with multiple-sample vacutainer needles (Becton & Dickinson Ltd), and stored in vacutainers (Becton & Dickinson, 3206U, formula 134). These were sealed in paraffin wax within two hours of receiving a gas sample. Temperature measurements were made in the sediment adjacent to the algal community, at the beginning and end of the experiment, and also in addition, serum bottles with algal cores were used as controls. Temperatures inside the bottles at the end of the assays never differed by more than 2°C from that of the surrounding sediments. Similar controls for Eh and pH (Potts & Whitton, 1976a) were also used in some experiments, with the exception that 30 ml McCartney bottles were used to enable introduction of the electrodes. The controls showed that in several experiments there were changes in pH which differed from those taking place in the surroundings. An experiment with a Rivularia community showed a sufficient rise in pH (c 1.0 pH unit), to suggest that carbon dioxide deficiency might be important at the end of the experiment in the smaller serum bottles. In contrast, samples of Scytonema showed a drop of pH even in the light. If allowance is made for changes in Eh associated with these pH changes, the controls showed that Eh underwent no such marked changes due to incubation in a confined volume.

At the end of the experiment algal cores were removed and dried carefully in the shade. These were then sealed in polythene bags (2.19) for subsequent extraction of chlorophyll a, and in the case of bacterial samples, bacteriochlorophyll a.

On return to Durham, 1 ml aliquots of the gas sample in each vacutainer (at 20°C), were analysed for acetylene and ethylene using gas chromatography. Analyses were carried out on a Varian Aerograph series 1200 gas chromatograph, fitted with a steel column (1800 mm x 3.2 mm) packed with Poropak R and maintained at 100°C. Nitrogen was used as a carrier gas, at a flow rate of 24 ml min⁻¹. The machine was calibrated using 99.8 % high purity ethylene (Air Products Ltd). The method of calibration was as follows: 1 ml of ethylene was injected into a one litre (1103.6 cc) medical flat fitted with a rubber 'Suba seal', and allowed to equilibrate at 20°C. 1 ml volumes were then removed by syringe and injected onto the column, and the magnitude of the peak produced by the ethylene (mass number 28) related to absolute concentrations of ethylene using the following relationship:

$$1 \text{ nM } C_2H_4 \text{ at } 20^\circ C \text{ occupies } \frac{293}{273} \times 22.4 \times 10^{-6} \text{ ml}$$

After the algal samples had been analysed for chlorophyll a, acetylene reduction rates were expressed as nM C₂H₄ produced $\mu\text{g chl } \underline{a}^{-1} \text{ min}^{-1}$.

2.113 Estimation of grid references and use of place names

In work areas grid references were estimated from maps and aerial photographs (Directorate Of Overseas Surveys, series 42-SY, Aldabra series), using the methods discussed by Donaldson and Whitton (1976c). All place names were those French names given by Stoddart (1971).

2.2 Physical and chemical laboratory techniques

2.21 Analysis of water samples

The methods used in the analysis of waters in situ were discussed in Section 2.14. On return to the U.K., samples were analysed for Na, K, Mg, Ca, conductivity and chloride.

Na, K, Mg, and Ca were all analysed using mass absorption spectrophotometry (Perkin Elmer model 403). Several points are worthy of discussion here. In the analysis for K, sodium chloride solution (1500 mg l^{-1}) is usually added to the sample before reading on the machine, to ensure that none of the K is in an ionized state. This was not necessary with Aldabra samples, due to the high sodium chloride concentrations in the sea water samples themselves (Table 2.11). It was thought that Ca might have precipitated onto the sides of the sample tube during storage. Several samples were tested as follows. Aristar HCl was added to the sample and the pH lowered to pH 3 (1 drop needed), Ca and Mg being read over a 24 h period. It was found that there was no change in the levels of Ca and Mg in the samples tested over a 24 h period, and all samples were therefore read assuming no precipitation of either Ca or Mg (Table 2.12). Na in the sea water caused interference when Mg was measured, therefore using a sodium chloride calibration curve, the true values were estimated.

Conductivity was measured using an electrolytic conductivity meter, model MC-1 Mark V (Electronic Switchgear, London, England).

Chloride was estimated using an argentometric technique (Strickland & Parsons, 1968 ; Standard Methods, 1966). Salinity

Table 2.11 Effects on the estimation of K in sea water by the omission of NaCl in the spectrophotometric technique (all values in mg l^{-1})

sample	Na (undiluted)	K (undiluted)	K (sample diluted and 1500 mg l^{-1} NaCl added)
1	12300	446	442
2	7170	294	290
3	6600	266	264
4	10850	433	435

Table 2.12 Changes in the levels of Mg and Ca in sea water samples by the lowering of the pH (measurements taken over 24 h, all values in mg l^{-1})

time after adding HCl	Mg	Ca
0	129	460
20 min	130	456
240 min	128	460
24 h	126	452

was calculated from standard chlorosity/salinity tables (Strickland & Parsons, 1968).

2.22 Analysis of photopigments

2.221 Extraction of chlorophyll a

A detailed discussion has been included here to explain and justify the methods adopted. A background to the problems involved in the extraction of algal pigments is given, together with methods used by certain authors, and an explanation of why certain techniques were modified.

Estimation of algal standing crop by determination of photosynthetic pigments, is a widely used method in the study of algal communities (Moss, 1967). Just as the methods used in pigment extraction have been known for some time (Smith & Benitez, 1955), so have the many problems associated with chlorophyll estimation (Strickland, 1960). The more important problems involved in the extraction and estimation of chlorophyll are outlined below.

i) Algal communities may sometimes contain chlorophyll degradation products, which in some instances can constitute a significant fraction of the total green pigmented materials present (Yeutsch & Menzel, 1963 ; Lorenzen, 1967). These breakdown products can give large errors in estimated chlorophyll a when spectrophotometry is used, as they absorb in the red part of the spectrum (Lorenzen, 1967). They may also be associated with local sediments combined with the communities.

ii) Only a certain percentage of the total pigments may

be obtained when using certain solvents. The widely used solvent acetone, is unsuitable for epilithic communities associated with sediments, and a stronger solvent such as methanol is required (Marker, 1972).

iii) Absorption coefficients are only partly known for some pigments e.g. phaeophorbide, which is a component of chlorophyll degradation products (Lorenzen, 1967). These vary from solvent to solvent (Marker, 1972), and some are only calculated for particular solvents. When small instrumental errors occur in conjunction with errors in the absorption coefficients, large inaccuracies in estimated chlorophyll a result (Marker, 1972).

iv) Light scattering and loss of definition of absorption bands, enhanced absorption values and long wavelength shift in the red band of chlorophyll a, are all errors associated with spectrophotometric light cells (Thomas & Nagaraja, 1973). These are overcome if ground-glass face cells are used.

On acidification each chlorophyll a molecule loses a magnesium atom and is converted to phaeophytin (Moss, 1967a). Lorenzen (1967) advocated this as a method of determining chlorophyll a in samples containing phaeopigments, showing that the addition of 1 N HCl brings about a change in the absorbance, which discriminates between chlorophyllous magnesium containing compounds, and those which are magnesium free. The calculation of phaeopigments assumes that all this pigment is phaeophytin, when in fact a small proportion will be other products (Patterson & Parsons, 1963). Moss (1967a) first

reported on the calculation of the chlorophyll a : phaeophytin a ratio, and then later derived simple equations to calculate the absolute concentrations of pigments (1967b). He stated that "when estimating chlorophyll a and phaeophytin a using the absorption at 665 nm, the extract may be assumed to contain only these two components". Lorenzen (1967) also based his method on the absorption at 665 nm, assuming there to be no effects due to pH, on the spectrum of phaeophytin a at 665 nm. He was justified in taking this view as Moss (1967a) had indicated very small effects attributable to pH, and Vernon (1960) had been unable to demonstrate any effect of pH using oxalic acid. Marker (1972) quotes Livingstone et al. (1953) as showing intermediate absorption spectra by varying the pH, but neglects to point out that this is within the 400 - 450 nm range, there being in fact very little change on the spectra at 665 nm. Livingstone et al. (1953) showed phaeophytin a to be stable in acid solution, forming an equilibrium with neutral forms at intermediate acidities. When Marker (1972) applied the principles of Lorenzen (1967) and Moss (1967a, 1967b) to the use of methanol as an extracting agent, he advocated neutralization of the acidified extract with magnesium carbonate to bring the solution to neutrality, and to compensate for spectral changes on acidification. Nevertheless he admitted that "the extremely poor replication, was due to precipitation of pigments upon neutralization". The use of DMA (di-methyl aniline) is also unreliable as irreversible changes occur when only slightly basic (A.F.H.

Marker, pers. comm.). There is no direct evidence of the effect of neutralization, and it is difficult to measure pH in aqueous organic solvents. It was decided to carry out a simple experiment to compare the effects of post-neutralization on absorption spectra (Table 2.13). Although several samples exhibited turbidity and precipitation effects with magnesium carbonate, in general there appeared to be little effect on the final acidified peaks by its addition. Donaldson (pers. comm.) also showed minimal effects on absorption spectra by the addition of magnesium carbonate, and he never used it in extractions of chlorophyll a from samples of terrestrial blue-green algae from Aldabra.

Methanol was used as the solvent in all extractions of pigments from Aldabra samples of blue-green algae and photosynthetic bacteria, and no extracts were post-neutralized with magnesium carbonate after extraction. The decision to use methanol as the extracting solvent, and not to use magnesium carbonate in neutralization was taken for several reasons. It had been shown by Marker (1972) that methanol was much more efficient in extracting pigments than was acetone. In several preliminary experiments using Aldabra samples of blue-green algae associated with sediments, it was near impossible to produce meaningful results when using acetone as the extracting solvent. A similar situation was found for terrestrial samples by A. Donaldson (pers. comm.). The use of magnesium carbonate in neutralization of extracts after acidification seemed open to errors (see above). Added to this was the fact that

Table 2.13 Comparison of the absorbance at 665 nm (A_{665}) of chlorophyll extracts in 95 % methanol from Scytonema sp., before and after neutralization with magnesium carbonate

extracting solvent	A_{665}	A_{665} (after acidification)	A_{665} (neutralized)
95 % methanol	0.37	0.21	0.20
	0.39	0.21	0.21
	0.39	0.25	0.26
	0.36	0.20	0.20
95 % methanol + $MgCO_3$	0.56 *	0.31	0.32
	0.53 *	0.28	0.28
	0.41 *	0.24	0.24
	0.47 *	0.25	0.24

* not to imply that increased values are due to addition of $MgCO_3$. All errors samples

neutralization was an extremely time consuming process, and it was not felt desirable to store any solutions of chlorophyll a due to the possibility of degradation. A concentrated chlorophyll a extract in 95 % methanol was stored in the dark at 5°C for three weeks and the results are shown in Table 2.14 and Fig. 2.1. These indicate that even when refrigerated in the dark, the chlorophyll a will decrease by 10 % within the first week, and phaeophytins increase.

The method used in the extraction of chlorophyll a was a modified version of that given by Hargreaves and Whitton (1976). This rapid method enabled up to 40 samples to be extracted and analysed daily. Before discussing the method it is necessary to describe several experiments carried out with dried samples, which influenced the pretreatment of samples before extraction. A. Donaldson (pers. comm.) and Myers (1974) had both shown pre-wetting to be essential if chlorophyll was to be extracted efficiently from dried Aldabra samples. Several samples were thus preincubated with distilled water, under various conditions before extracting the chlorophyll a, to estimate the optimum conditions for extraction ; the results are shown in Tables 2.15 and 2.16. These results were analysed using non-parametric statistics. For samples of Scytonema sp., there was significant increase in extracted chlorophyll a when samples were pre-wetted in distilled water as opposed to being left dry. The mean increase for three populations was 402 %, when pre-wetted for six hours. There was no significant difference in extracted chlorophyll a

Table 2.14 Storage of a concentrated chlorophyll extract (in 95 % methanol), for three weeks in the dark, at 5°C (all values in mg l⁻¹)

time (days)	chl a	% decrease chl a	phaeophytin a	% phaeophytin of total pigments (phaeo a + chl a)
0	10.0	-	-	0
1	9.76	2.79	-	0
7	9.12	9.16	0.240	2.61
21	7.76	22.7	0.770	9.01

Figure 2.1 Changes in the concentrations of chlorophyll a and phaeophytin a, in a concentrated pigment extract stored in the dark, at 5°C for three weeks

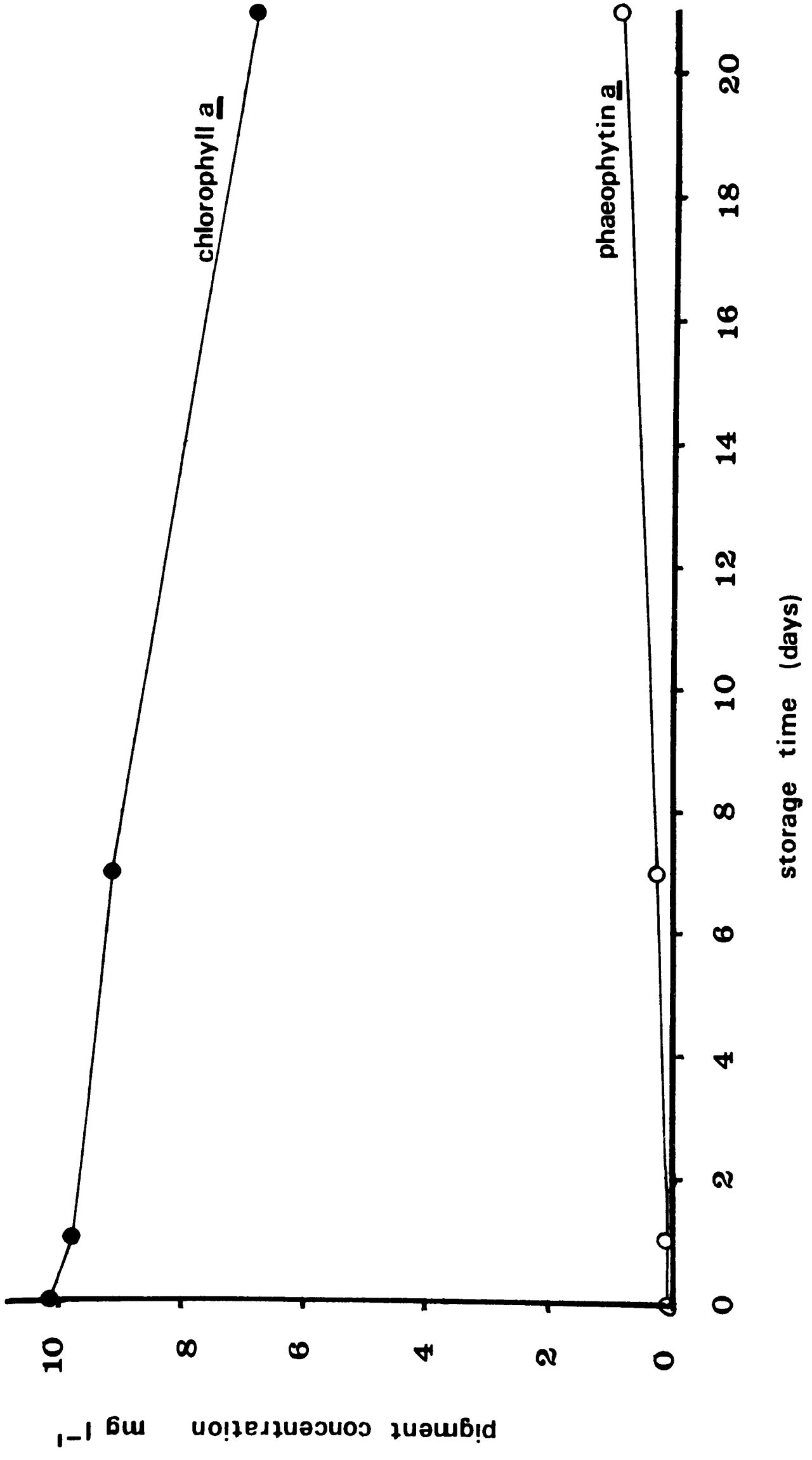


Table 2.15 Pretreatment of samples before chlorophyll extraction (weights of 1 cm² samples are given in g cm⁻² and concentrations of chlorophyll in $\mu\text{g cm}^{-2}$ in $\mu\text{g chl a cm}^{-2}$)

community	n	light intensity (lx)	°C	pre-wetting (h)	\bar{x}	s	\bar{x}	s
					g cm ⁻²		$\mu\text{g chl a cm}^{-2}$	
<u>Scytonema</u> C3	6	650	32	dry	0.070	0.0033	41.9	8.97
	6	650	32	1	0.072	0.023	123	27.2
	6	650	32	6	0.055	0.0062	130	11.6
	6	650	32	24	0.056	0.0030	99.7	20.0
	6	10000	32	6	0.063	0.0074	137	8.83
<u>Hvella</u> C5	6	650	32	dry	1.30	0.0544	12.8	2.66
	6	650	32	1	1.28	0.0246	15.5	1.59
	6	650	32	6	1.23	0.0247	15.5	2.24
	6	650	32	24	1.29	0.0600	13.4	2.25
	6	10000	32	6	1.24	0.0525	17.4	1.98

Table 2.16 Pretreatment of samples before chlorophyll extraction

community	n	light intensity (lx)	°C	pre-wetting (h)	\bar{x}	s	\bar{x}	s
					g cm ⁻²		µg chl a cm ⁻²	
<u>Hyella</u> C1	4	650	32	dry	0.45	0.022	53.9	2.98
	4	650	32	6	0.46	0.033	56.4	4.91
	4	10000	32	6	0.42	0.011	52.6	1.33
<u>Scytonema</u> C2	4	650	32	dry	0.37	0.031	36.4	12.2
	4	650	32	6	0.43	0.043	265	21.5
	4	10000	32	6	0.38	0.027	254	21.6
<u>Scytonema</u> C3	4	650	32	dry	0.07	0.002	83.8	8.18
	4	650	32	6	0.08	0.002	141	5.52
	4	10000	32	6	0.08	0.003	119	10.5
<u>Hyella</u>	4	650	32	dry	1.2	0.023	21.1	1.67
	4	650	32	6	1.3	0.0097	27.0	1.95
	4	10000	32	6	1.3	0.013	29.1	1.67
<u>Hyella</u> C6	4	650	32	dry	1.4	0.046	9.53	3.00
	4	650	32	6	1.5	0.027	11.0	1.69
	4	10000	32	6	1.5	0.035	10.8	1.98
<u>Phormidium</u>	4	650	32	dry	1.3	0.035	11.6	0.973
C8	4	650	32	6	1.3	0.0080	12.9	1.58
	4	10000	32	6	1.3	0.016	10.8	0.455

when pre-wetted at 650 lx for one, six or 24 hours. For one population there was a significant increase when pre-wetted for 6 hours at 10000 lx rather than at 650 lx. The other Scytonema populations showed no such increase. All the Scytonema samples after 24 hours wetting at 650 lx and 1000 lx, had a pronounced 'putrid' smell, and the water was coloured blue due to the release of extracellular phycocyanin.

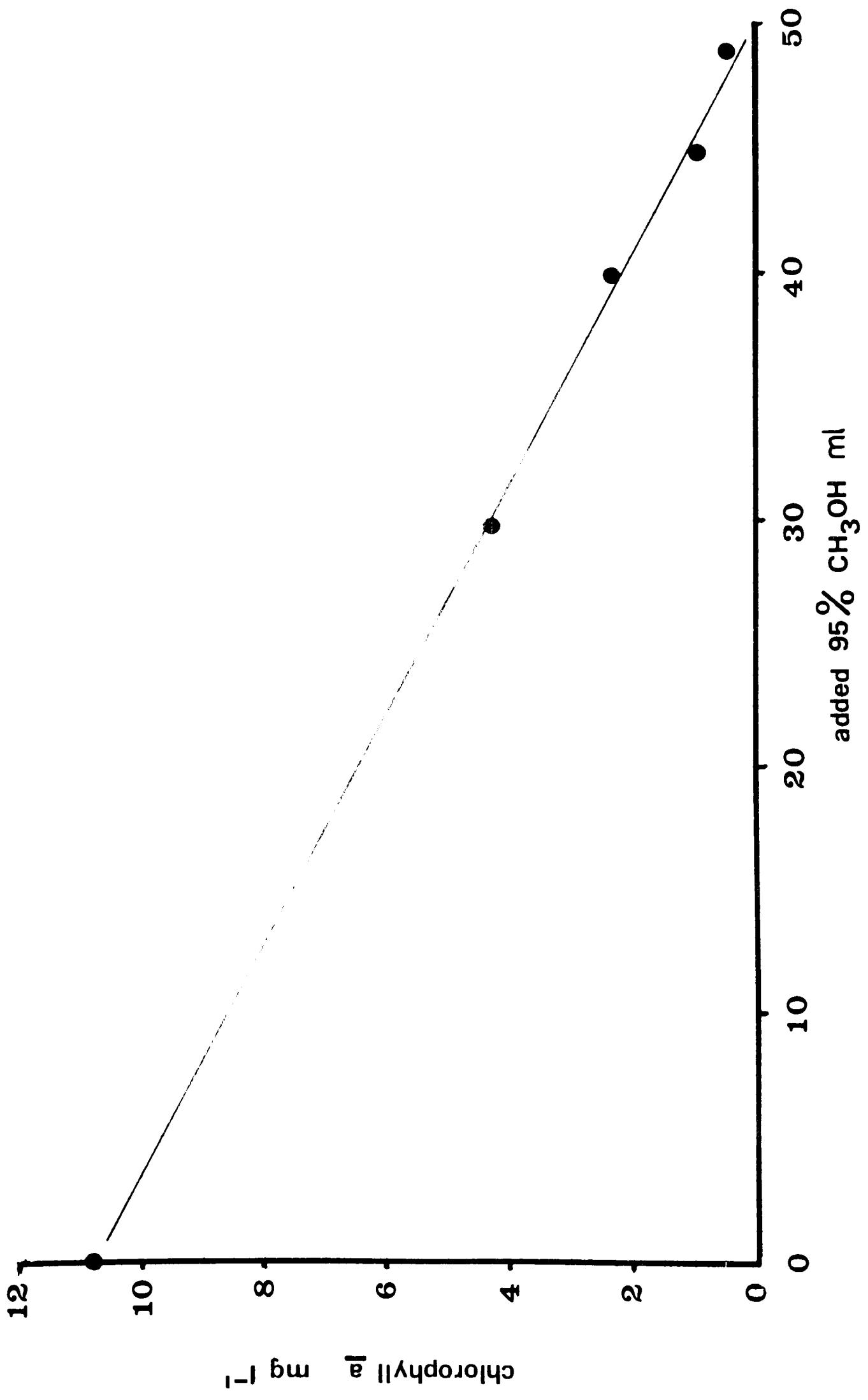
In contrast none of the four Hyella balani populations showed significant differences in extracted chlorophyll a when the samples were pre-wetted. There was no significant difference between the chlorophyll a extracted when dry, wet one hour, six or 24 hours at either 650 or 10000 lx. The same was true for the Phormidium molle community. In subsequent extractions all samples were soaked in distilled water at 650 lx and 32°C for two hours, prior to extraction of chlorophyll a.

In initial trial extractions, it became obvious that several samples e.g. Calothrix mats, would require a number of extractions to remove all the chlorophyll, whereas the predominantly sediment samples such as Hyella balani required only one extraction. There was therefore variability in the exact volume of solvent used to completely extract the pigments, and it was decided to investigate if the values of chlorophyll a were proportional to the added solvent when making up to a known volume. The results are shown in Table 2.17 and Fig. 2.2. When a concentrated chlorophyll solution was diluted with varying amounts of solvent and made up to a standard volume, the estimated chlorophyll a was proportional to the dilution.

Table 2.17 Estimated chlorophyll a from dilutions of a concentrated chlorophyll extract (in 95 % methanol) obtained from Scytonema samples

volume of extract (ml)	added CH ₃ OH (ml)	chl <u>a</u> (mg l ⁻¹)	% decrease in CH ₃ OH conc.	% decrease in chl <u>a</u> conc.
50	0	10.8	-	-
20	30	4.26	60.0	60.6
10	40	2.28	80.0	78.9
5	45	0.862	90.0	92.0
1	49	0.484	98.0	95.6

Figure 2.2 Changes in the concentration of chlorophyll a when a concentrated extract is diluted with 95% methanol



The findings of the previous experiments were used in the following method for the extraction of chlorophyll a with 95 % methanol.

Samples which had been pre-weighed and then wetted in distilled water for two hours at 650 lx and 32°C, were introduced into 30 ml McCartney bottles, containing 10 ml of 95 % methanol. The caps (with rubber liners) were screwed down tightly, and the bottles stood in a water bath maintained at 70°C. A cover-hood ensured that extraction was completed in the dark. Extraction was complete within five to ten minutes, however up to four extractions were required for certain of the mat samples. Extracts were then filtered immediately through 24 mm G/FC filter discs (Whatman), under reduced pressure, made up to a known volume with 95 % methanol (usually 50 ml) and aliquots transferred to ground-glass sided, high precision 1 cm optical cells (Thermal Syndicate Ltd). Absorption spectra were read at 665 nm using a Perkin Elmer model 402 Ultraviolet spectrophotometer ; for analysis of very dilute solutions a Pye Unicam SP 1800 Ultraviolet spectrophotometer was used. Extracts were then acidified by adding one drop of 1 N Analar HCl (B.D.H. Ltd), and the absorbance at 665 nm read one minute later.

2.222 Estimation of chlorophyll a and phaeophytin a

Chlorophyll a and phaeophytin a were calculated from the following formulae, these are essentially those given by Marker (1972) except that a different 'acid factor'-derived constant has been used.

$$\text{chl } \underline{a} = 2.17(A_b - A_a) \times (v/l) \times 13.1$$

$$\text{phaeo } \underline{a} = (A_b - 2.17(A_b - A_a)) \times (v/l) \times 13.1 \times 0.973 \times 1.85$$

A_b = absorbance at 665 nm

A_a = absorbance at 665 nm after acidification

v = volume of solvent used in making up extract

l = light path of optical cell (1 cm)

0.973 = correction factor to compensate for loss of Mg on acidification

13.1 = constant, assuming a specific absorption coefficient of chl \underline{a} in 95 % methanol of $76.07 \text{ l g}^{-1} \text{ cm}^{-1}$

2.17 = constant, derived from an 'acid factor' of 1.85

An explanation of why a different 'acid factor' was employed is given here. The 'acid factor' usually quoted in the literature denotes the ratio of the absorbance before acidification, to that after acidification. Lorenzen (1967) gave an average 'acid factor' of 1.7 in 80 - 90 % acetone, whereas Marker (1972) derived a factor of 1.5 for 95 % methanol.

$$\text{acid factor} = \frac{A_{665} \text{ (before acidification)}}{A_{665} \text{ (after acidification)}}$$

Marker (1972) calculated his 'acid factor' of 1.5 from chlorophyll \underline{a} extracts of four eukaryotic algae, all of which contained accessory pigments (chlorophyll \underline{a} and chlorophylls \underline{b} and \underline{c}). He studied no extracts from blue-green algae. The factor of 1.5 was also estimated from field growing populations and breakdown products were assumed to be absent. When Marker's 'acid factor' was used in calculations of Aldabra extracts, negative results were obtained for phaeophytin \underline{a}

concentrations. The acid factor calculated from 300 samples of Aldabra blue-green algae was $\bar{x} = 1.85$ ($s = 0.087$), although a certain degree of variation was noticed from species to species e.g for Calothrix crustacea $\bar{x} = 1.87$ ($n = 20$, $s = 0.042$), for Hyella balani $\bar{x} = 1.86$ ($n = 23$, $s = 0.063$) and for Scytonema sp. $\bar{x} = 1.9$ ($n = 20$, $s = 0.074$). When calculating the 'acid factor' from Aldabra terrestrial communities e.g. Nostoc commune $\bar{x} = 1.86$ ($n = 200$, $s = 0.054$). Sinclair (pers. comm.) found a similar 'acid factor' for laboratory grown cultures of Calothrix spp. ($\bar{x} = 1.9$). It was assumed in the calculation of an 'acid factor' for marine blue-green algal samples from Aldabra, that blue-green algae possess only one chlorophyll a (Myers & Kratz, 1955). As accessory chlorophylls were absent in the samples, and Marker's factor had been shown to give anomalous results, it seemed much more desirable to use the acid factor calculated from Aldabra samples i.e. 1.85. Using this factor of 1.85 a constant of 2.17 was derived for use in the equations for chlorophyll a and phaeophytin a estimation. 2.17 is the calculated ratio of the absorbance of the chlorophyll a solution before acidification, to the reduction in the absorbance due to the formation of phaeophytin a on acidification.

$$\frac{A_b}{A_a} = 1.86 \quad \text{let } A_b = 1.0, \quad \text{thus } \frac{1}{1.86} = 0.54 = A_a$$

$$\text{reduction in absorbance} = 1.0 - 0.54 = 0.46$$

$$\text{constant} = \frac{1}{0.46} = 2.17$$

Chlorophyll a and phaeophytin a were thus calculated using the equations given earlier.

2.223 Extraction and estimation of bacteriochlorophyll a

It was necessary to quantify the acetylene reduction rates with pigment content in samples of purple photosynthetic bacteria, as was done for blue-green algae. The structure and properties of bacteriochlorophylls have been summarised by Smith and Benitez (1955), and their occurrence in the various groups of photosynthetic bacteria, together with their nomenclature, discussed by Pfennig and Trüper (1974). There is few data available relating to the extraction of bacteriochlorophyll a from marine species of photosynthetic bacteria. A short review of some work is given here, to explain the methods used for the extraction and estimation of bacteriochlorophyll a.

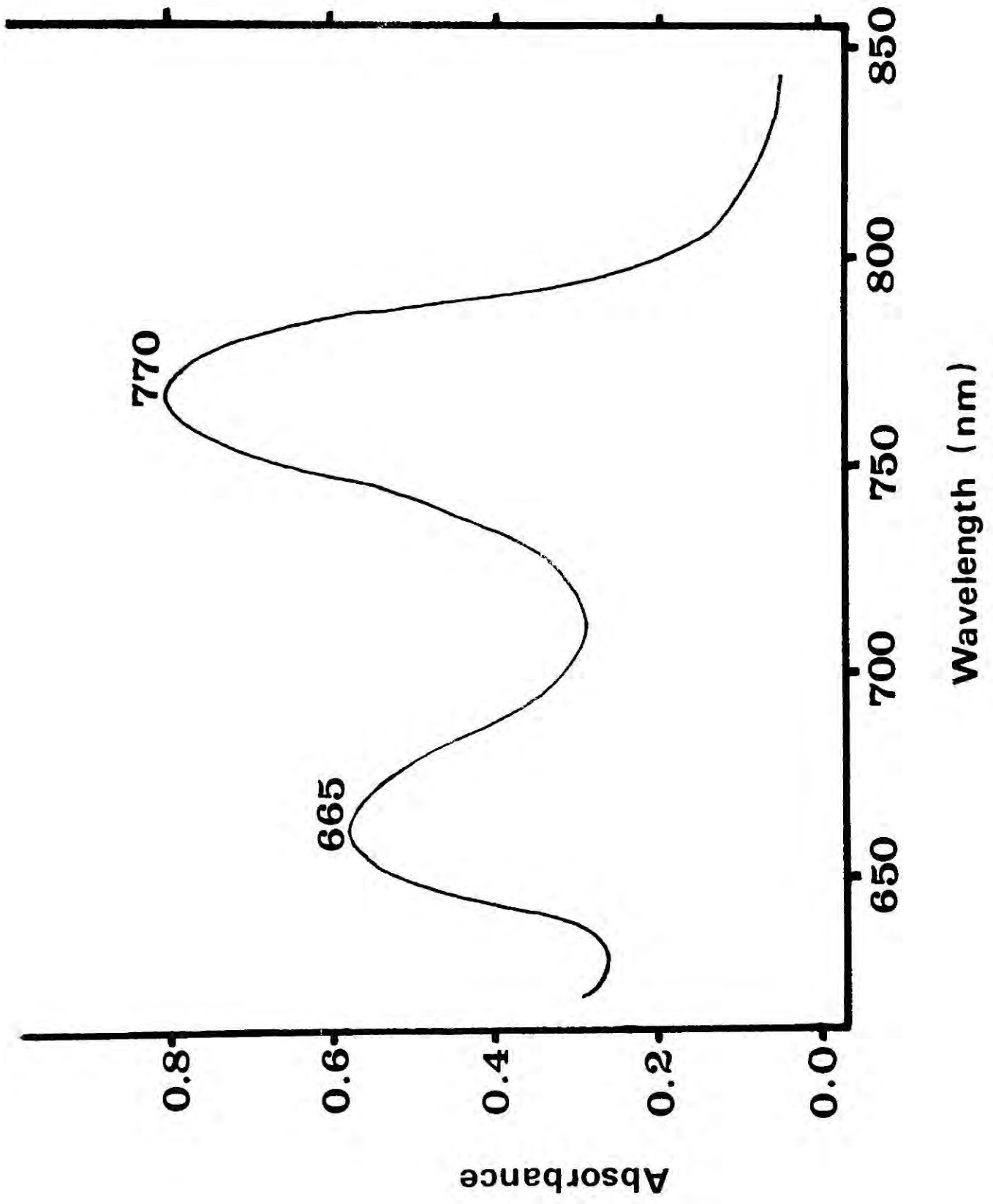
Members of the purple sulphur bacteria (Chromatiaceae) and purple bacteria (Rhodospirillaceae), contain bacteriochlorophylls a or b and various carotenoids. Jensen et al. (1964) characterized the bacteriochlorophylls and bacteriopheophytins from 18 species of phototrophic bacteria, using paper chromatography and absorption spectra ; they gave 770 nm as the A_{\max} for bacteriochlorophyll a. Recently Pierson and Castenholz (1974) isolated Bchl a from Chloroflexus aurantiacus, a thermophilic photosynthetic bacterium, giving 771 nm as the A_{\max} . Madigan and Brock (1976) have indicated that it is possible to estimate chl a and Bchl a from spectra in methanol, when both occur in mixed populations of photosynthetic bacteria and blue-green algae.

Essentially the same method of extraction for chlorophyll a

was used. Samples returned from Aldabra were in a dried out condition, the bacteria being associated with medium coarse sand from the area of La Gigi in which they were collected. After weighing, the samples were wetted with distilled water for two hours and introduced into 30 ml McCartney bottles, and 5 ml of absolute methanol added. The bottle caps were screwed down tightly, and each bottle incubated at 70°C in the dark for 15 minutes. Extracts were cleared by pressure filtration through 24 mm G/FC filters. Absorbances were read at 770 nm and 665 nm, using a Pye Unicam SP 1800 Ultra-violet Spectrophotometer.

Peaks were noted at 770 nm and 665 nm (Fig. 2.3), and the latter peak was assumed to be due to chlorophyll a, derived from Hyella balani endolithic in the sand grains. The absorbance of chlorophyll a at 770 nm was assumed to be negligible (non-specific background), but comparison of the spectra with those obtained by Pierson and Castenholz (1974), showed that Bchl a was absorbing significantly at 665 nm. A correction was thus applied to all peaks at 665 nm, so that the true absorbance = absorbance₆₆₅ - background absorbance₆₆₅ due to Bchl a. This was calculated from the spectra of pure Bchl a given by Pierson and Castenholz (1974), where the absorbance at 665 nm due to Bchl a was one fifth that of the absorbance at 770 nm. Absolute concentrations of Bchl a were calculated using the absorbance at 770 nm (corrected), and the extinction coefficient of 60 mM⁻¹ cm⁻¹ (Cohen-Bazire & Sistrom, 1966).

Figure 2.3 Absorption spectra of a mixed
chlorophyll a, bacteriochlorophyll a
extract in absolute methanol



2.23 Laboratory studies of nitrogen fixation

The method used in laboratory acetylene reduction assays was essentially the same as that used in situ, with several modifications.

As the algal material was in a dried condition, pre-incubation was varied from one minute to 24 hours, similar to that done in chlorophyll extractions (2.221). Pre-incubation was carried out using large samples e.g. large sections of mat, in pneumatic troughs at either 2000 or 10000 lx using warm white fluorescent strip lights (Thorn Electrical Ltd), at 32°C. Three media were used ; distilled water, ASP-2 (Provasoli et al., 1958) and natural filtered sea water collected from the Northumberland coast. For several experiments an attempt was made to produce a crude 'tidal cycle', by removing media after six hours, drying the sample over six hours, and then introducing fresh media into the culture vessel. A light cycle of 12 hours light, 12 hours dark was used in conjunction with the re-wetting. This was carried out over a period of four days.

For the acetylene reduction assays, the same method was used as given in 2.112. Assays were carried out as in situ, using two light regimes (2000 and 10000 lx) and a number of different gas phases. In addition to normal air mixtures, experiments were carried out with :

i) 78.08 % Ar / 0.02 % CO₂ / 20.0 % O₂

ii) 98.08 % Ar / 0.02 % CO₂ / 1.0 % O₂

A number of experiments were carried out using media supplemented with 4 mM Na₂S-S²⁻.

2.24 Statistical analysis

2.241 Parametric tests

The mean (\bar{x}) and standard deviation (s), were calculated for comparisons between samples where n was equal to or greater than four (Elliot, 1971).

2.242 Non parametric tests

The Mann-Whitney U-test (Siegel, 1956) was used in the treatment of the acetylene reduction data and chlorophyll a data. The Kruskal-Wallis test (Siegel, 1956) was used for the comparison of nitrogen fixation rates, in different populations of Scytonema sp.

3 TAXONOMY

3.1 Blue-green algae

3.11 Allocation of binomials

As mentioned in Section 2.110, binomials were allocated after study of specimens by light microscope and consultation of taxonomic literature. In certain cases it was often difficult or impossible to allocate a suitable binomial, and therefore a system of classification as devised in Durham (Whitton et al., 1976) was used. This system may be briefly discussed here.

The basic unit of information in the system is a six digit number, the 'species' number. As far as possible this number corresponds exactly to a strict binomial. It may also correspond to a size range with or without additional descriptive criteria (e.g. data on sheath). It is therefore possible that a number may correspond to several binomials which fall within the limits of the size category. This is true for genera within the order Chroococcales; in this case the most suitable name is given with the size range. The name is the oldest and first recorded binomial, whether or not this is a freshwater or marine species. For example, two species of Xenococcus may be applied to the size range Xenococcus $>4 \leq 6 \mu\text{m}$; X. acervatus described as a marine form, and X. keneri described as a freshwater form. However as X. keneri was the earliest described species, this is the name allocated to the 'species' number 018033 $>4 \leq 6 \mu\text{m}$, eventhough the material for which it has been allocated was recorded solely

from marine habitats.

3.12 Species list

Table 3.1 gives an alphabetical list of species recorded from marine and brackish habitats on Aldabra Atoll.

Information on each species was given in the following order : binomial; authority; size category. An asterisk was used to indicate species previously recorded by Donaldson and Whitton (1976b) from freshwater and terrestrial habitats on Aldabra. If the species was recorded exclusively from within the lagoon this is indicated by (L); from the seaward coasts by (O) ; from both inside the lagoon and the seaward coasts by (L and O).

3.13 Description of species

A standard scheme was followed in the presentation of data for each species. The scheme resembles that used by A. Donaldson in his parallel studies of the terrestrial and freshwater algae of Aldabra. The basic format is outlined in Table 3.2, followed by a detailed description of each section.

Table 3.2 Presentation of data for species

computer 'species' no. binomial authority date size range

- A) Description of Aldabra population; details of cell; colony etc.

Any problems associated with the applicability and allocation of a binomial

- B) Description of the 'type' species by the author, with taxonomic status

- C) Geographical locations on the atoll from which the species was recorded; grid references and number of

populations studied in making the description

- D) Specific biological and ecological data; comments on abundance and distribution
- E) If recorded from terrestrial and freshwater habitats; any comments made by Donaldson and Whitton (1976b)
- F) Review of relevant literature, giving distribution and ecological data

A) Information has been presented in a standard order throughout: average cell size or cell size range, length, shape, colour; size of specialised cells (nannocytes, exospores, endospores, akinetes, heterocysts, end cells), shape, colour, position in relation to other cells; arrangement of trichomes, shape, colour; width of filaments, shape; width of sheath, colour, if lamellate (or in the case of unicells, striate).

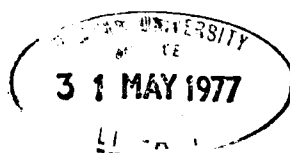
Description of colony.

Where a large number of populations have been studied, the cell size range, from the smallest to the largest recorded cell, is included. Where only a single or few populations have been studied, only the average cell size is given. In describing the genera Calothrix and Rivularia, the recording system of Kirkby (1975) was followed.

B) Relevant information of the 'type' species is given here.

The first locality from which it was described is included as a separate paragraph.

C) The geographical locations from which the species was



recorded. In most cases this is the island closest to the area of the intertidal zone studied. On no account does this imply the distribution to be restricted to only this area. The grid references indicate the general area in which populations of the species may be found. The total number of populations studied in giving the species description is included in brackets.

D) Abundance was indicated as either absent, present, occasional, frequent, abundant or very abundant. In those communities where a mat, crust or film was formed, the dominant species was included with the description of the colony form. Thus a community forming a crust over the surface of sediment, in which Calothrix crustacea was the dominant species, was described as a Calothrix crust. Similarly, Scytonema mats and Microcoleus films have been used to describe communities forming mats in which Scytonema sp. was dominant, or films in which Microcoleus chthonoplastes was dominant.

E) 'Yes' versus 'No' indicates if the species has been previously recorded by Donaldson and Whitton (1976), with the notes on distribution and abundance given by these authors.

F) The literature is not comprehensive, but is given where it was thought it had particular relevance to tropical marine blue-green algae.

Taxonomic texts and other literature referred to in giving 'type' descriptions, records by other authors, and ecological notes are all included in the reference list at the end of the thesis.

Table 3.1 Species list of blue-green algae recorded from brackish and marine intertidal habitats at Aldabra Atoll

* 010531	<u>Aphanocapsa concharum</u> Hansgirg	>1 ≤ 2 μm	L
* 010532	<u>A. montana</u> Cramer	>2 ≤ 4 μm	L
* 010533	<u>A. grevillei</u> (Hass.) Rabenhorst	>4 ≤ 6 μm	L
* 010534	<u>A. roeseana</u> de Bary	>6 ≤ 8 μm	L
* 010631	<u>Aphanothece saxicola</u> Nägeli	≤ 2 μm	L
* 010632	<u>A. microspora</u> (Menegh.) Rabenhorst	>2 ≤ 4 μm	L
* 010633	<u>A. microscopica</u> Nägeli	>4 ≤ 6 μm	L
010801	<u>Brachytrichia dalmatica</u> (Ercegović) Frémy <u>nov. comb.</u>		L+0
010916	<u>Calothrix aeruginea</u> (Kützing) Thuret		L
010917	<u>C. confervicola</u> (Roth.) Agardh		L
010918	<u>C. contarenii</u> (Zanard.) Bornet <u>et</u> Flahault		L+0
010919	<u>C. crustacea</u> Thuret		L+0
010922	<u>C. pulvinata</u> Agardh		L
010923	<u>C. scopulorum</u> (Weber <u>et</u> Mohr.) Agardh <u>ex</u> Bornet <u>et</u> Flahault		L
011301	<u>Chlorogloea conferta</u> (Kützing) Setchell <u>et</u> Gardner		L
011533	<u>Chroococcus schizodermaticus</u> West	>6 ≤ 8 μm	L
* 011534	<u>C. turgidus</u> (Kützing) Nägeli	>8 ≤ 16 μm	L
011535	<u>C. westii</u> (W. West) Boye-Peterson	>16 ≤ 32 μm	L
011536	<u>C. macrococcus</u> (Kützing) Rabenhorst	>32 μm	L
011537	<u>C. minimus</u> (Keissl.) Lemmermann	≤ 4 μm	L
* 011538	<u>C. minutus</u> (Kützing) Nägeli	>4 ≤ 6 μm	L
* 011539	<u>C. membraninus</u> (Menegh.) Nägeli	>6 ≤ 8 μm	L
* 011540	<u>C. turicensis</u> (Nägeli) Hansgirg	>8 ≤ 16 μm	L+0

Table 3.1 con.

- * 011541 C. spelaeus Ercegović >16 ≤ 32 μm L
- 011542 Chroococcus sp. >32 μm L
- * 018101 Chroococcopsis gigantea Geitler L
- 018201 Dalmatella buaensis Ercegović L
- 012004 Dermocarpa hemisphaerica Setchell et Gardner L
- 012005 D. leibleiniae (Reinsch) Bornet et Thuret L+O
- 012006 D. olivacea (Reinsch) Tilden L+O
- 012008 D. sphaerica Setchell et Gardner L
- 012009 D. minima Geitler O
- 012050 Dermocarpa sp. L+O
- 012113 Dichothrix rupicola Collins L
- * 012201 Entophysalis granulosa Kützing L+O
- 012637 Gloeocapsa atrata (Turp.) Kützing >4 ≤ 6 μm L
- 012638 G. crepidinum Thuret >6 μm L
- * 012640 G. dermochroa Nägeli >2 ≤ 4 μm L
- 012646 G. alpina (Nägeli) emend. Brand >4 ≤ 6 μm L
- * 012647 G. sanguinea (Agardh) Kützing >6 ≤ 8 μm L
- * 012732 Gloeothece palea (Kützing) Rabenhorst >2 ≤ 4 μm L
- * 012733 G. rupestris (Lyng.) Bornet >4 μm L
- 013402 Hormathonema epilithicum Ercegović L
- 013403 H. violaceo-nigrum Ercegović L+O
- 013533 Hydrocoleus sp. >6 ≤ 8 μm L
- 013604 Hyella balani Lehmann L+O
- 013605 H. tenuior Ercegović
- * 013801 Johannesbaptistia pellucida (Dickie) Taylor et Drouet L
- * 014201 Lyngbya aestuarii Liebm. ex Gomont L

Table 3.1 con.

- * 014202 L. allorgei Frémy L
- * 014204 L. confervoides C. Agardh ex Gomont L
- * 014205 L. digueti Gomont L
- * 014206 L. epiphytica Hieron. L
- * 014208 L. kutzingii Schmidle L
- * 014209 L. limnetica Lemmermann L
- * 014210 L. majuscula Harvey ex Gomont >16 ≤ 32 μm L
- * 014211 L. martensiana Menegh. ex Gomont L
- 014212 L. nordgardii Wille L
- * 014214 L. pusilla (Rabenhorst) Hansgirg ≤ 1 μm L
- 014219 L. majuscula Harvey ex Gomont >32 μm L
- * 014232 Lyngbya sp. >1 ≤ 2 μm L
- 014501 Mastigocoleus testarum Lagerheim L+O
- * 014631 Merismopedia minima G. Beck. ≤ 1 μm L
- * 014632 M. tenuissima Lemmermann >1 ≤ 2 μm L
- * 014633 M. punctata Meyen. >2 ≤ 4 μm L
- * 014634 M. glauca (Ehrenb.) Nageli >4 ≤ 6 μm L
- 014635 M. littoralis (Oersted) Rabenhorst >6 ≤ 8 μm L
- * 014801 Microcoleus chthonoplastes Thuret ex Gomont L+O
- 014831 M. tenerrimus Gomont L
- 014851 Microcoleus sp. ≤ 2 μm L
- 014852 Microcoleus sp. >2 ≤ 4 μm L
- 014854 Microcoleus sp. >6 ≤ 8 μm L
- 014855 Microcoleus sp. >8 μm L
- 014903 Microcystis reinboldii (Richter) Forti L+O
- 015101 Nodularia harveyana Thuret L

Table 3.1 con.

015102	<u>Nodularia spumigena</u> Mertens <u>ex</u> Bornet <u>et</u> Flahault	L
015402	<u>Oncobyrsa rivularis</u> (Kützing) Menegh.	L
015519	<u>Oscillatoria nigro-viridis</u> Thwaites <u>ex</u> Gomont	L
* 015532	<u>Oscillatoria</u> sp. >2 ≤4 μm	L
* 015732	<u>Phormidium molle</u> (Kützing) Gomont >2 ≤4 μm	L
015733	<u>P. submembranaceum</u> (Ard. <u>et</u> Straff) Gomont >4 ≤6 μm	L
015734	<u>Phormidium</u> sp. >6 ≤8 μm	L
018301	<u>Placoma vesiculosa</u> Schousb.	L
015801	<u>Plectonema battersii</u> Gomont	L
015810	<u>P. nostocorum</u> Bornet <u>ex</u> Gomont	
* 015811	<u>P. notatum</u> Schmidle	L
015814	<u>P. terebrans</u> Bornet <u>et</u> Flahault	
015850	<u>Plectonema</u> sp.	L
015932	<u>Pleurocapsa fuliginosa</u> Hauck >4 ≤8 μm	L+O
015933	<u>P. crepidinum</u> Collins >8 ≤16 μm	L+O
015934	<u>Pleurocapsa</u> sp. >16 μm	
016303	<u>Radaisia epiphytica</u> Setchell <u>et</u> Gardner	L
0165 69	<u>Rivularia</u> sp. A	L
0165 70	<u>Rivularia</u> sp. B	L
0165 71	<u>Rivularia</u> sp. C	O
0165 72	<u>Rivularia</u> sp. D	O
* 016602	<u>Schizothrix arenaria</u> (Berk.) Gomont	L
* 016604	<u>S. calcicola</u> (Agardh) Gomont	L+O
016626	<u>S. minuta</u> (Hansgirg) Forti	L
016628	<u>S. gracilis</u> Golubić	L
016732	<u>Scytonema endolithicum</u> Ercegović >8 ≤12 μm	O

Table 3.1 con.

016750	<u>Scytonema</u> sp.	L+0	
* 016901	<u>Spirulina subsalsa</u>	Oersted <u>ex</u> Gomont	L
016932	<u>S. labyrinthiformis</u>	(Menegh.) Gomont	>1 ≤2 μm L
016933	<u>Spirulina</u> sp.	>2 ≤4 μm	L
018201	<u>Solentia intricata</u>	Ercegović	L
018202	<u>Solentia stratosa</u>	Ercegović	L+0
017434	<u>Synechococcus brunneolus</u>	Rabenhorst	>6 ≤8 μm L
* 017602	<u>Tolypothrix byssoidea</u>	(Berk.) Kirchner	L
018401	<u>Trichodesmium erythraeum</u>	Ehrenberg <u>ex</u> Gomont	L
018402	<u>T. thiebautii</u>	Gomont	0
018032	<u>Xenococcus laysanensis</u>	Lemmermann	>2 ≤4 μm L+0
* 018033	<u>X. keneri</u>	Hansgirg	>4 ≤6 μm L
018034	<u>X. schousboei</u>	Thuret	>6 ≤8 μm L+0
018035	<u>X. cladophorae</u>	(Tilden) Setchell <u>et</u> Gardner	>8 ≤16 μm L+0
018036	<u>X. chaetomorphae</u>	Setchell <u>et</u> Gardner	>16 μm L

010531 Aphanocapsa concharum Hansgirg >1 ≤ 2 μm

- A) Cells of average diameter 1.5 μm, light blue-green; distributed in irregular mucilage.
- B) Largest cell size given 1.5 μm, up to twice longer than broad, spherical or elliptical.

Described from shells and marine algae (Peyssonelia) in the Adriatic. Considered by Frémy (1933) as possibly a species of Aphanothece.

- C) Île Picard (0610 +0895; 0650 +0937), Grande Terre (3380 +0673), Îles Moustique (9005 +5250); L ; 9.
- D) Occasional among Scytonema mats.
- E) Yes; six freshwater pools, Île Picard; CC 9 (Bassin Flamant), Grande Terre.

010532 Aphanocapsa montana Cramer >2 ≤ 4 μm

- A) Cells of average diameter 2.5 μm, blue-green to pale green.
- B) Cell size range 2.5 to 4.0 μm, spherical, light blue-green or yellow.

Described from soil, rock and moss in a greenhouse.

- C) Île Picard (0650 +0937; 066 +101), Île Malabar (2705 +1099; 3138 +1187), Grande Terre (3770 +0620); L; 8.
- D) Occasional among other algal communities; recorded as very abundant on one occasion, over the surface of silt at the inland tidal pool, Bassin Lebine, Île Picard.
- E) Yes; seven freshwater pools, Île Picard; T 2 (Bassin Takamaka), CC 10, Grande Terre.

010533 Aphanocapsa grevillei (Hass.) Rabenhorst >4 <6 μm

A) Cell size range 4.3 to 5.6 μm , spherical, light blue-green; distributed in irregular mucilage.

As the lower size range for this species is given as 3.2 μm , this 'species' number and size range exclude that part of the cell range 3.2 to 4.0 μm . Cells in this range would thus be coded under the previous number (010532).

B) Cell size range 3.2 to 5.6 μm , spherical or hemispherical; closely arranged in homogenous mucilage.

Planktonic in rivers and lakes, also found on soil and rock.

C) Île Picard (0610 +0895, 0625 +0907, 066 +101, 061 +098),
Île Malabar (3138 +1187), Grande Terre (3770 +0620); L; 17.

D) Frequent among other algal communities; recorded as very abundant at Cinq Cases, Grande Terre, where it formed bright green films over the surface of sediment.

E) Yes; six freshwater pools, Île Picard; T 2 (Bassin Takamaka), six freshwater pools, Cinq Cases, Grande Terre.

F) Lagoon shores, Curaçao (van den Hoek et al., 1971).

010534 Aphanocapsa roeseana de Bary $>6 \leq 8 \mu\text{m}$

A) Cells of average diameter $6.3 \mu\text{m}$, pale green; densely packed in mucilage.

As the lower cell size for this species is given as $5.0 \mu\text{m}$, the 'species' number excludes cells in the range 5.0 to $6.0 \mu\text{m}$; these would be recorded under 010533.

B) Cell size range 5.0 to $8.0 \mu\text{m}$, nearly oval, pale blue-green; homogenous mucilage.

Planktonic in ponds; on embankments.

C) Île Picard (0610 +0895, 066 +101); L; 3.

D) Present among other algal communities; recorded from only two localities, La Gigi and the inland tidal pool, Bassin Lebine.

E) Yes; five freshwater pools, Île Picard; T 2, three freshwater pools, Cinq Cases, Grande Terre.

010631 Aphanothece saxicola Nägeli $\leq 2 \mu\text{m}$

- A) Cell size range 1.3 to 1.8 μm , often slightly curved; dispersed in slimy mucilage.
- B) Cell size range 1.0 to 2.0 μm , two to three times longer than broad, cylindrical, pale blue-green, seldom many together. Described from moist rock and planktonic in ponds.
- C) Île Picard (0610 +0895, 0625 +0907), Îles Moustique (9005 +5250); L; 7.
- D) Present among other algal communities.
- E) Yes; one freshwater pool, Île Picard; two freshwater pools, Cinq Cases, Grande Terre.

010632 Aphanothece microspora (Menegh.) Rabenhorst $>2 \leq 4 \mu\text{m}$

- A) Cells of average size 2.5 x 3.8 μm .
- B) Cells 2.0 to 3.0 μm broad, two to three times longer than broad, cylindrical, slightly bent, bright blue-green; often with drawn out sheath. Originally described from rocks, banks of streams, and a greenhouse.
- C) Île Picard (0610 +0895), Île Malabar (1448 +1182, 2705 +1099, 3138 +1187), Grande Terre (3380 +0673), Îles Moustique (9005 +5250); L; 8.
- D) Frequent among other algal communities, widespread.
- E) Yes; two freshwater pools, Île Picard; T 2, two freshwater pools, Cinq Cases, Grande Terre; recorded as being endolithic.

010633 Aphanothece microscopica Nägeli $>4 \leq 6 \mu\text{m}$

A) Cell size range 5.0 to 6.0 μm .

B) Cells 4.5 μm broad, one and a half to twice long as broad, oblong and cylindrical; prominent sheath.

Described from standing water as planktonic, Baltic Sea.

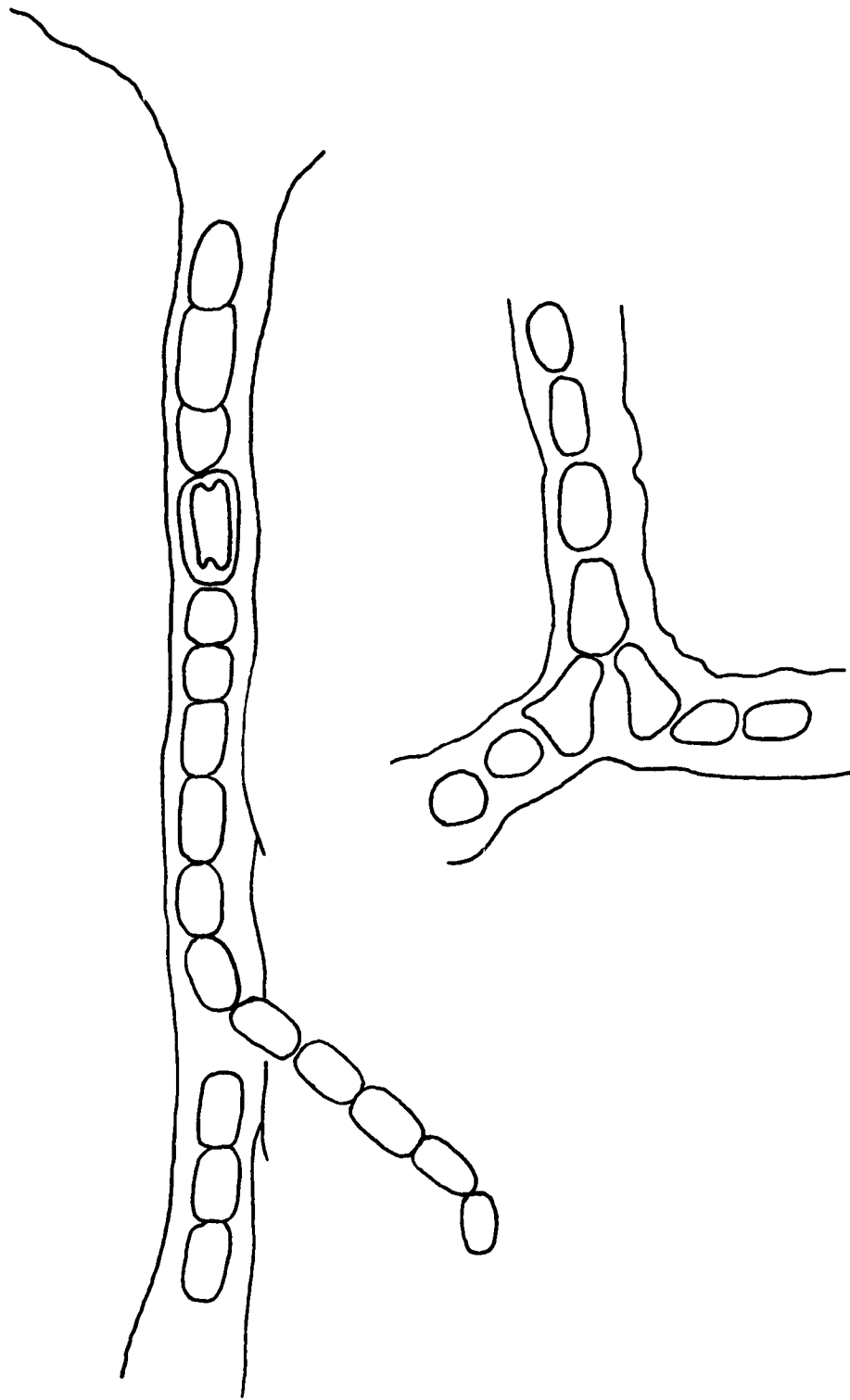
C) Île Picard (0610 +0895, 0625 +0907), Île Malabar (1448 +1182);
L; 11.

D) Very abundant in areas of La Gigi beach where it formed green films over the surface of sand; the only locality it was recorded away from Île Picard was at the end of the track from Anse Porche to the lagoon, Île Malabar.

E) Yes; six freshwater pools, Île Picard; two freshwater pools, Cinq Cases, Grande Terre.

—
10 μm

-113-



Brachytrichia dalmatica

010801 Brachytrichia dalmatica (Ercegović) Frémy nov. comb.

A) Cells of average size 5.0 to 8.0 μm , longer than broad; heterocysts quadratic, longer than broad; filaments of average width 8.8 μm , reverse-V-branched; thin, colourless sheath.

The computer system has numbers for both the genera Brachytrichia and Kyrtuthrix, and as such two numbers could apply to the species description.

B) Cell size range 5.0 to 9.0 μm ; heterocysts 9.0 μm broad; distinct sheath, often yellow brown in the basal regions.

Thallus endolithic, yellow-green at rock surface.

First described as Kyrtuthrix dalmatica by Ercegović (1929), endolithic in rocks along the Dalmatian Coast (the islands of Ciovo, Solta and Brac).

There is confusion regarding the taxonomic status of the genera Kyrtuthrix and Brachytrichia. Geitler (1932) includes Kyrtuthrix and Brachytrichia as separate genera in the Mastigocladaceae, the former being endolithic and the latter non-endolithic. Although both Frémy (1933) and Desikachary (1952) grouped both genera under Brachytrichia, Frémy favoured the Rivulariaceae as the family, whereas Desikachary included Brachytrichia in the Mastigocladaceae.

The Aldabra material most resembles B. dalmatica. I agree with the decision of Desikachary (1952) to include this in the Mastigocladaceae.

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920), Île Malabar (2705 +1099, 3138 +1187, 253 +129, 145 +126, 360 +113), Grande Terre (404 +089, 1858 +013, 2623 +037, 2623 +0433); L+0; 35.

- D) Frequent endolith in rocks of the lower intertidal zone, both inside the lagoon and on the seaward coasts; typically colouring the rock surface a yellow-brown.
- E) No.
- F) Supra-littoral zone, Marseille coast (Le Campion-Alsumard, 1969). B. quoyi from shores of Costa Rica and Nicaragua (Dawson, 1962).

010916 Calothrix aeruginea (Kützing) Thuret

A) Cell size range 7.5 to 9.0 μm , average length 3.1 μm , shape of basal cell not known; trichome slightly swollen at base, cell indentation not known; short hair present; arrangement of trichomes not known; width of basal cell with respect to heterocysts not known; presence of spores not known; heterocysts basal, number of heterocysts not known, shape of basal heterocysts not known; range of filament width 9.3 to 10.6 μm , length of filaments not known; shape of sheath not known, texture of sheath not known, average width of sheath 1.5 μm , colourless, non-lamellate, laceration of sheath not known.

Colony form not known, height not known, confluence not known; calcification not known, distribution of CaCO_3 and texture not known.

B) Cell size range 7.0 to 9.0 μm , trichome extended in long hair; filament size range 9.0 to 10.0 μm (rarely 12.0 μm); sheath colourless or yellow at the base; heterocysts basal and sometimes intercalary.

Widespread in marine habitats, on larger algae.

C) Île Picard (061 +098, 066 +101); L; 2.


D) Present among other algal communities in tidal depressions behind the research station, and at Bassin Lebine.

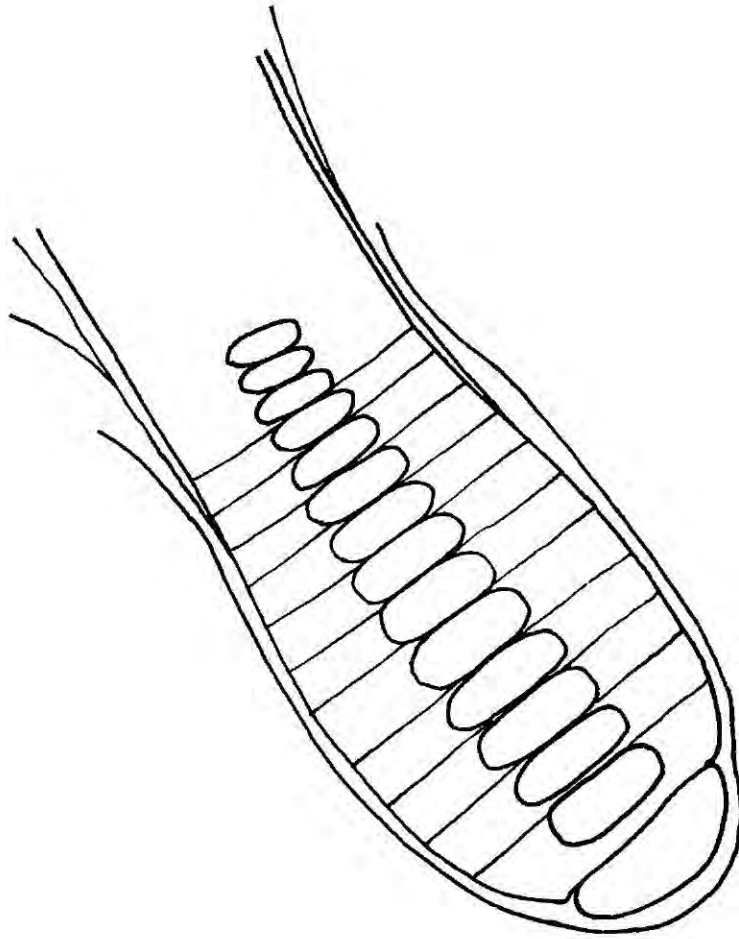
E) No.

F) Lagoon shores, Curaçao (van den Hoek et al., 1971).

010917 Calothrix confervicola (Roth) Agardh

- A) Cells of average width 10.1 μm , shorter than broad, shape of basal cell not known; trichomes not greatly swollen at the base, cells constricted, presence of hair not known, arrangement of trichomes not known; presence of spores not known; width of basal cell with respect to the heterocyst not known, position of heterocysts basal, shape of basal heterocysts not known; range of filament width 18.0 to 21.3 μm , length of filaments not known; shape of sheath not known, texture of sheath not known, average width of sheath 5.0 μm , colourless, non-lamellate, lacerations not-known. Colony form not known, height not known, confluence not known; calcification not known, distribution of CaCO_3 and texture not known.
- B) Cell size range 10.0 to 18.0 μm , trichome extended in long hair, heterocysts basal; filament size range 12.0 to 25.0 μm ; sheath colourless or yellow-brown, non-lamellate.
Widely distributed in marine environments, epiphytic on larger algae.
- C) Île Picard (0610 +0895, 0625 +0907, 066 +101); L; 4.
- D) Present among other mat forming communities at La Gigi and in tidal depressions, 'back path'.
- E) No.
- F) In littoral pools, Charlotte Amalia, St. Thomas (Hispaniola), (Taylor, 1937); salt pans, Curaçao (Koster, 1963); lagoon shores, Curaçao (van den Hoek et al., 1971).


5 μ m



Calothrix contarenii

010918 Calothrix contarenii (Zanardini) Bornet et Flahault

A) Cells of average width 7.5 μm , 2.5 to 3.0 μm long, shorter than broad, basal cell swollen, cell constriction not known; slight hair; arrangement of trichomes not known; presence of spores not known; width of basal cell with respect to the heterocyst not known, heterocyst basal, number not known, shape of basal heterocysts not known; average width of filaments 15.0 μm , up to 22.0 μm at the base, length not known; sheath in 'funnel' arrangement, average width 4.0 μm , brown, lamellate.

Colony form not known, height not known, confluence not known; calcification not known, distribution of CaCO_3 and texture not known.

B) Cell size range 6.0 to 8.0 μm , extended in long hair, heterocysts 1 or 2, basal; filament size range 9.0 to 15.0 μm ; sheath dilated like a funnel, brown or colourless, lamellate or non-lamellate.

Colony crustaceous, orbicular.

Described originally from wood and stones in the upper intertidal zone of coasts in North America and Europe.

C) Île Picard (0610 +0895, 0625 +0907, 058 +092), Île Malabar (Anse Badamier, 255 +129); L+0; 15.

D) Frequent among other mat communities of Scytonema and Schizothrix, never recorded as very abundant or forming a mat or crust.

E) No.

010919 Calothrix crustacea Thuret

A) Cells of average width 12.5 μm , shorter than broad, slight swelling at base; cell constrictions not known; hair absent from all populations studied (5); arrangement of trichomes not known, presence of spores not known, width of basal cell with respect to the heterocyst not known, heterocysts basal and intercalary, number not known, shape of basal heterocysts not known; range of filament width 13.8 to 15.6 μm , length not known; shape of sheath not known, average width 1.5 μm , brown, lamellate.

Black to dark green crusts over sediments.

B) Cell size range 8.0 to 15.0 μm , often extended in a long hair, heterocysts 1 to 3, basal and intercalary; filament size range 12.0 to 20.0 μm ; sheath colourless to yellow-brown, lamellate in older filaments.

Colony caespitose, blackish-green to brown.

Described from rocks, larger algae and marine phanerogams, cosmopolitan.

C) Île Picard (0610 +0895, 0625 +0907, 061 +098, 058 +092); L+0; 5.

D) Very abundant in some areas of La Gigi beach, forming mats and crusts.

E) No.

F) Coasts of Bayeaux, Les Roseaux, Haiti (Taylor, 1941); lagoon sand crusts, Clipperton Island, Pacific (Dawson, 1959); sea coasts, Costa Rica and Nicaragua (Dawson, 1962); over wide range of substrates, Oahu, Pacific (Khan, 1969); lagoon shores,

Curaçao (van den Hoek et al., 1971); crenulate stromatolites,
Coorong Lagoon, South Australia (Walter et al., 1973).

010922 Calothrix pulvinata Agardh

- A) Cells of average width 12.0 μm , up to 1/3 long as broad, basal cell not swollen; cell constriction not known; short hair; arrangement of trichomes not known; presence of spores not known; width of basal cell with respect to heterocysts not known, position of heterocysts not known, number not known, shape of basal heterocysts not known; average width of filament 18.8 μm at base, long; shape of sheath not known, average width 3.0 μm , yellow-brown, non-lamellate. Green films, height not known, confluence not known, calcification not known, distribution of CaCO_3 and texture not known.
- B) Cell size range 8.0 to 12.0 μm , short hair, heterocysts basal; filament size range 15.0 to 18.0 μm , slightly swollen at the base; sheath clear to yellow-brown, lamellate in older filaments.
Colonies green, 2 to 3 mm high.
Described from rocks, wood and larger marine algae; Europe, North America and Australia.
- C) Île Picard (0610 +0895, 0625 +0907), Grande Terre (3770 +0620, 1120 +0280); L; 4.
- D) Very abundant at Cinq Cases, forming green films over champignon in the upper intertidal zone.
- E) No.

010923 Calothrix scopulorum (Weber et Mohr.) Agardh ex
 Bornet et Flahault

- A) Cells of average size 6.0 x 1.3 to 1.5 μm , shorter than broad, slight swelling of basal cell; cell constriction not known, hair not known; arrangement of trichomes not known; presence of spores not known; width of basal cell with respect to the heterocyst not known, position of heterocysts not known, number of heterocysts not known, shape of basal heterocysts not known; average width of filaments 15.0 μm , length not known; shape of sheath not known, average width 3.0 μm , colourless, non-lamellate. Colony form not known, distribution of CaCO_3 and texture not known.
- B) Cell size range 8.0 to 15.0 μm ; extended in long hair; heterocysts basal, often many; filament size range 10.0 to 18.0 μm , swollen at base; sheath colourless to yellow-brown, non-lamellate or lamellate.
Colony caespitose, dull green, 1 mm high.
Described from pebbles, wood and larger marine algae, cosmopolitan.
- C) Île Picard (0610 +0895, 0635 +0920), Grande Terre (3770 +0620),
Îles Moustique (9005 +5250); L; 7.
- D) Present as isolated filaments among other algal communities.
- E) No.
- F) Intertidal zone, Raroia Atoll, Pacific (Newhouse, 1954); on limestone and lava substrates, Oahu, Pacific (Khan, 1969).

011301 Chlorogloea conferta (Kützing) Setchell et Gardner

A) Cell size range 0.8 to 1.5 μm , arranged in distinct rows.
Thallus brown.

The original size range given by the authors was 0.8 to 1.2 μm , I have therefore extended the definition to include cells up to 1.5 μm .

B) Cell size range 0.8 to 1.2 μm , sometimes longer than broad, regularly arranged in mucilage, bright blue-green.

Originally described from filaments of the red alga Rhodocorton rothii, collected from coasts of California.

C) Île Picard (0625 +0907); L; 2.

D) Present among a Scytonema mat at La Gigi, epiphytic on filaments, also epiphytic on Rhizoclonium.

E) No; but Chlorogloea microcystoides Geitler recorded as an epiphyte from two pools, Île Picard.

011533 Chroococcus schizodermaticus West $>6 \leq 8 \mu\text{m}$

A) Cells of average size $6.3 \times 8.8 \mu\text{m}$, yellow-brown; striate sheath; colony up to $16.3 \mu\text{m}$.

The upper size limit is given by West (1892) as $11.0 \mu\text{m}$, thus the limits of the recording system, and 'species' number would exclude cells $>8.0 \mu\text{m}$, these would be recorded under 011534 $>8 \leq 16 \mu\text{m}$.

B) Cell size range 5.8 to $11.0 \mu\text{m}$, in groups of 2 to 4; sheath yellow-brown, striated.

First recorded from swamps and moorland, England and Africa.

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920), Îles Moustique (9005 +5250); L; 4.

D) Abundant among Scytonema mats at La Gigi.

E) No.

011534 Chroococcus turgidus (Kützing) Nägeli >8 ≤16 μm

A) Cells of average width 12.5 μm, bright blue-green to pale green; striate sheath.

The upper size for C. turgidus is 32.0 μm, so that this 'species' number will exclude all sizes >16.0 μm, these being recorded by 011535 >16 ≤32 μm.

B) Cell size range 8.0 to 32.0 μm, spherical or ellipsoidal, in groups of 2 or 4; sheath colourless, not distinctly striate. Described from stagnant and standing water, also recorded from mangrove areas.

C) Île Picard (0625 +0907, 061 +098), Grande Terre (3380 +0673); L; 6.

D) Present among other algal communities, never becoming abundant.

E) Yes; widespread in freshwater pools, Île Picard; Grande Terre.

F) Lagoon shores, Curaçao (van den Hoek et al., 1971).

011535 Chroococcus westii (W. West) Boye-Peterson $>16 \leq 32 \mu\text{m}$

A) Cell size range 17.3 to 31.5 μm ; sheath colourless, striate.

The size range of this 'species' number includes cells in the range $>16 \leq 32 \mu\text{m}$, as can be seen from the descriptions below, it excludes cells 13.0 to 16.0 μm , and overlaps at the upper range where the upper cell size is 27.0 μm .

B) Cell size range 13.0 to 27.0 μm , violet, in groups of 2 to 4; sheath colourless, striate.

Recorded from damp rocks and standing water. Desikachary (1959) noted that no 'type' variety had been recorded so far.

C) Île Picard (0610 +0895, 0625 +0920, 061 +098), Grande Terre (3380 +0673); L; 7.

D) Frequent among other algal communities, never becoming abundant.

E) No.

011536 Chroococcus macrococcus (Kützing) Rabenhorst > 32 μm

- A) Cell size range 33.2 to 37.5 μm ; sheath colourless, striate.
The lower size range for the species is 25.0 μm , this 'species' number excludes cells 25.0 to 32.0 μm .
- B) Cell size range 25.0 to 50.0 μm , spherical, 2 to 4 together, also single; sheath thick, colourless, striate.
- C) Île Picard (066 +101); L; 5.
- D) Present among other algal communities; found at only two localities, both at the inland tidal pool, Bassin Lebine, the base of limestone residuals, low intertidal zone.
- E) No.

011537 Chroococcus minimus (Keissler) Lemmermann ≤ 4 μm

- A) Cells of average width 2.5 μm ; sheath colourless, non-striate.
- B) Cell size range 2.0 to 3.0 μm , spherical or ellipsoid, 2 or many in colony; sheath non-striate.
Planktonic in standing water and the sea.
- C) Île Picard (0610 +0895), Grande Terre (3380 +0673); L; 5.
- D) Present among other algal communities; found at only two localities, La Gigi and Takamaka.
- E) No.

011538 Chroococcus minutus (Kützing) Nägeli >4 ≤6 μm

A) Cells of average width 5.6 μm; sheath colourless, non-striate.

This 'species' number only includes those cells in the range >4 ≤6 μm, and excludes the larger cell sizes.

B) Cell size range 4.0 to 10.0 μm, spherical or oblong, blue-green; sheath colourless, non-striate.

Planktonic instanding water, swamps and saltwater.

C) Île Picard (0625 +0907), Grande Terre (3380 +0673, 1858 +0287), Îles Moustique (9005 +5250); L; 2.

D) Occasional among mats of Scytonema and Schizothrix.

E) Yes; four pools at Île Picard; two freshwater pools at Cinq Cases, Grande Terre.

011539 Chroococcus membraninus (Meneghini) Nägeli >6 ≤8 μm

A) Cells of average size 7.5 to 5.0 μm, yellow-green; sheath of average width 1.3 μm, faint pink, non-striate.

This size range excludes cells >3.0 ≤6.0 μm.

B) Cell size range 3.0 to 8.0 μm, single or 2 to 4; sheath thick, clear, non-striate.

Recorded from mud and water hot springs, among Oscillatoria and other algae.

C) Île Picard (0625 +0907, 0635 +0920), Île Malabar (3138 +1187, 1448 +1182); L; 5.

D) Present among other algal communities.

E) Yes; four freshwater pools, Île Picard; three freshwater pools, Cinq Cases, Grande Terre.

011540 Chroococcus turicensis (Nägeli) Hansgirg >8 <16 μm

A) Cell size range 8.8 to 12.5 μm , olive-green; sheath width range 1.3 to 1.5 μm , colourless, non-striate.

This 'species' number includes several other species apart from C. turicensis, as the range for this species is 13.0 to 15.0 μm .

B) Cell size range 13.0 to 15.0 μm , usually 2 to 4, sometimes 16 in a colony; sheath non-striate.

Recorded from damp rocks.

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 061 +098),
Île Malabar (1448 +1182, 145 +126, 3138 +1187); L+0; 19.

D) Frequent among other algal communities.

E) Yes; two freshwater pools, Île Picard; T 1, T 2, one freshwater pool, Cinq Cases, Grande Terre.

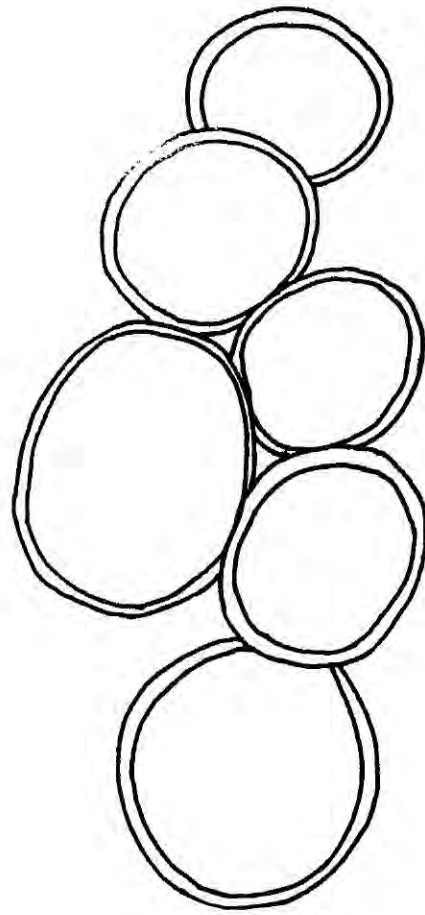
011541 Chroococcus spelaeus Ercegović >16 ≤32 μm

- A) Cell size range 16.3 to 27.0 μm, yellow-green to olive-green; sheath colourless, non-striate.
- B) Cell size range 15.0 to 30.0 μm, usually 16.0 to 24.0 μm, spherical; sheath 5.0 to 6.0 μm, colourless, non-striate. Recorded from damp rocks, among other algae.
- C) Île Picard (061 +098, 066 +101), Île Malabar (2705 +1099, 3138 +1187), Grande Terre (3770 +0620, 2623 +0433), Île Sylvestre (114 +064); L; 23.
- D) Frequent among other algal communities, widespread in the lagoon.
- E) Yes; recorded only once at W 4, Île Picard.

011542 Chroococcus sp. >32 μm

- A) Cell size range 37.5 to 45.0 μm; sheath non-striate, colourless.
There is apparently no suitable binomial which can be used here.
C. turgidus has the size range, but it has clearly striate sheaths.
- C) Île Picard (061 +098), Île Malabar (3138 +1187), Grande Terre (3770 +0620); L; 5.
- D) Recorded as present among mats of Calothrix scopulorum or Schizothrix calcicola.
- E) No.

—
10 μm



Chroococcopsis gigantea

018101 Chroococcopsis gigantea Geitler

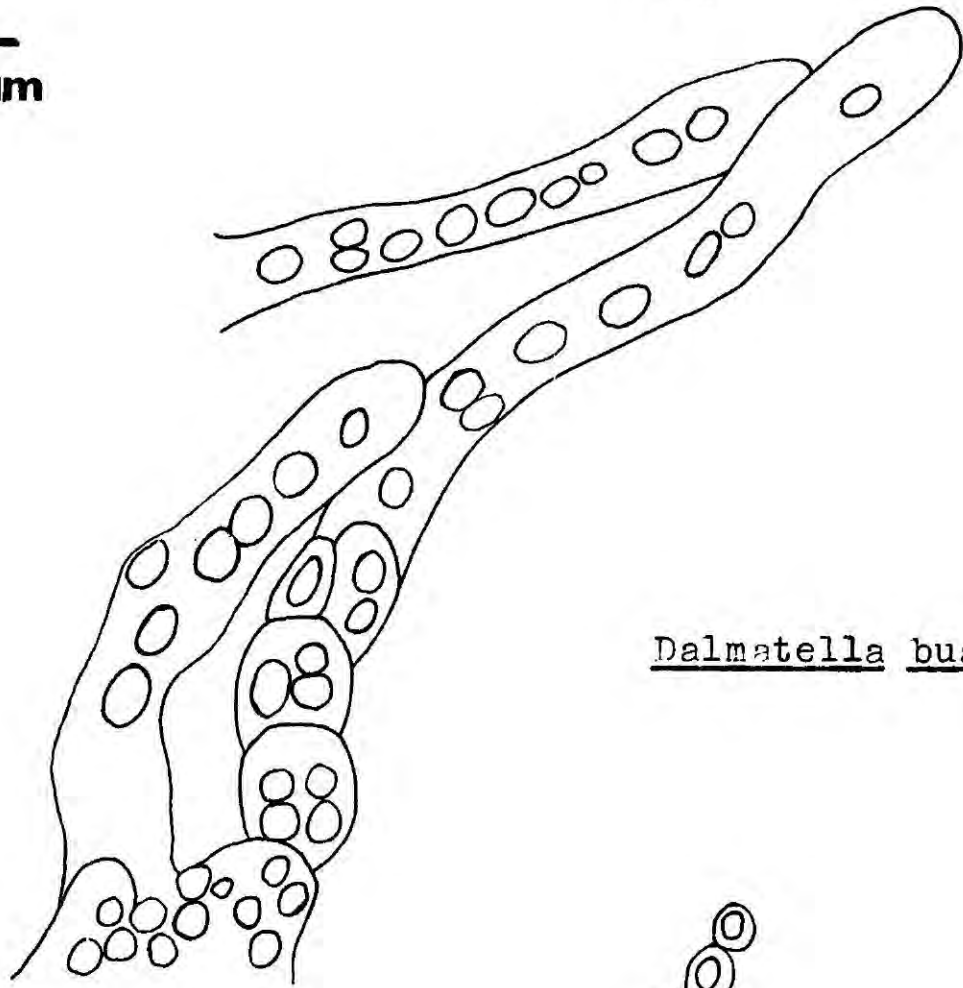
- A) Cells of average size 15.0 μm , spherical, often clavate ('club shaped'), clear to pale yellow-brown.
- B) Cell size range 7.0 to 36.0 μm , spherical to elliptical or polygonal, blue-green, yellow or dark green; endospores 1.5 to 2.5 μm .

Described from rocks, soil, pools, and among Lithoderma and Hildenbrandia; Latvia.

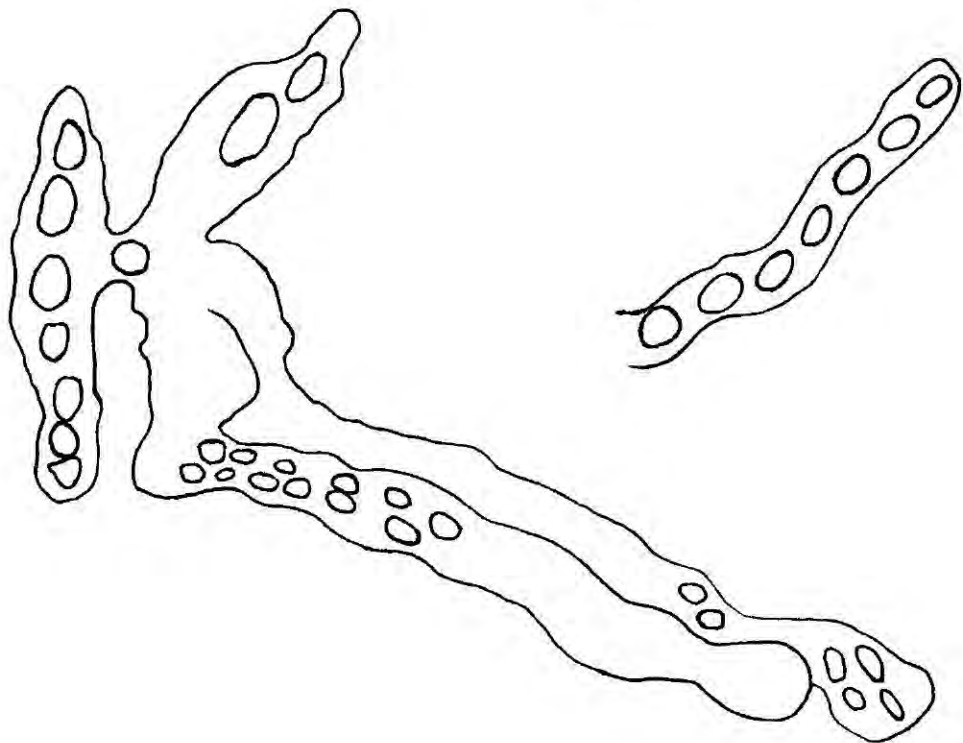
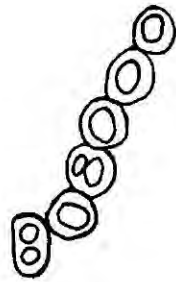
Frémy (1933) considered both Pleurocapsa amethystea and P. fuliginosa as doubtful species, suggesting that they perhaps be placed in Chroococcopsis.

- C) Île Malabar (2705 +1099); L; 2.
- D) Recorded from only one location, present among a surface film of Microcoleus chthonoplastes.
- E) Yes; three freshwater pools, Île Picard, especially abundant in W 2.

10 μ m



Dalmatella buaensis



018201 Dalmatella buaënsis Ercegović

A) Cells of average diameter 5.0 μm ; average width of filaments 12.5 μm , some filaments with single rows of cells, others with several.

B) Cell size range 2.0 to 6.0 μm , 2.0 to 8.0 μm long for epilithic portions, 4.0 to 15.0 x 3.0 to 7.0 μm for endolithic portions; epilithic filaments 6.0 to 10.0 μm , endolithic filaments 12.0 to 30.0 μm ; sheath sometimes brown to yellow, lamellate.

Thallus yellow-brown, up to 0.5 mm thick.

Frémy (1933) expressed the view that the five species he recorded from european coasts were possibly forms of only one or two species. Geitler (1932) includes only D. buaënsis.

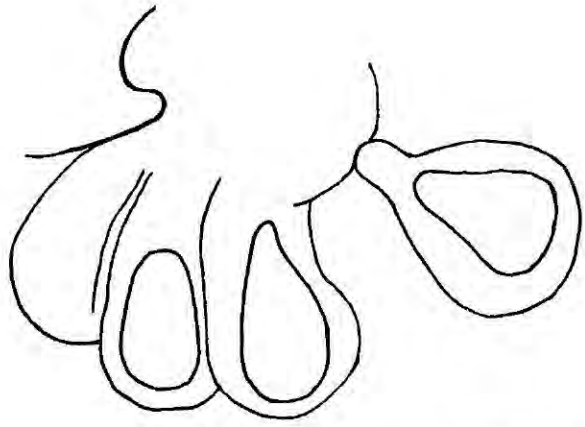
C) Île Picard (0635 +0920); L; 3.

D) Recorded on only one occasion from champignon islets off La Gigi beach; occasional as endolithic filaments in limestone of the upper intertidal zone.

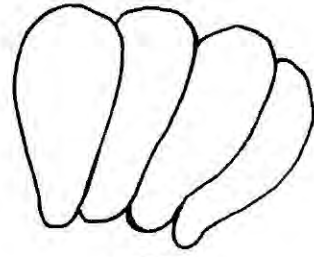
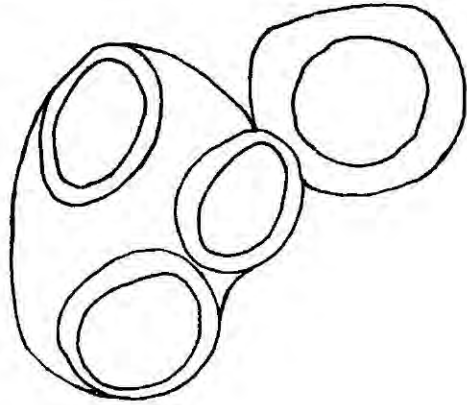
E) No.

F) Coasts near Marseille, France (Le Campion-Alsumard, 1969).

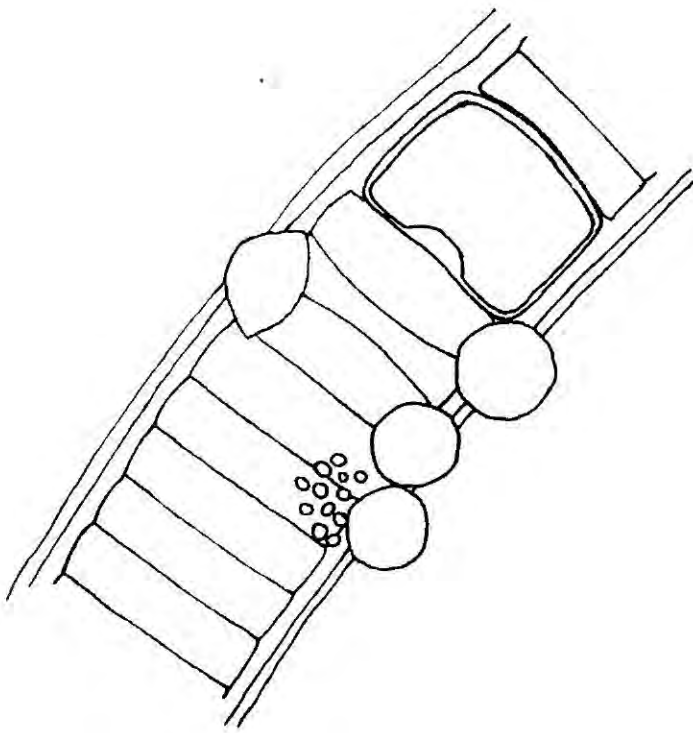
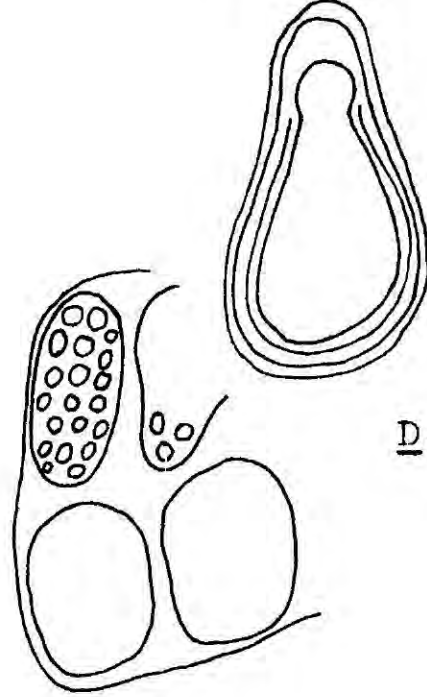
—
10 μm



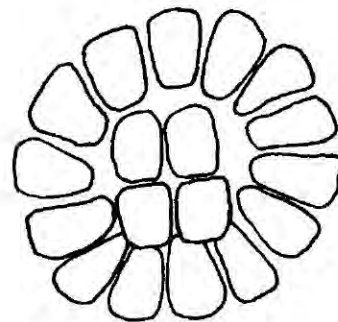
Dermocarpa leibleinae



D. olivacea



D. sphaerica



Dermocarpa sp.

Due to the mode of growth of Dermocarpa it was often impossible to assign a satisfactory binomial. Cells were often in different stages of growth, and when using cell width as a characteristic feature, it was not possible to arrive at a binomial. The computing number 012050 has been used in this instance for all cases where Dermocarpa is recognised as the genus, but where it is impossible to identify to the level of species. This number may include several species or one species.

012004 Dermocarpa hemisphaerica Setchell et Gardner

A) Sporangia size range 18.0 to 21.0 μm .

B) Sporangia size range 18.0 to 21.0 μm , 10.0 to 13.0 μm high; wall colourless, non-striate.

On Rhodocorton rothii, coasts of California.

C) Île Picard (061 +098); L; 1.

D) Occasional epiphyte on filaments of Rhizoclonium sp., in tidal pools.

E) No.

012005 Dermocarpa leibleiniae (Reinsch) Bornet et Thuret

A) Sporangia of average diameter 20.0 μm , hemispherical to elongate, obvious sterile bases, olive-green.

B) Sporangia size range 8.0 to 20.0 μm , elongate or oval, blue-green or olive-green; membrane thick and striate.

Described from the Adriatic, English coasts and open sea, epiphytic on other algae.

C) Île Picard (0610 +0895), Grande Terre (1858 +0130); L+0; 3.

D) Present as epiphyte on Scytonema sp. and Rivularia sp.

E) No.

012006 Dermocarpa olivacea (Reinsch) Tilden

A) Sporangia of average size 12.0 x 5.0 μm , prominent stalk, light green; endospores not obvious.

The smallest cells recorded for this species are somewhat smaller than the smallest size given by the author. I have extended the definition of this species to include cells 5.0 to 17.0 μm and 12.0 to 25.0 μm .

B) Sporangia size range 9.5 to 17.0 μm broad, 13.0 to 25.0 μm long, broad pyriform to spherical, marked elongation of base into a stalk; wall thick and striate; many endospores, spherical.

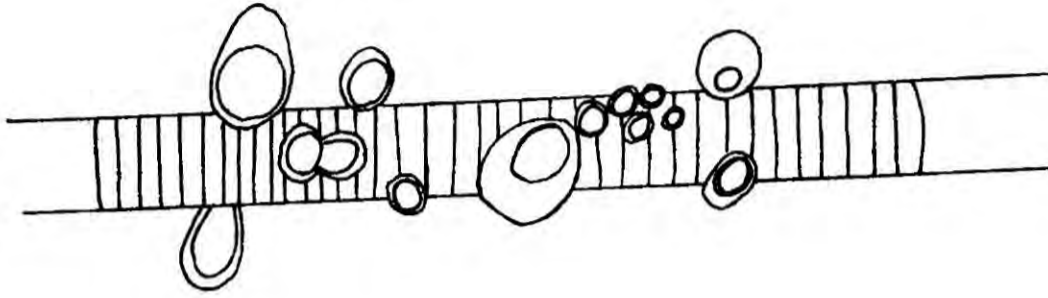
On fronds of Chaetomorpha, Gelidium and Ceramium; coasts of the Adriatic, Labrador, Canada and England.

C) Île Picard (0625 +0907, 0635 +0920), Grande Terre (3380 +0673, 2623 +037, 0810 +0505); L+0; 11.

D) Frequent epiphyte on Calothrix spp. and Scytonema sp.

E) No.

—
10 μm



Dermocarpa minima

012008 Dermocarpa sphaerica Setchell et Gardner

- A) Sporangia size range 10.0 to 16.0 μm , pale yellow; thin membrane.
- B) Sporangia size range 8.0 to 16.0 μm , spherical, bright blue-green; membrane thin, clear.

Epiphytic on many different algae of the coasts of California.

- C) Île Picard (2705 +1099, 3138 +1187), Grande Terre (1858 +0287, 3380 +0673); L; 7.

D) Occasional epiphyte on Scytonema sp.

E) No.

012009 Dermocarpa minima Geitler

- A) Average cell size 5.0 x 6.3 μm , subspherical to hemispherical, pale yellow-green.
- B) Sporangia size range 5.0 to 7.0 μm when mature, subspherical; endospores 8.0 to 12.0 μm , sometimes up to 16.0 μm .

Frémy (1933) comments on the similarity of this species to Xenococcus schousboei.

Epiphytic on many algae (Lyngbya, Oscillatoria, Cladophora); the Dalmatian Coast.

- C) Grande Terre (1858 +0287); 0; 4.

D) Recorded on only one occasion as an epiphyte on filaments of Scytonema sp.

E) No.

012201 Entophysalis granulosa Kützing

A) Cell size range 3.7 to 5.0 μm , commonly 3.8 μm , spherical, arranged in rows with general appearance of 'Gloeocapsa'-like cells, pale yellow-brown.

Colonies up to 2 mm thick, crustaceous, gelatinous when wet, subspherical and usually attached to substratum.

B) Cell size range 2.0 to 5.0 μm ; sheath colourless, yellow to brown.

Thallus crustaceous, yellow-brown, granular, cartilaginous.

Cosmopolitan along rocky coasts, in upper intertidal zone.

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937, 066 +101, 061 +098), Île Malabar (3138 +1187), Grande Terre (404 +089, 3380 +0673, 3770 +0620, 1858 +0287, 2623 +0371), Îles Moustique (9005 +5250); L+0; 32.

D) Very abundant in the upper intertidal zone of the 'mini' lagoon, Îles Moustique, forming small spherical gelatinous colonies over the surface of the cemented fine silt; abundant over champignon and cerethid shells in the upper intertidal zone of the lagoon and seaward coasts; widespread distribution.

E) Yes; as an epiphyte in three freshwater pools, Île Picard; two freshwater pools, Cinq Cases, Grande Terre.

F) Coasts near Marseille, France (Le Campion-Alsumard, 1969).

012113 Dichothrix rupicola Collins

A) Average width of cells at base 10.0 μm ; basal and intercalary heterocysts; several trichomes in each sheath; average width of filaments 16.0 μm ; sheath up to 2.5 μm , yellow-brown, lamellate.

I have extended the definition of Collins (1900) to include cells up to 10.0 μm .

B) Trichome size range 7.0 to 9.0 μm , cells quadratic; filament size range 15.0 to 22.0 μm , tapered, many together; sheath yellow-brown, lamellate.

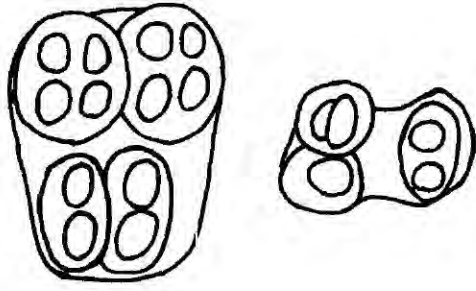
Recorded from coasts of Maine (North America).

C) Grande Terre (3770 +0620); L; 3.

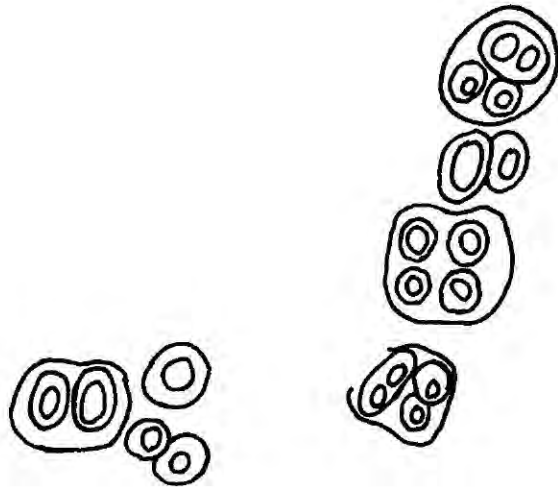
D) Very abundant at Cinq Cases as bright green films in the upper intertidal zone; these films have a blistered appearance.

E) No.

10 μ m



Gloeocapsa atrata



Gloeocapsa dermochroa

012637 Gloeocapsa atrata (Turp.) Kützing $>4 \leq 6 \mu\text{m}$

A) Average cell diameter $5.0 \mu\text{m}$, 2 to 4 cells in packets, light green; sheath width range 5.3 to $5.5 \mu\text{m}$, colourless, non-striate.

The size range for this species is 3.5 to $5.0 \mu\text{m}$, and as such the 'species' number will exclude the lower cell sizes.

B) Cell size range 3.5 to $4.5 \mu\text{m}$, often up to $5.0 \mu\text{m}$, pale blue-green, many in colony; sheath colourless or pale blue, non-striate.

Thallus mucilaginous, black.

Geitler (1932) considers this a colourless form of another species.

Recorded from damp rocks.

C) [^]Ile Picard (0625 +0907, 066 +101); L; 4.

D) Present among other algal communities, only recorded from La Gigi and Bassin Lebine.

E) No.

012638 Gloeocapsa crepidinum Thuret >6 µm

- A) Average cell diameter 6.3 µm, in packets of four, pale green; sheath up to 5.0 µm, colourless, non-striate.
This 'species' number will exclude any cells ≤6 µm.
- B) Cell size range 4.0 to 8.0 µm, closely arranged in peripheral portions of the colony; sheath colourless, non-striate.
Recorded from stones and rocks, the intertidal zone of inland waters and open ocean.
- C) Île Picard (0610 +0895); L; 2.
- D) Recorded only from La Gigi, among other algal communities.
- E) No.
- F) On shells, coast of Laesø Island, Denmark (Nielsen, 1973).

012640 Gloeocapsa dermochroa Nägeli >2 ≤4 µm

- A) Average cell diameter 2.8 µm, spherical, usually four together, brown to yellow; sheath yellow-brown, non-striate.
The cell size range used with the 'species' number will exclude all cells >1.5 ≤2.0 µm.
- B) Cell size range 1.5 to 3.0 µm, blue-green; sheath yellow-brown, non-striate.
Recorded from damp rocks.
- C) Île Picard (0625 +0907); L; 1.
- D) Recorded from one locality at La Gigi, among a Scytonema mat.
- E) Yes; two freshwater pools, Île Picard.

012646 Gloeocapsa alpina (Nägeli) emend. Brand >4 ≤6 μm

A) Cell size range 4.0 to 6.0 μm, dark violet to dark green; sheath violet, non-striate; nannocytes present.

The size range for this 'species' number is the same as the observed cell size range in Aldabra material. G. alpina status coloratus is the most suitable binomial.

B) Cell size range 4.0 to 6.0 μm, sometimes up to 8.0 μm; sheath often dark violet, sometimes clear; nannocytes 2.5 to 3.5 μm diameter.

Recorded from damp rocks, damp wood and snow, areas of dolomitic limestone.

C) Île Picard (0625 +0907); L; 2.

D) Recorded from one locality at La Gugi, among a Scytonema mat.

E) No.

F) Over dolomitic limestone, Cortina d'Ampezzo, Italy (Potts, unpublished data); The Burren, Co. Clare, S. Ireland (Potts, unpublished data).

012647 Gloeocapsa sanguinea (Agardh) Kützing >6 ≤8 μm

A) Average cell diameter 6.3 μm; sheath dark violet, non-striate.

This 'species' number excludes cells >4.5 ≤6.0 μm.

B) Cell size range 4.5 to 6.5 μm, pale blue-green; sheath bluish-red, non-striate.

Recorded from rocks and snow (Lappland, Spitzbergen, Greenland)

C) Île Picard (061 +098); L; 1.

D) Present among a surface film of Lyngbya confervoides, over silt in a tidal depression, close to the research station.

E) Yes; all freshwater pools discussed by the authors on Île Picard, predominantly terrestrial; sheath red-violet-blue.

012732 Gloeotheca palea (Kützing) Rabenhorst >2 ≤4 μm

A) Average cell width 3.8 μm.

This size range excludes cells in the 'type' description which are >4.0 μm.

B) Cell size range 2.5 to 4.5 μm, 1.5 to 3 times longer than broad, cylindrical; sheath colourless, non-striate.

Recorded from damp rocks, moss, and at the edges of warm water springs.

C) Île Picard (0610 +0895); L; 1.

D) Abundant as the second dominant species with Aphanothece microscopica over sand, La Gigi; this was the only record.

E) Yes; two freshwater pools, Île Picard.

012733 Gloeotheca rupestris (Lyngbye) Bornet >4 μm

A) Average cell width 6.9 μm , purple-brown; sheath colourless. Although the 'species' number covers all cell sizes for this species I have extended the definition to include cells up to 6.9 μm .

B) Cell size range 4.0 to 5.5 μm , sometimes up to 6.0 μm , 1.5 to 3 times longer than broad, elliptical to cylindrical; envelopes colourless or brown towards the periphery of the colony, lamellate or non-lamellate.

Recorded from damp rocks and warm water springs.

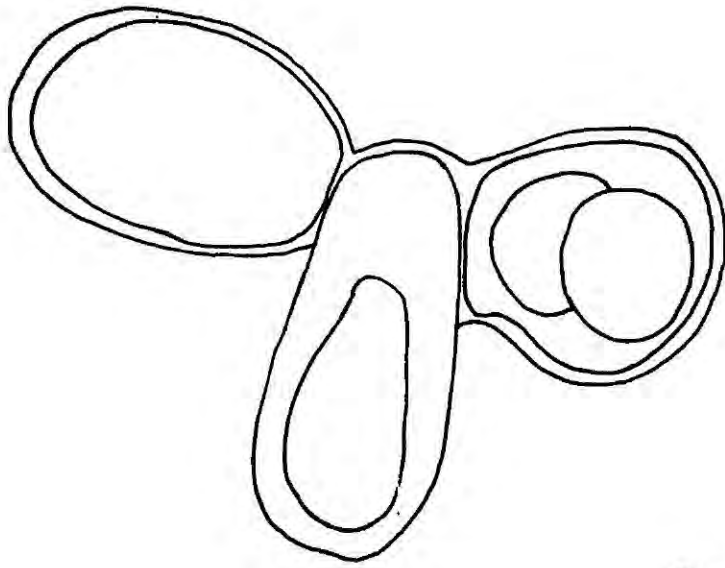
C) [^]Ile Picard (061 +098); L; 1.

D) Present among a community dominated by Lyngbya confervoides, in a tidal pool.

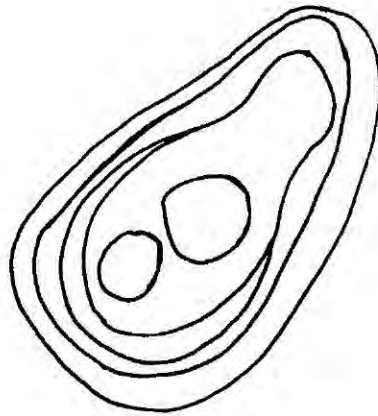
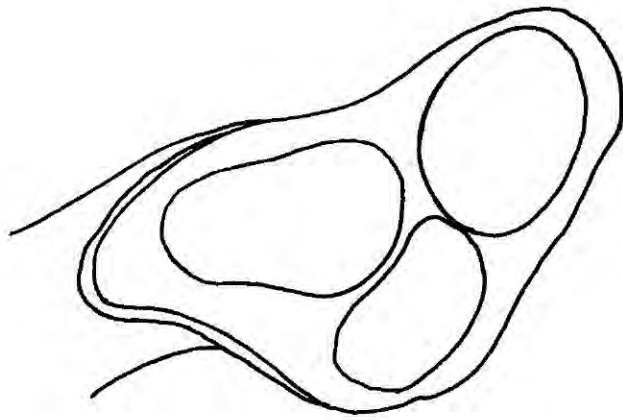
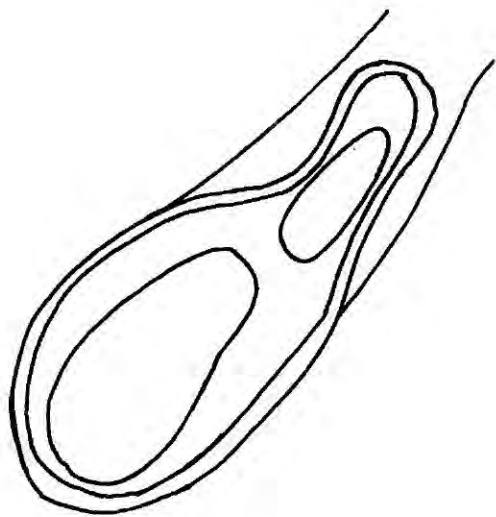
E) Yes; freshwater pools, [^]Ile Picard.

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10µm

-150-



Hormathonema epilithicum



013402 Hormathonema epilithicum Ercegović

A) Average cell size 6.3 μm at base, 10.0 μm at top, 16.0 μm long, typically clavate; average width of filaments 16.3 μm . This species is distinct in its form from either Hyella or Solentia. The cells are of a pronounced 'club' shape, with no pseudoparenchymatous cell masses or endospores. The endolithic filaments are very short.

B) Cell size range 9.0 to 18.0 μm wide, 9.0 to 16.0 μm long, a small number of cells in each filament, green; average filament width up to 40.0 μm , up to 130 μm long.

Thallus ash grey in colour.

Desikachary (1959) does not include this genus, whereas Geitler (1932) includes only H. paulocellulare Ercegović. Frémy (1933) commented that in his opinion it was difficult to separate H. epilithicum and H. paulocellulare because of the numerous intermediate forms between them. He also discussed the possibility of Hormathonema being a growth form of Gloeocapsa, secreting mucilage by phototropic movements.

C) Grande Terre (2623 +0433); L; 1.

D) Frequent endolith in champignon near the landing in the lagoon, leading to Dune Jean Louis.

E) No.

F) Supralittoral zone, coasts near Marseille, France (Le Campion-Alsumard, 1969).

013403 Hormathonema violaceo-nigrum Ercegović

A) Cell size range 3.0 to 6.3 μm , typically 4.3 to 4.5 μm , light green; sheath a faint purple-violet colour.

Thallus violet to black, as a thin (≤ 1 mm) crust.

When treated with acid, cells and sheath take on a red colour.

Several cells were noted which were strictly outside the cell range given for this species, these have still been included under this species; the definition is extended to include cells up to 6.3 μm .

B) Cell size range 2.0 to 5.0 μm wide, 2.0 to 8.0 μm long, many in each filament, green; filaments of an indefinite length, up to 30.0 μm wide; cell envelopes becoming red on treatment with acid.

Thallus violet to black.

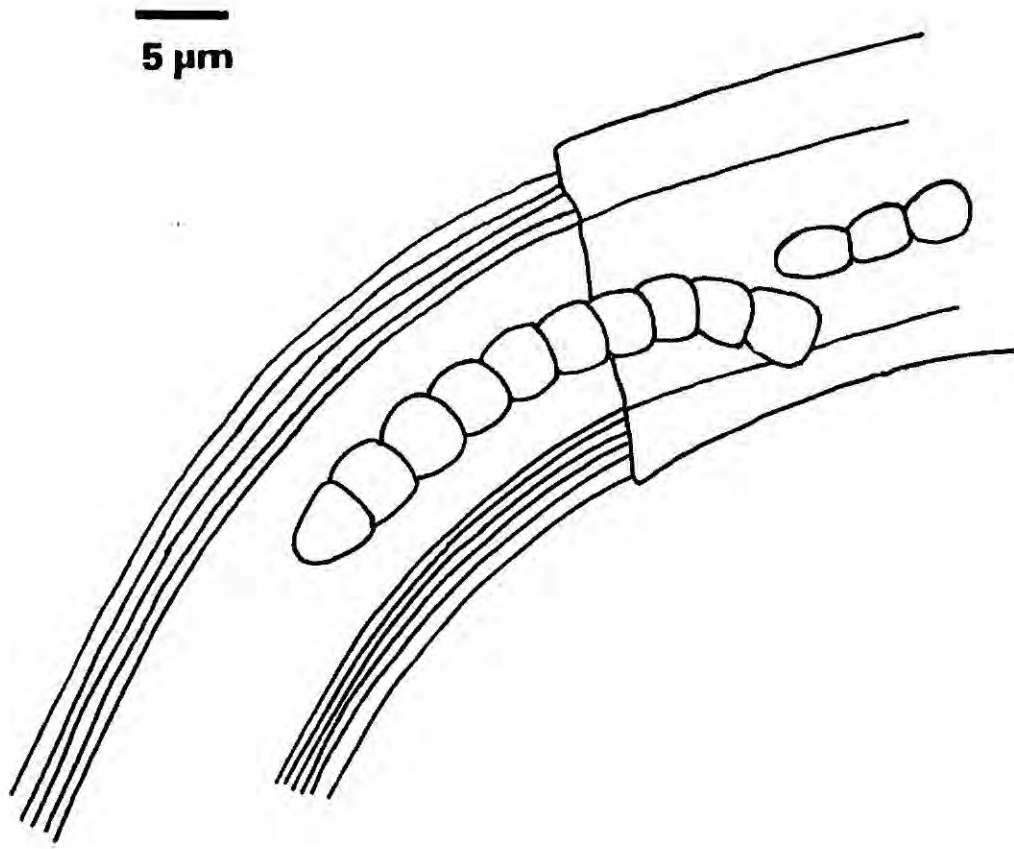
Described from rocks in the intertidal zone of the Dalmatian Coast.

C) Île Picard (0625 +0907, 058 +092, 061 +098), Grande Terre (1858 +013, 2623 +037, 2623 +0433, 1858 +0287), Îles Moustique (9005 +5250); L+0; 30.

D) Abundant as scattered dark mosaic over rocks in upper intertidal and mid intertidal zones of the lagoon and seaward coast.

E) No.

F) Coasts near Marseille, Île Ratoneau, France (Frémy, 1933).



Hydrocoleus sp. > 68 μm

013533 Hyarocoleus sp. $>6 \leq 8 \mu\text{m}$

A) Average cell width $6.9 \mu\text{m}$, slightly shorter than broad, 'barrel' shaped, granular, calyptra absent in all populations studied (3), pale green; two trichomes in each filament; average width of filament $15.0 \mu\text{m}$; sheath 'trumpet' shaped in places, colourless, lamellate.

Thallus bright green, forming films.

There appears to be no particularly suitable binomial that can be applied to this material. It is useful however to compare those species which would be included within this 'species' number $>6 \leq 8 \mu\text{m}$.

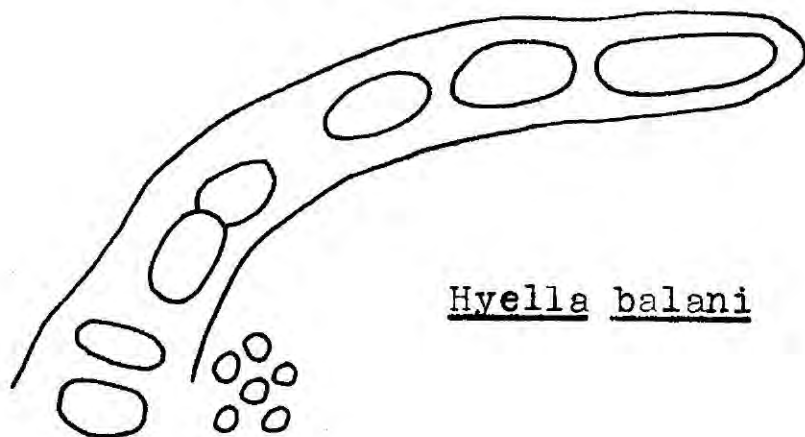
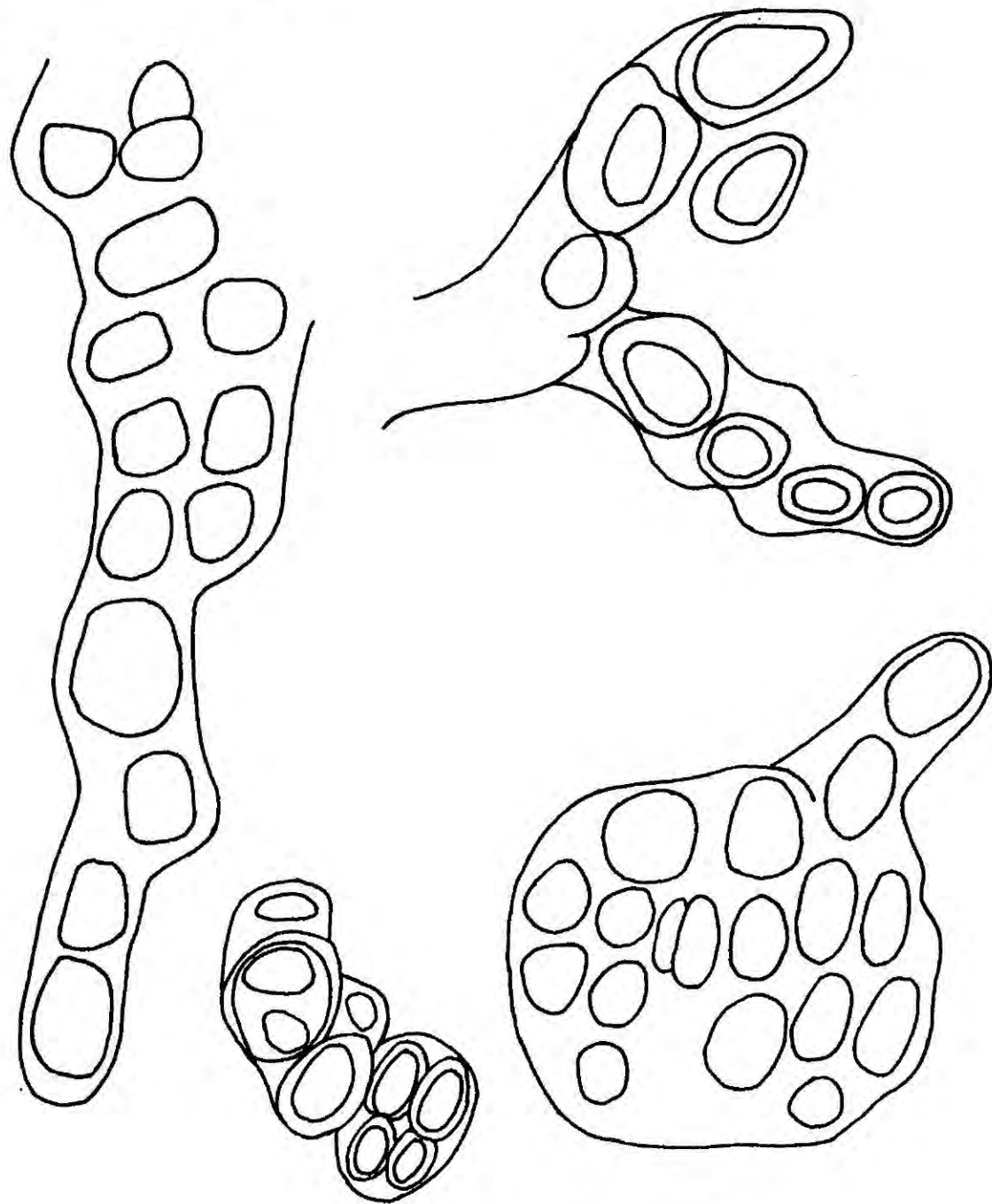
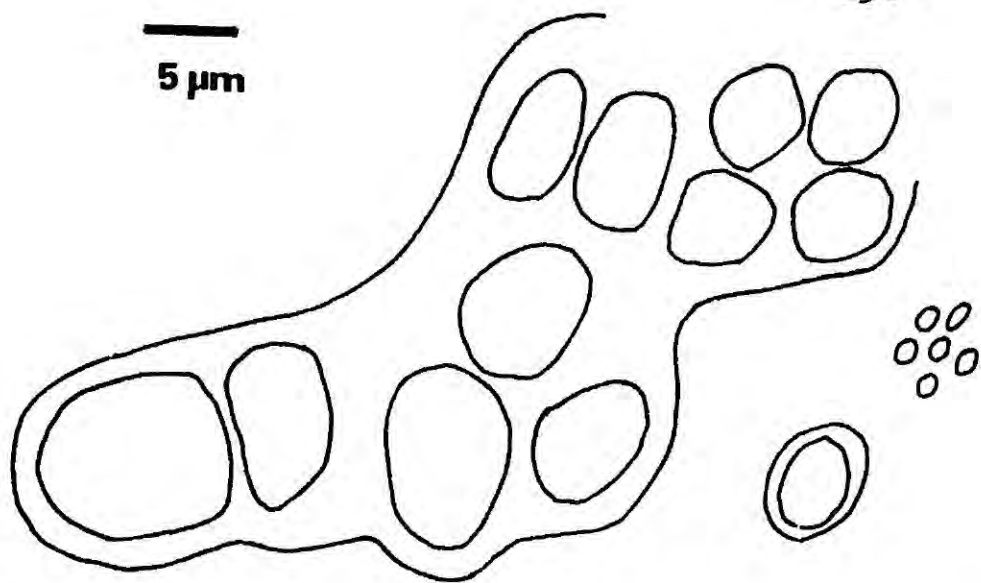
H. oligotrichus A. Braun ; cells $\approx 6.0 \mu\text{m}$; trichome tapered towards end, calyptra present; H. homoeotrichus Kützing ; cells 6.0 to $8.0 \mu\text{m}$, many trichomes in sheath, calyptra present; H. turfusus Woronich; cells 6.0 to $6.3 \mu\text{m}$, 1, 2 or 3 trichomes in sheath; H. lyngbyaceus Kützing ex Gomont; cells 8.0 to $16.0 \mu\text{m}$, with calyptra; H. meneghinianum Kützing; cells 3.0 to $7.0 \mu\text{m}$, 3 trichomes in sheath, recorded from mangrove swamps; H. floccosum (Hauck) Gomont; cells 8.0 to $12.0 \mu\text{m}$, trichomes red, attenuated ends; H. coccineum Gomont; cells 5.5 to $9.5 \mu\text{m}$, few trichomes in sheath, attenuated ends, recorded from the Indian Ocean; H. brebissonii Kützing; cells 8.0 to $10.0 \mu\text{m}$, 1 or many trichomes in sheath, tapered towards end.

Of these, the most suitable binomial on comparing with the Aldabra material is H. coccineum, even so, this species differs in the length of its cells, in the attenuation of the

trichome, and the presence of a calyptra.

- C) Île Picard (0610 +0895); L; 3.
- D) Abundant among other algal communities at La Gigi, close to the headland of Passe Femme, close to where the old pirogues are anchored; dominant species in these communities; pale green coloured films over the surface of sand sediments.
- E) No.
- F) I identified a Hydrocoleus sp. from samples collected from intertidal environments of The Bay Of Cadiz, Spain, by Dr M. Tucker. This material was strikingly similar to that described from Aldabra; cell size range 6.0 to 8.0 μm , average length 3.2 μm , shorter than broad, 2 trichomes in sheath; filaments in bundles of 16.1 μm ; no calyptra.

5 μ m



Hyella balani

013604 Hyella balani Lehmann

A) Average width of cells 7.5 μm , end cells much longer than others, yellow-green to brown; sheath up to 1.5 μm , commonly 1.3 μm to 1.5 μm , no division of membrane; pseudo-branched; filament size range 8.8 to 9.0 μm .

B) Cell size range 4.0 to 8.0 μm , end cells of the perforating endolithic filaments up to 20.0 μm long, end portions of the filaments usually one cell thick; elliptical sporangia, usually 7.0 to 8.0 μm broad, 13.0 μm long.

Thallus brown, greenish or brown-violet.

Described from Trondheim and Norwegian coasts, endolithic in shells of Balanus, Patella and Littorina.

Desikachary (1959) includes only H. caespitosa Bornet et Flahault.

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937, 066 +101, 061 +098), Île Malabar (2705 +1099, 3138 +1187, 253 +129, 185 +126, 1448 +1182, 139 +127, 145 +126), Grande Terre (360 +113, 3770 +0620, 3380 +0673, 2623 +0433, 1858 +0287, 1120 +0282, 2623 +037, 1858 +013, 404 +089), Îles Moustique (9005 +5250), Île Sylvestre (114 +064); L+0; 33.

D) Frequent in the majority of rock samples from the upper intertidal zone; endolithic.

Very abundant at La Gigi beach, where a large expanse of intertidal sandflat is coloured green, most vivid at \underline{c} 5 mm depth. In this situation H. balani is endolithic in sand grains and Microcystis reinboldii is epilithic on the grains. Beachrock on the seaward facing coats is coloured blue, due to

the perforating filaments of Hyella balani (Fig. 3.2a).

Widespread distribution both inside the lagoon and on the seaward facing coats.

- E) No; however H. caespitosa and H. fontana both recorded from freshwater pools, Île Picard.
- F) Coasts of Europe, Frémy (1933); coasts near Marseille, France (Le Campion-Alsumard, 1969); this author considered H. balani a form of H. caespitosa; endolithic in shells, Laesø Island, Denmark (Nielsen, 1972).

013605 Hyella tenuior Ercegović

- A) Average cell size 4.5 x 6.3 μm , up to twice long as broad; average width of filaments 6.3 μm , very long perforating filaments; membrane violet.
- B) Cell size range 2.0 to 5.0 μm , up to 40.0 μm long, spherical or cylindrical; filaments up to 8.0 μm , 400 μm long; membrane colourless.

Thallus endolithic, grey, olive-green or violet.

Described from rocks and shells in the low intertidal zone, Dalmatian Coast.

C) Île Picard (058 +092); 0; 1.

D) Abundant endolith in rocks on seaward coast in front of Settlement, below overhang; the only record.

The same rock formation and surface colouration were seen at many points along the coast of Île Picard, Île Polymnie, Île Malabar and parts of Grande Terre; it is probable that this species is fairly widespread on the seaward coast.

E) No; see comments for the previous species.

F) Coasts of Europe, Frémy (1933).

013801 Johannesbaptistia pellucida (Dickie) Taylor et Drouet

A) Average cell size 6.3 x 3.8 μm , discoid, yellow-green; average width of filaments 8.8 μm , curved.

The upper size limit for this species is 5.2 μm , I have extended the definition to include cells up to 6.3 μm .

B) Cell size range 3.9 to 5.2 μm , 2.6 to 3.9 μm long, discoid or sphaerico-discoid, arranged in straight rows; filaments 7.9 to 10.8 μm , up to 20 μm broad, straight or curved.

Described from standing water, Puerto Rica.

This genus was first described by Gardner (1927) as Cyanothrix.

Frémy (1933) did not consider this a valid genus, and several authors have commented on the possibility of this being a stage in a pathogenic condition of a Lyngbya sp.

Desikachary (1959) has reviewed the literature in detail.

C) Île Sylvestre (114 +064); L; 1.

D) Present in a mixed community dominated by Hyella balani and Schizothrix calcicola, over sandflats close to Île Sylvestre; the only record.

E) Yes; only recorded from the brackish pool CC 9 (Bassin Flamant); in plankton.

F) In sinkholes, Andros Island, Bahamas (Monty, 1967); northwest coasts of Curaçao (Koster, 1963); over limestone, littoral zone, Oahu, Pacific (Khan, 1969); lagoon shores, Curaçao (van den Hoek et al., 1971).

014201 Lyngbya aestuarii Liebmann ex Gomont

- A) Cell size range 10.0 to 15.0 μm , average length 3.8 μm ;
filaments up to 25.0 μm , straight; sheath brown, lamellate.
- B) Cell size range 8.0 to 24.0 μm , commonly 10.0 to 16.0 μm ,
not constricted at cross-walls, often granular; sheath
yellow-brown, lamellate.

Thallus a dull brown or blue-green colour, sometimes with
calcium incrustation; sometimes with false branching;
cosmopolitan; planktonic or attached, in sea water.

- C) ^AIle Picard (061 +098), Grande Terre (3380 +0673); L; 1.
- D) Very abundant in tidal pools, forming dark brown films over
the surface of silts.
- E) Yes; only recorded from the brackish pool CC 9, Grande Terre;
very abundant.
- F) Over lagoon sediments, Clipperton Island, Mexico (Taylor,
1939); oceanic sandflats, North Carolina (Williams, 1950);
attached to Porolithon, Raroia Atoll (Newhouse, 1954);
in brackish pools, Onotoa Atoll (Moul, 1957); littoral zone,
El Salvador (Dawson, 1961); littoral zone, Oahu (Khan, 1969);
brown sheets over the lagoon floor, Andros Island (Monty,
1967); lagoon shores, Curaçao (van den Hoek et al., 1971);
intertidal and estuarine environments, Bay Of Cadiz, Spain
(1975, samples collected by Dr M. Tucker).

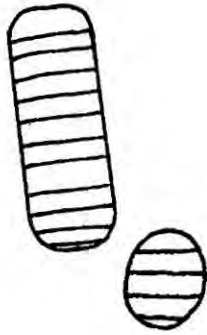
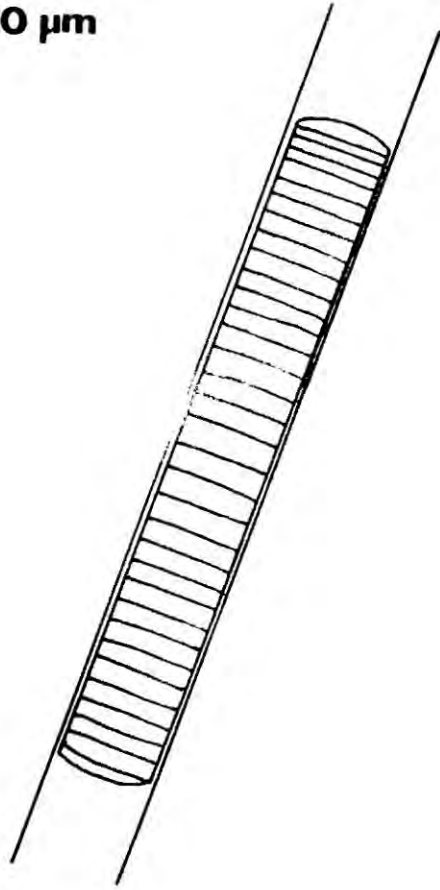
014202 Lyngbya allorgei Frémy

- A) Average cell size 3.5 x 2.0 μm , unstricted, slightly tapered end cell; trichomes long, straight; sheath colourless.
- B) Cell size range 3.5 to 4.0 μm , quadratic or 1 to 1.5 times longer than broad, calyptra absent; trichomes unstricted; sheath colourless.

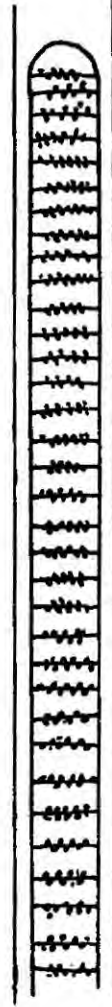
Recorded from standing water, French Equitorial Africa.

- C) Île Picard (061 +098), Grande Terre (3380 +0673); L; 3.
- D) Occasional among other algal communities.
- E) Yes; four freshwater pools, Île Picard; T 2, two freshwater pools, Cinq Cases, Grande Terre.

10 μ m



Lyngbya confervoides



Lyngbya martensiana

014204 Lyngbya confervoides C. Agardh ex Gomont

- A) Cell size range 12.5 to 13.8 μm , unstricted, granular; thick, colourless sheath.
- B) Cell size range 9.0 to 25.0 μm , commonly 10.0 to 16.0 μm , a third to an eighth as long as broad, unstricted; sheath colourless, up to 5.0 μm , lamellate.
Cosmopolitan; inland waters, intertidal zone of rocky coasts.
- C) Île Ficard (066 +098), Grande Terre (3380 +0673, 0810 +0505), Îles Moustique (9005 +5250); L; 11.
- D) Often very abundant as sheets over sediment; widespread inside the lagoon.
- E) Yes; four freshwater pools, Cinq Cases, Grande Terre.
- F) In tide pools, Hispaniola, Île de la Tortue (Taylor, 1937); surfbeaten rocks, Isla de Lobos, Uruguay (Taylor, 1939); coasts of Bayeaux, Haiti (Taylor, 1941); in the lagoon, Onotoa Atoll (Moul, 1957); sediment crusts, Texas Lagoons (Sorenson & Conover, 1959); on coral rock, Clipperton Island (Dawson, 1959); crusts and sediments, southwest Gulf Coast, Texas (Conover, 1962).

014205 Lyngbya digueti Gomont

A) Average cell size 2.5 x 2.5 to 3.1 μm , quadrate, end cell round; sheath thin, colourless.

This is the binomial that has been applied to much of the Aldabra material Lyngbya spp. $>2 \leq 4 \mu\text{m}$.

B) Cell size range 2.0 to 3.0 μm , unconstricted, nearly quadrate, no calyptra; sheath thin, colourless.

Recorded from standing water (Sweden, California, Uruguay, French Equatorial Africa).

C) Île Picard (0625 +0907), Grande Terre (3380 +0673, 0810 +0505), Îles Moustique (9005 +5250); L; 4.

D) Frequent among other algal communities; widespread.

E) Yes; nine freshwater pools, Île Picard; T 2, one freshwater pool, Cinq Cases, Grande Terre; widespread.

014206 Lyngbya epiphytica Hieronymus

A) Cell size range 1.5 to 2.0 μm , uncontracted; sheath thin, colourless.

I have extended the definition to include cells up to 2.0 μm .

B) Cell size range 1.0 to 1.5 μm , 1.0 to 2.0 μm long, uncontracted, end cells hemispherical, not attenuated; thin colourless sheath.

Cosmopolitan; epiphyte on Oedogonium, Lyngbya etc., mostly in salt water.

C) Île Picard (0625 +0907), Grande Terre (0810 +0505), Îles Moustique (9005 +5250); L; 4.

D) Frequent epiphyte on Scytonema and Rhizoclonium; widespread.

E) Yes; four freshwater pools, Île Picard; frequently recorded epiphyte on Plectonema gloeophilum and Oedogonium sp.

014208 Lyngbya kützingii Schmidle

A) Cell size range 1.5 to 2.0 μm , uncontracted; trichome tapered at ends; sheath thin, colourless.

B) Cell size range 1.5 to 2.0 μm , half to third long as broad, uncontracted; one end of filament attached.

Cosmopolitan; on filaments of other algae in standing water.

C) Île Picard (0625 +0907); L; 2.

D) Frequent epiphyte on Cladophora filaments.

E) Yes; pool W 5 only; occasional epiphyte on Oedogonium.

014209 Lyngbya limnetica Lemmermann

A) Average cell size 1.5 x 1.5 μm , spherical end cell; thin colourless sheath.

B) Cell size range 1.0 to 1.5 μm , 1.0 to 1.3 μm long, unstricted, end cell not tapered.

Recorded as planktonic and on other algae in salt water habitats (Europe, Java, Africa); cosmopolitan.

C) Île Picard (0625 +0907, 0635 +0920); L; 5.

D) Present among a community dominated by Calothrix contarenii, La Gigi.

E) Yes; five freshwater pools, Île Picard; widespread.

014210 Lyngbya majuscula Harvey ex Gomont >16 ≤32 μm

A) Cell size range 18.8 to 30.5 μm, unstricted; sheath colourless, lamellate.

This is an example of where the computing system has split one species into two size ranges. The range of L. majuscula is 16.0 to 60.0 μm; two 'species' numbers split this range into >16 ≤32 μm and >32 μm.

B) Cell size range 16.0 to 60.0 μm, very short cells (sixth to fifth long as broad), end cell round; sheath up to 11.0 μm, colourless, lamellate.

Described as the typical marine form in the tropics (Java); cosmopolitan.

C) Île Picard (066 +101, 0650 +0937, 0635 +0920); L; 6.

D) Abundant among other algal communities; found in plankton in central parts of the lagoon.

E) Yes.

F) Considered as indicator species for the edge of the sublittoral, Raroia Atoll (Newhouse, 1954); lagoon shores, Curaçao (van den Hoek et al., 1971).

014211 Lyngbya martensiana Meneghini ex Gomont

- A) Average cell size 7.3 x 2.8 μm , unstricted, bright blue-green, granular at cross-walls; sheath colourless.
- B) Cell size range 6.0 to 10.0 μm (rarely 13.0 μm), unstricted, cross-walls sometimes granular, half to quarter as long as broad; sheath colourless.

Described from standing water, thermal springs, also on Patella and Lithophyllum.

- C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937), Grande Terre (3380 +0673, 0810 +0505); L; 11.
- D) Frequent among algal mat communities, never becoming abundant.
- E) Yes; five freshwater pools, Cinq Cases, Grande Terre; widespread and often abundant, either among other algae, or forming sheets as the dominant species.

014212 Lyngbya nordgardii Wille

- A) Cell size range 1.5 to 2.0 μm , typically 2.6 μm long, constricted cross-walls, round end cells; sheath colourless.
- B) Cell size range 1.5 to 2.0 μm , 1.0 to 1.5 as long as broad.

Recorded from the Norwegian and Californian coasts on Rhizoclonium.

- C) Île Picard (0610 +0895); L; 1.
- D) Present among other algal communities.
- E) No.

014214 Lyngbya pusilla (Rabenhorst) Hansgirg

- A) Cells $\leq 1 \mu\text{m}$, uncontracted, round end cell; sheath thin, colourless; erect and attached.
- B) Filaments $\leq 1.0 \mu\text{m}$, often only $74.0 \mu\text{m}$ long; thin, clear sheath.

Recorded from filaments of other algae (Czechoslovakia).

- C) Île Picard (0625 +0907), Grande Terre (3770 +0620); L; 14.
- D) Present among other algal communities.
- E) Yes; six freshwater pools, Île Picard; T 1, CC 9, Grande Terre.

Frequent epiphyte of Plectonema gloeophilum, Oedogonium and Pithophora.

014219 Lyngbya majuscula Harvey ex Gomont $>32 \mu\text{m}$

- A) Cell size range 32.0 to $45.0 \mu\text{m}$, commonly $45.0 \mu\text{m}$ long, uncontracted, pale yellow; thin, colourless sheath.
- B) This species has already been described, see 014210.
- C) Île Picard (066 +101, 0650 +0937), central lagoon; L; 25.
- D) Abundant in plankton of lagoon, often associated with Trichodesmium in floating flocks.
- E) No.
- F) Shores of Costa Rica and Nicaragua (Dawson, 1962); rocks, sand, silt and salt-pans, Curaçao (Koster, 1963).

014232 Lyngbya sp. $>1 \leq 2 \mu\text{m}$

A) Cell size range 1.5 to 1.6 μm , unstricted, pale blue-green; thin, colourless sheath.

L. subtilis W. West is probably the most suitable binomial.

B) Cell size range 1.5 to 1.8 μm , cells twice long as broad; thin colourless sheath.

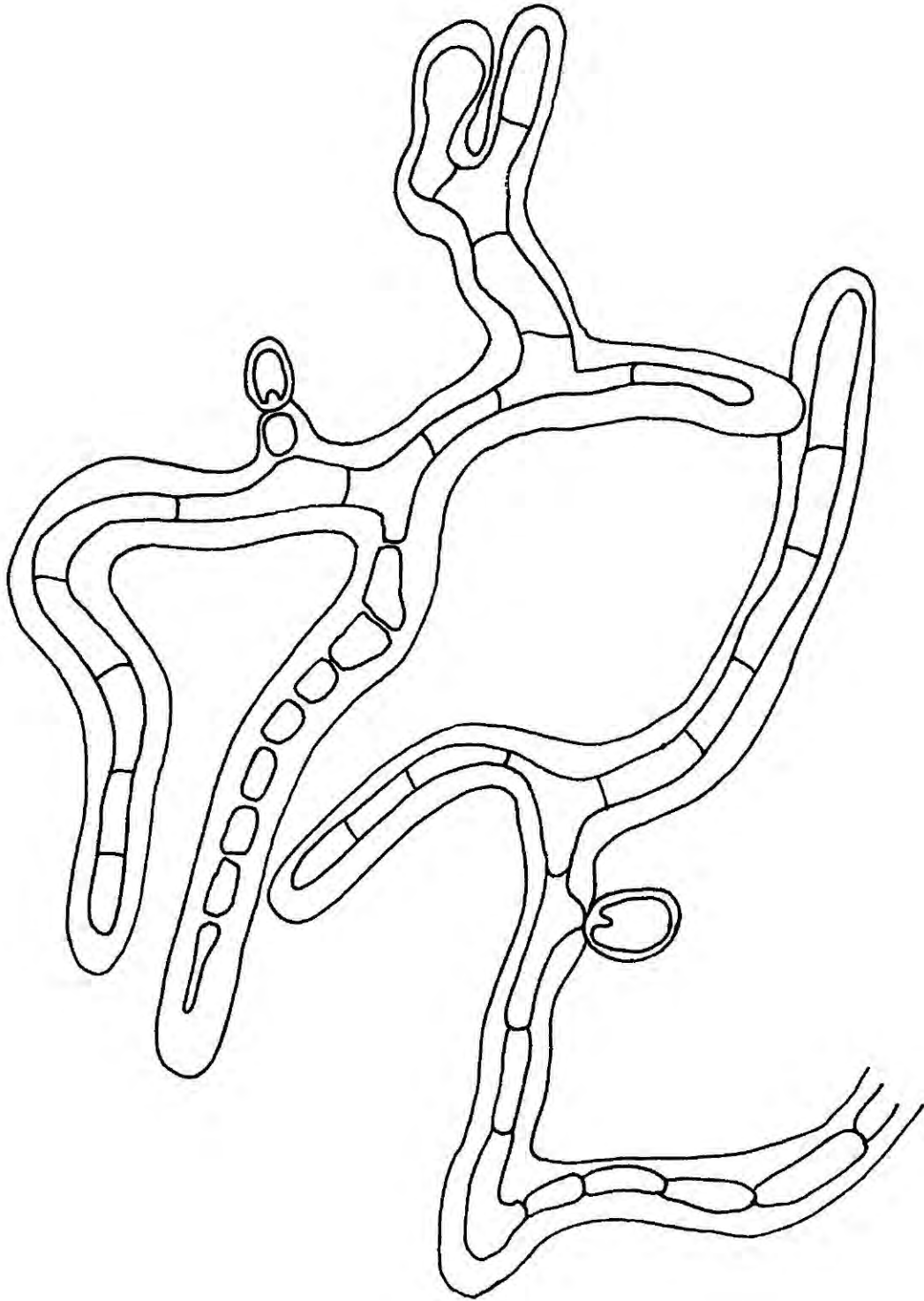
Recorded from the sea (Europe, Dominica, Java).

C) Île Picard (0650 +0937), Grande Terre (1120 +0280); L; 15.

D) Present among other algal communities.

E) No.

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5 μ m



Mastigocoleus testarum

014501 Mastigocoleus testarum Lagerheim

- A) Cell size range of intercalary cells 3.8 to 4.0 μm , at tips usually 3.0 μm , constricted; average width of filaments 8.3 μm ; ends of filaments never appear as tapered as any illustrations in the literature; sheath thin, colourless; average size of heterocysts 9.3 to 6.0 μm , sub-spherical. Thallus a dull yellow-brown.
- B) Cells size range 3.5 to 6.0 μm , cylindrical or sub-cylindrical; heterocysts broader than trichomes, 6.0 to 18.0 μm , terminal or lateral, rarely intercalary, 6.6 to 7.9 μm broad, 6.6 to 10.5 μm long. Thallus at first thin, blue-green or rose, perforating. Cosmopolitan on rocky shores (Atlantic, Jamaica, California); first described from mussel shells.
- C) Île Picard (0650 +0937, 066 +101, 061 +098), Île Malabar (2705 +1099, 3138 +1187, 145 +126, 139 +127, 1448 +1182, 185 +126, 253 +129), Grande Terre (360 +113, 3380 +0673, 2623 +037, 1858 +013, 404 +089, 1120 +0280), Île Sylvestre (114 +064); L+0; 50.
- D) Occasional in rocks of the mid intertidal and low intertidal zone of the lagoon and seaward coast.
- E) No.
- F) Rocks in the intertidal zone, Raroia Atoll (Newhouse, 1954); coasts of Clipperton Island, Pacific (Dawson, 1959); midlittoral zone, coasts near Marseille, France (Le Campion-Alsumard, 1969); endolithic in shells, Laesø Island, Denmark (Nielsen, 1972); Golubić and Le Campion-Alsumard (1973) have described the boring pattern of this alga.

014631 Merismopedia minima G. Beck $\leq 1 \mu\text{m}$

A) Average cell width $0.7 \mu\text{m}$.

I have extended the range to include cells up to $0.7 \mu\text{m}$.

B) Cell size range 0.5 to $0.6 \mu\text{m}$, four to many in colonies, pale blue-green.

Recorded from rocks in the Tyrol, also planktonic in pools near Bombay.

C) Grande Terre (3380 +0673); L; 3.

D) Present among other algal communities; recorded from only one location.

E) Yes; Grande Terre only.

014632 Merismopedia tenuissima Lemmermann $>1 \leq 2 \mu\text{m}$

A) Cell size range 1.8 to $2.0 \mu\text{m}$.

B) Cell size range 1.3 to $2.0 \mu\text{m}$, sub-spherical.

Described from standing water, other algae and surface plankton.

C) [^]Ile Picard (066 +101); L; 1.

D) Present among other algal communities at the inland tidal pool Bassin Lebine.

E) Yes; T 2, CC 5, Grande Terre only.

014633 Merismopedia punctata Meyen >2 ≤4 μm

A) Average cell width 3.3 μm.

B) Cell size range 2.5 to 3.5 μm, spherical or ovoid, pale blue-green.

Recorded from thermal springs, plankton of standing and brackish water.

C) Île Picard (066 +100); L; 3.

D) Present among other algal communities; recorded from only one locality.

E) Yes; W 2, Île Picard; the only record away from Grande Terre.

014634 Merismopedia glauca (Ehrenberg) Nägeli >4 ≤6 μm

A) Average cell width 5.6 μm.

This 'species' number excludes cells less than 4.0 μm.

B) Cell size range 3.0 to 6.0 μm, oval or spherical, closely arranged, bright blue-green.

Recorded from standing water, saltwater and other algae.

C) Île Picard (066 +101); L; 1.

D) Present among other algal communities; only one record from the inland tidal pool Bassin Lebine.

E) Yes; T 2, two freshwater pools, Cinq Cases; restricted to Grande Terre.

014635 Merismopedia littoralis (Oersted) Rabenhorst >6 ≤8 μm

A) Average cell width 6.8 μm.

B) Average cell width 7.0 μm, green; small colonies.

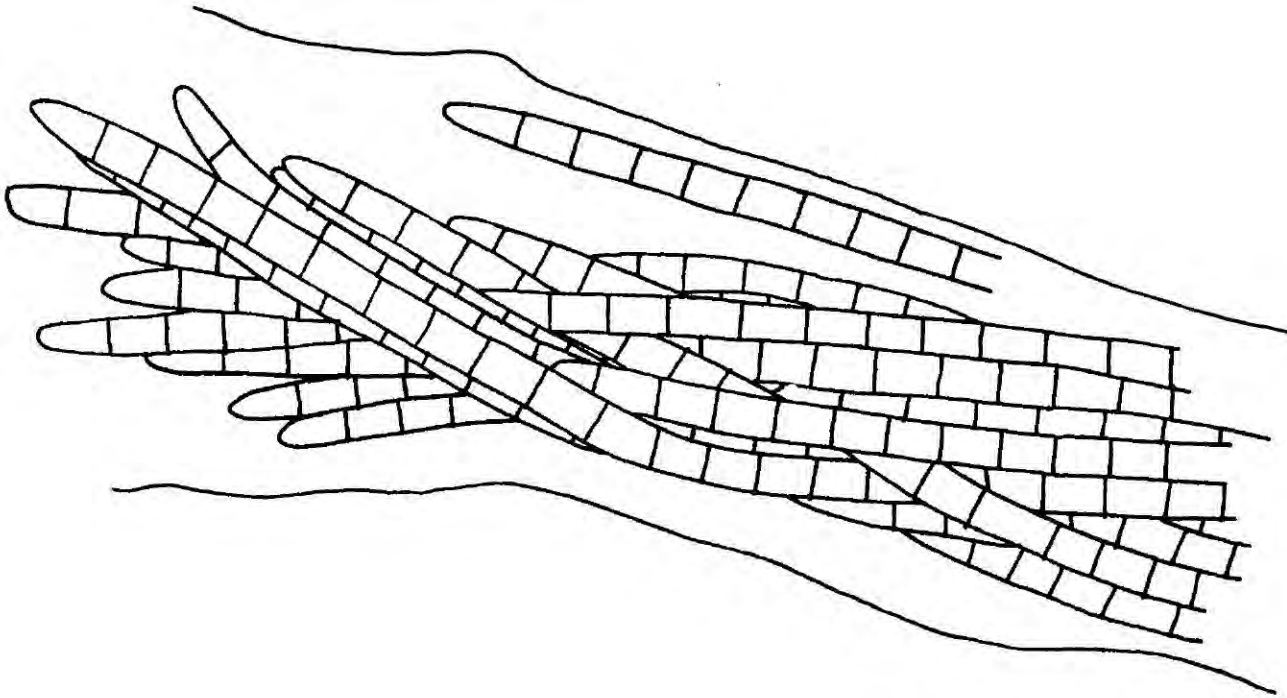
Described from saline waters, coasts of Denmark.

C) Île Picard (066 +101); L; 4.

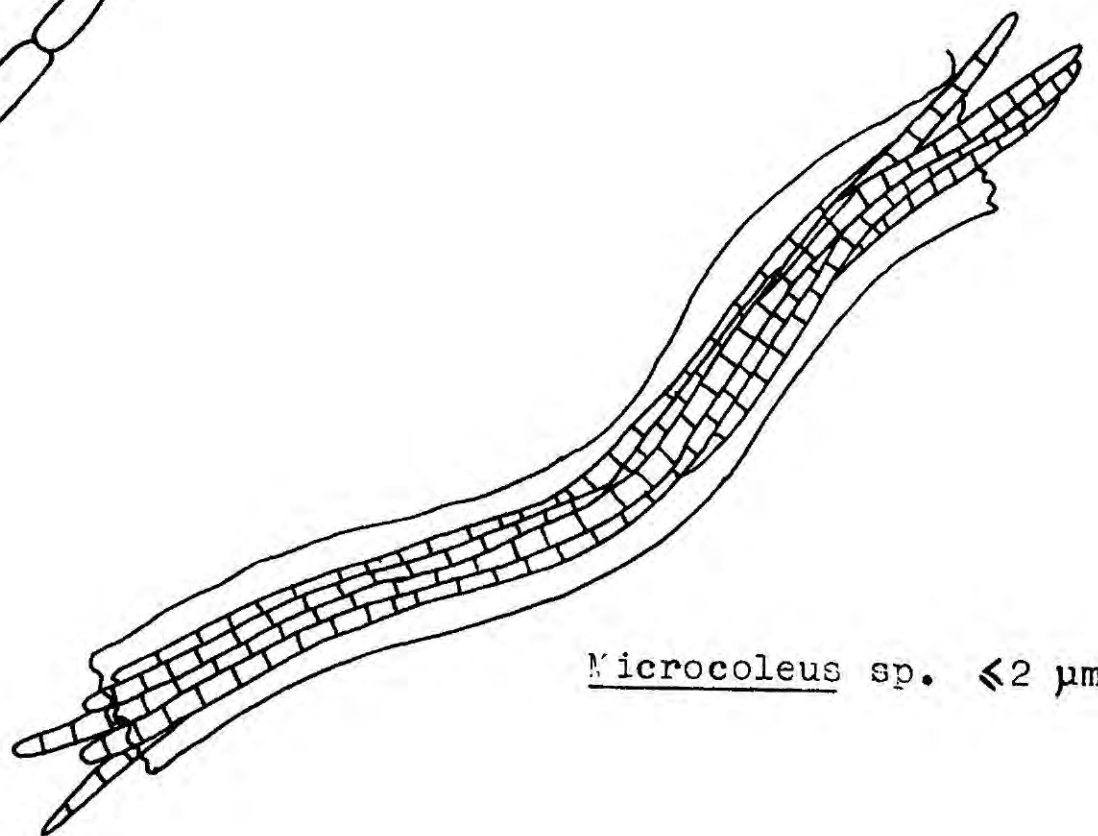
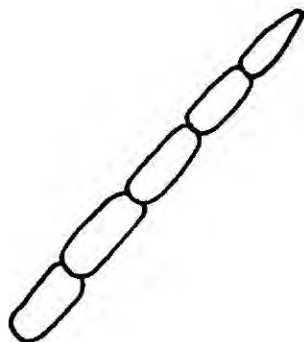
D) Present among other algal communities; only one record from Bassin Lebine.

E) No.

—
10 μm



Microcoleus chthonoplastes



Microcoleus sp. $\ll 2 \mu\text{m}$

014801 Microcoleus chthonoplastes Thuret ex Gomont

- A) Cell size range 3.6 to 6.0 μm , longer than broad, constricted, bright blue-green; filaments forming long sinuous bundles. Thallus bright blue-green, typically forming films up to 2 mm high.
- B) Cell size range 2.5 to 6.0 μm , up to two times longer than broad, blue-green, constricted at cross-walls; filaments single or forming expanded thallus; sheath seldom branched. Cosmopolitan in inland waters and saltwater as 'Meteorpapier'.
- C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937, 066 +101, 061 +098), Île Malabar (2705 +1099, 3138 +1187), Grande Terre (3770 +0620, 3380 +0673, 2623, +0433, 1858 +0287, 1120 +0280, 0810 +0505), Îles Moustique (9005 +5250); L+0; 50.
- D) Very abundant in many areas of the lagoon, typically forming bright green films over sediment; forms stratiform stromatolites with Schizothrix calcicola at Îles Moustique, covering areas of several km^2 .
- E) Yes; one freshwater pool, Île Picard; one freshwater pool, Cinq Cases, Grande Terre.
- F) Oceanic sandflats, North Carolina (Williams, 1950); intertidal habitats, El Salvador (Dawson, 1961); shores of Costa Rica and Nicaragua (Dawson, 1962); northwest coasts of Curaçao (Koster, 1963); lagoon shores, Curaçao (van den Hoek et al., 1971); stratiform stromatolites, Coorong Lagoon, South Australia (Walter et al., 1973); laminated mats, Mannar Lagoon, Sri Lanka (Gunatilaka, 1975); estuarine habitats, Bay Of Cadiz, Spain (1975, material collected by M. Tucker).

014831 Microcoleus tenerrimus Gomont

- A) Average cell size 1.5 x 3.0 μm , cross-walls constricted, granular, end cells conspicuously tapered and/or conical, bright blue-green.

I have extended the definition to include cells up to 3.0 μm long.

- B) Cell size range 1.5 to 2.0 μm , longer than broad, cross-walls constricted; end cell very tapered, not capped.

Described from rockpools, inland waters, on Rhodocorton rothii (Europe, North America, Australia).

- C) Île Picard (0635 +0920), Île Malabar (3138 +1187); L; 3.

- D) Frequent, usually occurring with Microcoleus chthonoplastes.

- E) No.

- F) Reefs, Île de la Tortue, Hispaniola (1937); lagoon shores, Curaçao (van den Hoek et al., 1971).

014851 Microcoleus sp. $\leq 2 \mu\text{m}$

- A) Cell size range 1.8 to 2.3 μm , cross-walls constricted, end cell rounded; filaments densely packed in bundles.

It was felt that this material was quite distinct from Microcoleus tenerrimus. The definition of $\leq 2 \mu\text{m}$ is also extended to include cells up to 2.3 μm .

- C) Île Picard (0625 +0920); L; 2.

- D) Present among other algal communities, usually those dominated by Schizothrix calcicola.

- E) No.

014852 Microcoleus sp. $>2 \leq 4 \mu\text{m}$

A) Cell size range 2.8 to 3.8 μm , cells wide apart, end cell conical and bent to one side.

There is no particularly suitable binomial for this material, the closest is M. sociatus.

B) Cell size range 2.7 to 3.0 μm , 2 to 3 times longer than broad, cross-walls constricted, end cell up to 5 times longer than broad, end cell rounded and pointed.

Described from damp soil in Turkey and Angola.

C) Île Picard (066 +101); L; 4.

D) Frequent among other algal communities, Bassin Lebine.

E) Yes; W 7, Île Picard; the only record; occasional never abundant.

014854 Microcoleus sp. $>6 \leq 8 \mu\text{m}$

A) Average cell size 7.0 to 7.3 x 10.0 μm , slight constriction; filaments forming bundles up to 37.5 μm ; sheath thick, colourless.

M. subtorulosus (Bréb.) Gomont, would be the most suitable binomial here, but cells in the range $>8 \mu\text{m}$ would be excluded by the 'species' number range.

B) Cell size range 6.0 to 10.0 μm , 5.0 to 10.0 μm long, sometimes barrel shaped, cross-walls constricted; end cell round.

Described from standing water and aquatic plants, Europe, Florida.

C) Île Picard (061 +098, 066 +101); L; 4.

D) Frequent among other algal communities; among Microcoleus spp. at Bassin Lebine.

E) No.

014855 Microcoleus sp. >8 μm

A) Average cell size 8.0 to 8.1 x 4.3 μm , constricted, end cell up to 15.0 μm long, conical and pointed, bright blue-green; many filaments in bundles, up to 125 μm wide; sheath up to 12.5 μm .

M. acutirostris (Cramer) Gomont is the closest binomial; the size limits for this species are 9.0 to 11.0 μm , and the cells are unconstricted. M. weeksii Setchell et Gardner has widths of 7.0 to 8.0 μm , but the upper length of the cells is 2.5 μm .

C) Grande Terre (3770 +0620); L; 6.

D) Very abundant at Cinq Cases as green films over the surface of sediment in the extreme upper intertidal zone.

E) No.

014903 Microcystis reinboldii (Richter) Forti

A) Cell size range 3.2 to 4.0 μm , spherical, bright blue-green, no gas vacuoles.

B) Cell size range 3.0 to 4.0 μm , spherical and long, bright blue-green, no gas vacuoles; colony up to 50.0 μm .

Described from sand, pebbles and beaches, Baltic Sea.

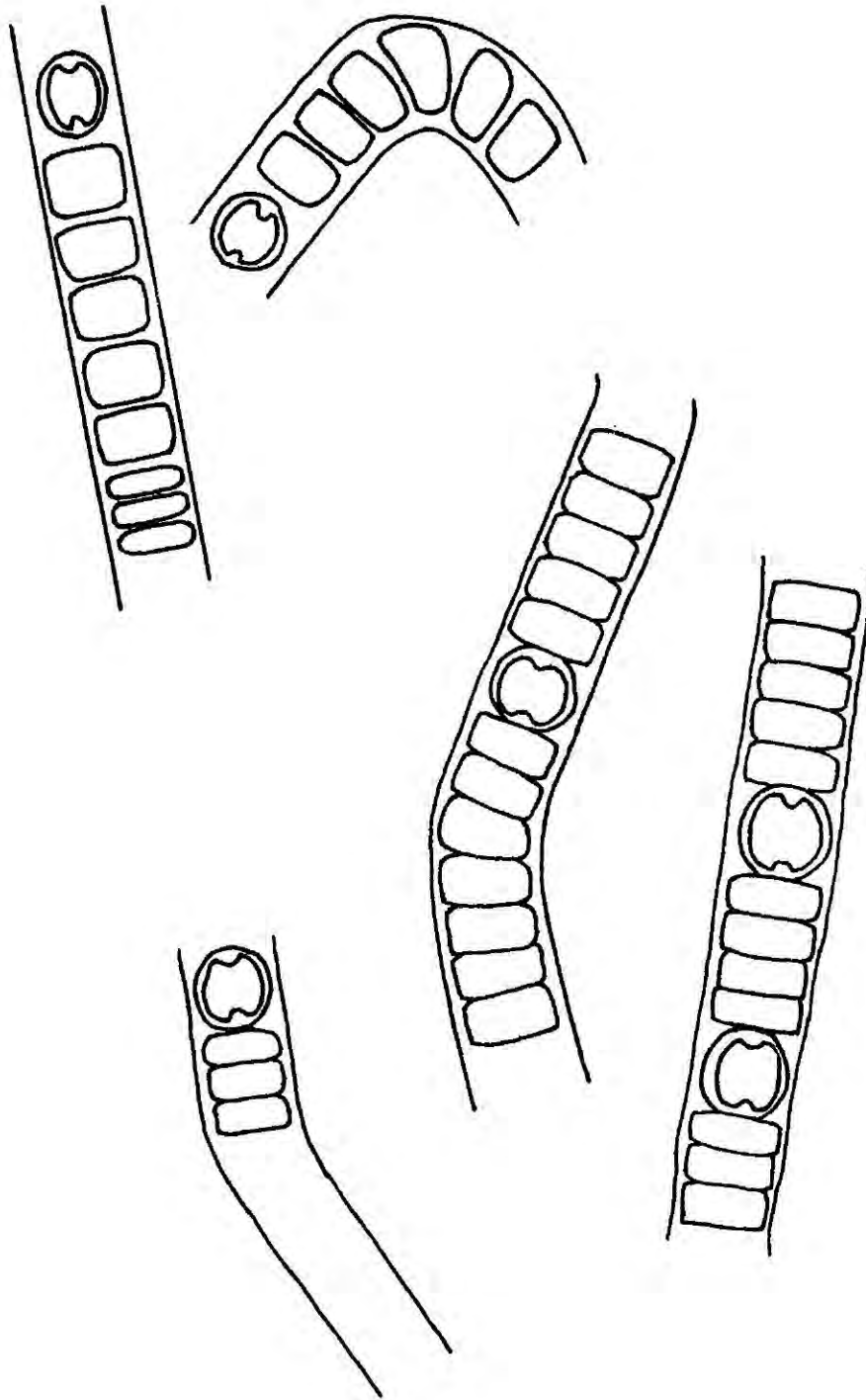
C) Île Picard (0635 +0920, 058 +092); L+0; 5.

D) Abundant at La Gigi where it colours much of the open beach flat green, together with Hyella balani ; abundant in beach rock in front of Settlement.

E) No; but Microcystis flos-aquae noted on Grande Terre.

F) Coasts of Europe, Frémy (1933).

—
10 μm



Nodularia spumigena

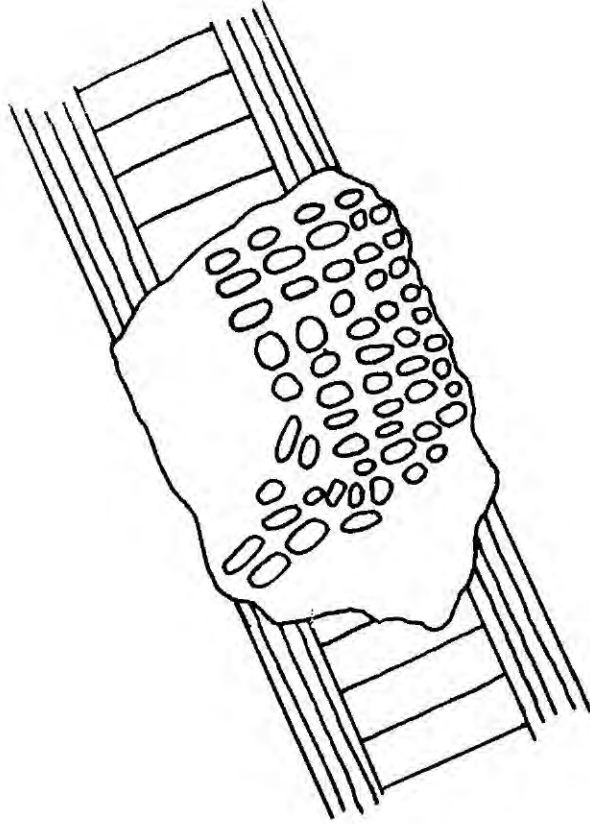
015101 Nodularia harveyana Thuret

- A) Average cell size 3.6 μm , barrel shaped; heterocysts spherical; average filament width 5.6 μm .
- B) Spores 2 to 16 in number, barrel shaped; heterocysts spherical, broader than vegetative cells; filament size range 4.0 to 5.0 μm , straight; sheath thin and colourless.
- Described from standing water, thermal springs (North America, Europe, Java).
- C) [^]Ile Picard (plankton sample from the lagoon coast); L; 3.
- D) Present in plankton samples from the lagoon.
- E) No.

015102 Nodularia spumigena Mertens ex Bornet et Flahault

- A) Average cell size 7.0 x 3.8 μm , regular shape, light yellow-green to blue-green; intercalary heterocysts, typically 7.5 x 3.8 μm ; average filament width 10.0 μm ; sheath up to 1.3 μm , firm, non-lamellate, colourless.
- B) Cells short, discoid, third to quarter as long as broad, heterocysts broader than vegetative cells; spores in series, seldom one, sub-spherical, 12.0 μm x 8.0 to 9.0 μm long; episporos yellow-brown.
- Described from saltwater environments (Australia, Europe and North America).
- C) [^]Ile Picard (0635 +0920); L; 3.
- D) Present among Scytonema mats from the lagoon beach of La Gigi.
- E) No.

—
10 μm



Oncobyrsa rivularis

015402 Oncobyrsa rivularis (Kützing) Meneghini

A) Average cell size 6.0 x 3.0 μm , elongate or spherical, in definite rows.

Thallus forming a 'collar' around host filaments.

B) Cell size range 1.3 to 3.5 x 6.0 μm , usually isodiametric; filaments usually 1.3 to 6.0 μm wide.

Thallus blue, violet or brown.

Described from rocks, filamentous algae, mosses (particularly Fontinalis), in stagnant water (Europe, North America, Equatorial Africa).

C) Île Picard (0625 +0907); L; 3.

D) Present as an epiphyte on filaments of Scytonema sp.

E) No.

015519 Oscillatoria nigro-viridis Thwaites ex Gomont

A) Average cell size 11.3 x 3.8 μm , slight or no constriction, granular, motile, dull purple, end cell 'nipped' at apex.
I have extended the definition of this species from 11.0 to 11.3 μm , for the upper limit of width.

B) Cell size range 7.0 to 11.0 μm , constricted, bent at ends, attenuated, 3.0 to 5.0 μm long.

Cosmopolitan on rocks and walls, and also piers along sea coasts.

C) [^]Ile Picard (066 +101); L; 3.

D) Very abundant in tidal depressions at Bassin Cabri, [^]Ile Picard; dark brown films over the surface of sediment.

E) No.

015532 Oscillatoria sp. $>2 \leq 4 \mu\text{m}$

A) Average cell size 2.8 μm , slightly longer than broad, constricted, generally quadratic, end cell hooked, tapered.
The closest binomial for this species is O. schultzii Lemm.; the upper limit for this species is 2.6 μm .

C) [^]Ile Picard (0625 +0907, 0635 +0920); L; 1.

D) Present among other algal communities dominated by Microcoleus chthonoplastes.

E) No.

015732 Phormidium molle (Kützing) Gomont >2 ≤4 μm

- A) Cell size range 3.1 to 3.3 x 3.1 μm, some cells up to 7.5 μm long, constricted, end cell slightly conical with a single refractive granule at the tip; sheath thin, colourless.
- B) Cell size range 2.7 to 3.3 μm x 3.0 to 7.8 μm, constricted, end cell rounded, calyptra absent.

Thallus mucilaginous, thin, light blue-green.

recorded from stagnant water, on leaves of aquatic plants, surface of shells (snails), damp rocks and soil (Europe, Africa, Madagascar).

- C) Île Picard (0625 +0907), Grande Terre (1120 +0280), Île Malabar (3138 +1187); L; 4.
- D) Very abundant at Passe Houareau, forming bright green films over the surface of silt in tidal depressions.
- E) Yes; three freshwater pools, Île Picard; T 2, Grande Terre.

015733 Phormidium submembranaceum (Ard. et Straff) Gomont

A) Average cell size 5.0 x up to 10.0 μm , slightly constricted, slight calyptra, pale blue-green.

B) Average cell size 5.0 μm , cells subquadrate, 4.0 to 10.0 μm , constricted, depressed, rounded calyptra.

Thallus membranous, leathery, dull green.

Recorded from rocks along European and North American coasts.

C) Île Picard (0635 +0920, 0650 +0937); L; 3.

D) Abundant among other algal communities dominated by Lyngbya confervoides and L. martensiana, at the base of champignon islets, La Gigi.

E) No.

015734 Phormidium sp. >6 <8 μm

A) Cell size range 6.8 to 7.0 x 5.0 μm, slightly constricted, end cell tapered and conical, bent to one side, non-capitate; thin, colourless sheath.

Thallus gelatinous, dark brown to black.

There appears to be no particularly suitable binomial for this material; for the 'species' number range, Phormidium ceylanicum Wille could be used.

B) Cell size range 7.0 to 9.0 μm, as long as broad or a half to third long as broad, slightly constricted, end cells slightly tapered, non-capitate, calyptra absent.

Thallus olive blue-green or dull green.

Recorded from moss on trees, Sri Lanka.

C) [^]Ile Picard (061 +098, 066 +101); L; 1.

D) Very abundant over silt in tidal depressions as thin, dark coloured sheets.

E) No.

018301 Placoma vesiculosa Schousboe

- A) Cell size range 3.8 to 4.0 μm , 'Gloeocapsa'- like in appearance, in dense arrays, rows towards periphery of colony dark brown.
Colonies macroscopic, light brown, gelatinous when wet and 'currant' shaped.
- B) Cells of average size \approx 4.0 μm ; sheath at periphery of colony firm, mostly coloured yellow-brown, in the inside gelatinous and diffluent, soft, colourless.
Thallus gelatinous, hemispherical, irregularly folded, hollow in the inside, when old, expanded; cells in soft balloon shaped, concentric sheaths.
Recorded from rocks in the spray zone of rocky coasts (North Africa).
- C) Grande Terre (1858 +0287); L; 2.
- D) Abundant as separate colonies in the upper intertidal zone, lagoon landing to Dune d'Messe; colonies conspicuous; the only record.
- E) No.
- F) Coasts near Marseille, France (Le Campion-Alsumard, 1969).
This author recorded this species from the highest part of the supralittoral zone, showing a seasonal variation in its abundance, probably correlated with wave action, and the inability of colonies to remain fixed during strong wave action. She considered this a distinct species.

015801 Plectonema battersii Gomont

- A) Cell size range 2.5 to 3.1 μm , pale blue-green; sheath thin, colourless.
- B) Cell size range 2.0 to 3.5 μm , slightly tapered towards end of trichome, end cell rounded, cells up to quarter long as broad; sheath thin, colourless.
Described from rocks of the coasts of England, Norway and North America.
- C) Île Picard (061 +098); L; 3.
- D) Very abundant as bright green sheets over the surface of silt, tidal depressions, 'back' path.
- E) No.
- F) Epilithic over rocks, intertidal zone, Marseille (Le Campion-Alsumard, 1969).

015810 Plectonema nostocorum Bornet ex Gomont

A) Average cell size 2.0 x 6.0 μm , unstricted, branched, round end cell; sheath thin, colourless.

I have extended the definition of this species to include cells up to 2.0 μm wide and 6.0 μm long.

B) Cell size range 1.0 to 1.5 μm , 2.0 to 2.5 μm long, constricted end cell rounded.

Recorded from the mucilage of Nostoc muscorum and other algae, in warm waters, sometimes in brooks; cosmopolitan.

C) Île Picard (066 +101); L; 5.

D) Present in the sheaths of Calothrix spp. and Rivularia spp., Bassin Lebine.

E) No.

F) Oceanic sandflats, North Carolina (Williams, 1950); from the surface of leaves of Eleocharis sp., Onotoa Atoll (Moul, 1957); beachrock, Clipperton Island, Pacific (Dawson, 1959).

015811 Plectonema notatum Schmidle

A) Cell size range 1.8 to 2.3 x 3.8 μm , unstricted, granule at cross-walls, bright blue-green.

I have extended the definition to include cells of width up to 2.3 μm .

B) Cell size range 1.7 to 2.0 μm , false branching sparse, 2 to 3 times longer than broad, unstricted, two granules at the cross-wall, end cell rounded, pale blue-green.

Recorded from a spring trough.

C) Île Picard (0625 +0907, 0635 +0920); L; 1.

D) Present among Scytonema mats, La Gigi.

E) Yes; W 9, Île Picard; CC 9, Cinq Cases, Grande Terre.

015814 Plectonema terebrans Bornet et Flahault

- A) Cell size range 1.0 to 1.8 μm , unstricted, round end cell; filaments branched, bright blue-green; sheath thin, colourless.

I have extended the definition of this species to include cells up to 1.8 μm , and also an endolithic habit in rocks as well as shells, as well as among other algal communities not as endolith.

Frémy (1933) gives details of a species P. endolithicum Ercegović; this species has a size range more suitable to the Aldabra material and is endolithic in rocks of the lower intertidal zone. However, Frémy concludes that this alga does not differ essentially from P. terebrans, and that it may simply be a form of P. terebrans. I follow his view in this instance and prefer to extend the definition, rather than use P. endolithicum.

- B) Cell size range 0.95 to 1.5 μm , 2.0 to 6.0 μm long, unstricted, granule at either side of the cross-wall, end cells rounded.

Recorded from salt water habitats in the shells of mussels, coasts of Europe, North America, Sumatra and Africa; from freshwater habitats in the shells of Unio sp.

- C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 058 +092), Grande Terre (1858 +0130), Île Sylvestre (114 +064); L+0; 13.
- D) Abundant in rocks of the intertidal zone, both inside the lagoon and on the seaward coast. Present among other algal communities, particularly sand dune crusts dominated by

Polypothrix and Microcoleus.

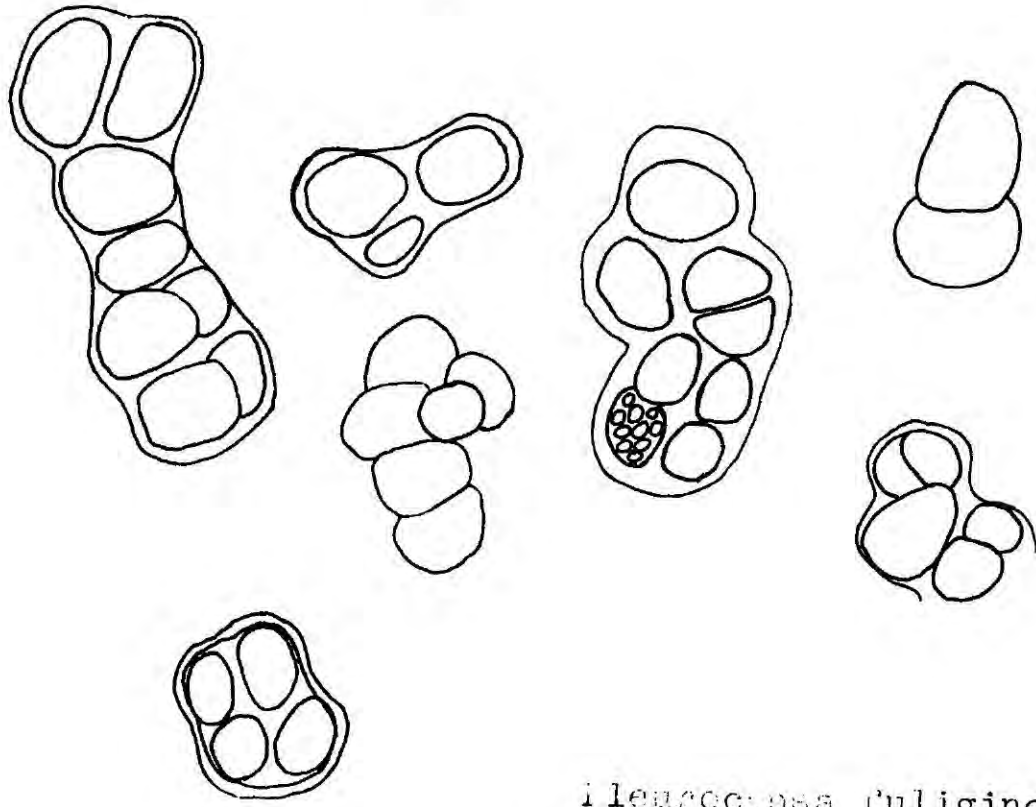
E) No.

F) Perforating shells below the low tide level, Raroia Atoll (Newhouse, 1954); crusts on coral sand, Clipperton Island (Dawson, 1959); endolithic in rocks, coasts near Marseille (Le Campion-Alsumard, 1969); endolithic in shells, Laesø Island, Denmark (Nielsen, 1972); mid intertidal zone, coasts near Marseille (Le Campion-Alsumard, 1975).

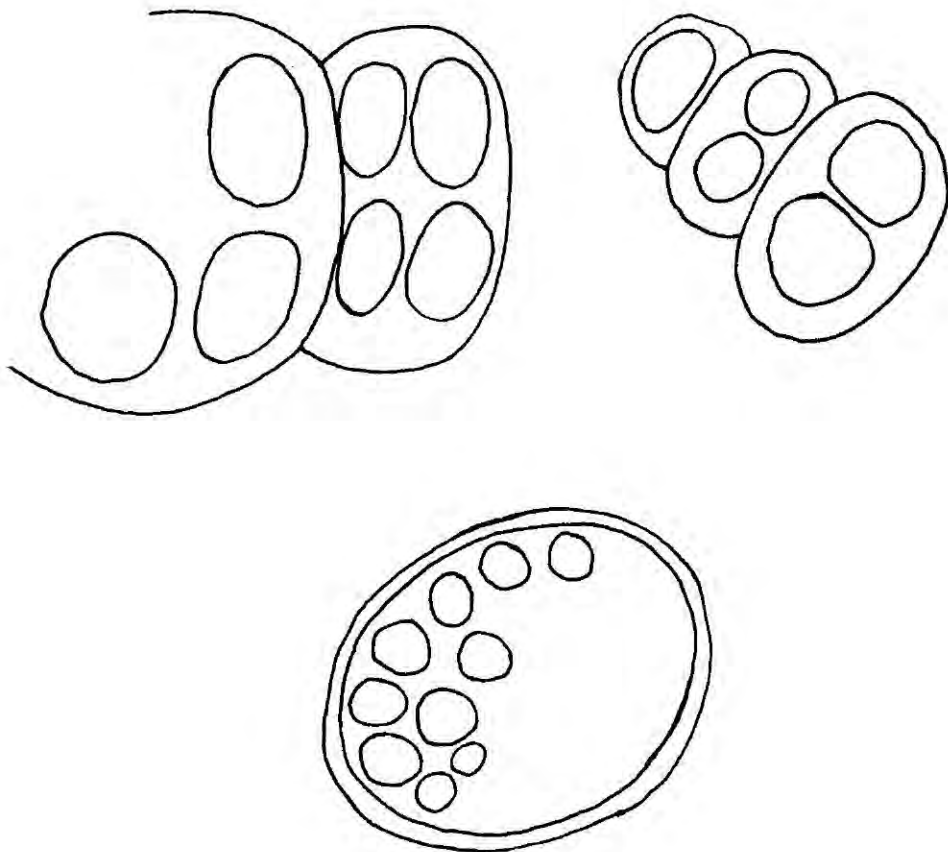
015850 Plectonema sp.

- A) Average cell size 2.5 μm , cells long as broad, constricted, bright blue-green; average width of filaments 5.0 μm .
There appears to be no suitable binomial which can be applied to this material.
- C) Grande Terre (1120 +0280); L; 1.
- D) Abundant over rock in the upper intertidal zone; with Pleurocapsa forming a dark colouration to the rock at Gros Îlot Cavalier.
- E) No.

—
5 μ m



Aleurocapsa fuliginosa



Aleurocapsa crepidinum

015932 Pleurocapsa fuliginosa Hauck >4 ≤8 μm

A) Average cell size 6.3 μm, spherical, dark violet, sometimes pale yellow-green; sheath colourless.

Geitler (1932) gives the size range for this species as 5.0 to 20.0 μm, whereas Frémy (1933) gives the range as 2.0 to 4.0 μm.

B) Cell size range 5.0 to 20.0 μm, single or in groups of 2 to 4, gold, red-brown or dark violet.

recorded from rocks in the intertidal zone, Adriatic, Baltic Sea, Trondheimfjord.

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937, 061 +098), Île Malabar (2705 +1099, 3138 +1187), Grande Terre (3770 +0620, 3380 +0673, 2623 +037, 1120 +0280), Île Sylvestre (114 +064), Îles Moustique (9005 +5250); L+0; 67.

D) Frequent or abundant among other algal communities, widespread distribution inside the lagoon.

E) No.

015933 Pleurocapsa crepidinum Collins >8 ≤16 μm

A) Cell size range 8.3 to 12.5 μm, pale green; sheath black-violet, becoming red on treatment with acid; endospores up to 3.0 μm.

Thallus forming a thin black crust (≤1 mm) in exposed situation, pale yellow-brown where shaded.

P. crepidinum has a cell range outside the 'species' number size range, thus cells ≤8 μm would be excluded.

B) Cell size range 5.0 to 15.0 μm, spherical or polygonal; sheath thin, clear; endospores c 2.0 μm.

Recorded from rocks, algae and shells of Balanus, North American coasts.

C) Île Picard (0635 +0937, 0650 +0937, 058 +092, 066 +101, 061 +098), Île Malabar (1448 +1182), Grande Terre (2623 +0433, 3380 +0673), Îles Moustique (9005 +5250); L+0; 30.

D) Very abundant over rocks in the upper intertidal zone, often forming crusts.

E) No.

015934 Pleurocapsa sp. >16 μm

A) Average cell size 17.5 μm ; numerous endospores.

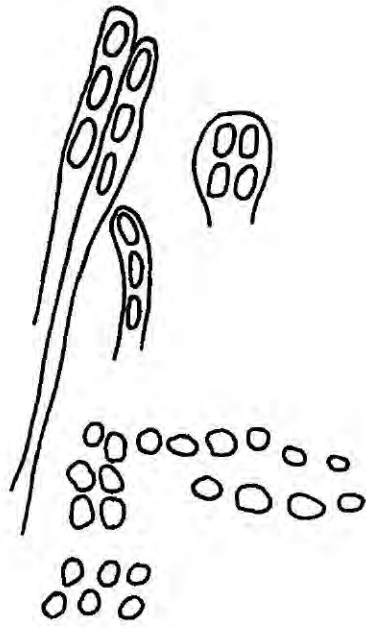
Because of the form of the cells the closest binomial is P. magna Weber van Bosse, but as the lower cell size for this species is 18.0 μm , the Aldabra material would be excluded. P. fuliginosa would also be suitable, but this binomial has already been applied to 015932. I take the view that these cells of 17.5 μm , are the same species as $>8 \leq 16 \mu\text{m}$, the computer system is in fact producing an artifact of two separate species.

C) Île Picard (0635 +0920); L; 1.

D) Present among a community dominated by Calothrix contarenii,
La Gigi.

E) No.

—
10 μm



Radaisia epiphytica

016303 Radaisia epiphytica Setchell et Gardner

A) Average cell size 2.5 μm , spherical or elongate, in rows;
Thallus brown.

I have extended the definition to include cells in the lower
size range of 2.5 to 3.0 μm .

B) Cell size range 3.0 to 5.0 μm , blue-green; endospores 1.8
to 2.4 μm .

Thallus forming crusts.

Recorded from Iridae minor, the California Coast.

C) Îles Moustique (9005 5250); L; 5.

D) Present as an epiphyte on filaments of Scytonema sp.

E) No; but Radaisia cornuana Sauv. recorded as an epiphyte from
two freshwater pools, Île Picard.

016569 Rivularia sp. A

A) Average cell size 8.8 x 15.0 μm , longer than broad, shape of basal cell not known, basal swelling not known, cell constriction not known; heterocysts wider than basal cell, position of heterocysts not known, width of heterocyst usually same as the length or greater than the length; arrangement of trichomes not known; shape of sheath not known, texture not known, sheath width $>2 \leq 4 \mu\text{m}$, colour not known, non-lamellate, lacerations not known; spores not known.

Small, black, shiny hemispherical colonies; height of colony $>4 \leq 8 \text{ mm}$, colonies non-confluent, solid, calcification moderate to slight, distribution of CaCO_3 not known, firm texture.

There is no suitable binomial that can be applied to this material.

C) [^]Île Picard (066 +101), Grande Terre (1858 +0287); L; 2.

D) At Bassin Lebine this species forms small, shiny colonies over the surface of silt at the periphery of the Bassin; the species is very abundant along the southern coast of the lagoon, forming hemispherical colonies over the surface of silt covered limestone hummocks, slightly calcified (Fig. 3.1d).

E) No.

016570 Rivularia sp. B

A) Cell size range $>4 \leq 8 \mu\text{m}$, average length $3.8 \mu\text{m}$, shorter than broad, swelling at base not known, constricted; width of heterocysts not known, position of heterocysts not known; trichomes in bundles, closely appressed, tapered towards apex; hair absent; sheath parallel and close to the trichome, texture not known, width $\leq 2 \mu\text{m}$, yellow-brown, non-lamellate, lacerations not known; spores not known. Forming small, black, shiny, hemispherical colonies, height $>1 \leq 2 \text{ mm}$, non-confluent, solid, moderate to slight calcification, distribution of CaCO_3 not known, texture hard to firm.

No suitable binomial can be applied to this material.

C) Île Picard (066 +101); L; 2.

D) Only recorded on one occasion at the periphery of the the standing water left at low tide, Bassin Lebine.

E) No.

016571 Rivularia sp. C

A) Average cell size $5.6 \times 2.5 \mu\text{m}$, shorter than broad, base of trichome not swollen, constriction not known, width of basal cell with respect to the heterocyst not known, number of heterocysts not known, position of heterocysts not known, shape of basal heterocyst not known; arrangement of trichomes not known, tapering towards the apex, hair short; shape of sheath not known, texture not known, width $\leq 2 \mu\text{m}$, colour purple to violet, lamellation not known, lacerations not known; spores not known.

Forming hemispherical colonies, height not known, colonies non-confluent, solid, calcification moderate, distribution of CaCO_3 not known, texture firm.

No suitable binomial can be applied to this material.

C) Grande Terre (1858 +013); 0; 1.

D) Recorded from only one locality, over rocks and among calcified barnacles, seaward coast, Dune d'Messe.

E) No.

016571 Rivularia sp. D

A) Average cell size 8.5 x 2.5 μm , shorter than broad, non-swollen at base, constriction not known; width of heterocyst greater than basal cell, number of heterocysts not known, position of heterocysts not known; arrangement of trichomes not known, tapering abrupt, presence of hair not known; shape of sheath not known, texture not known, width up to 1.0 μm , colourless, non-lamellate, lacerations not known; spores not known.

Forming brown, hemispherical colonies, height not known, confluence not known, hollowness not known, calcification not known, distribution of CaCO_3 not known, texture not known.

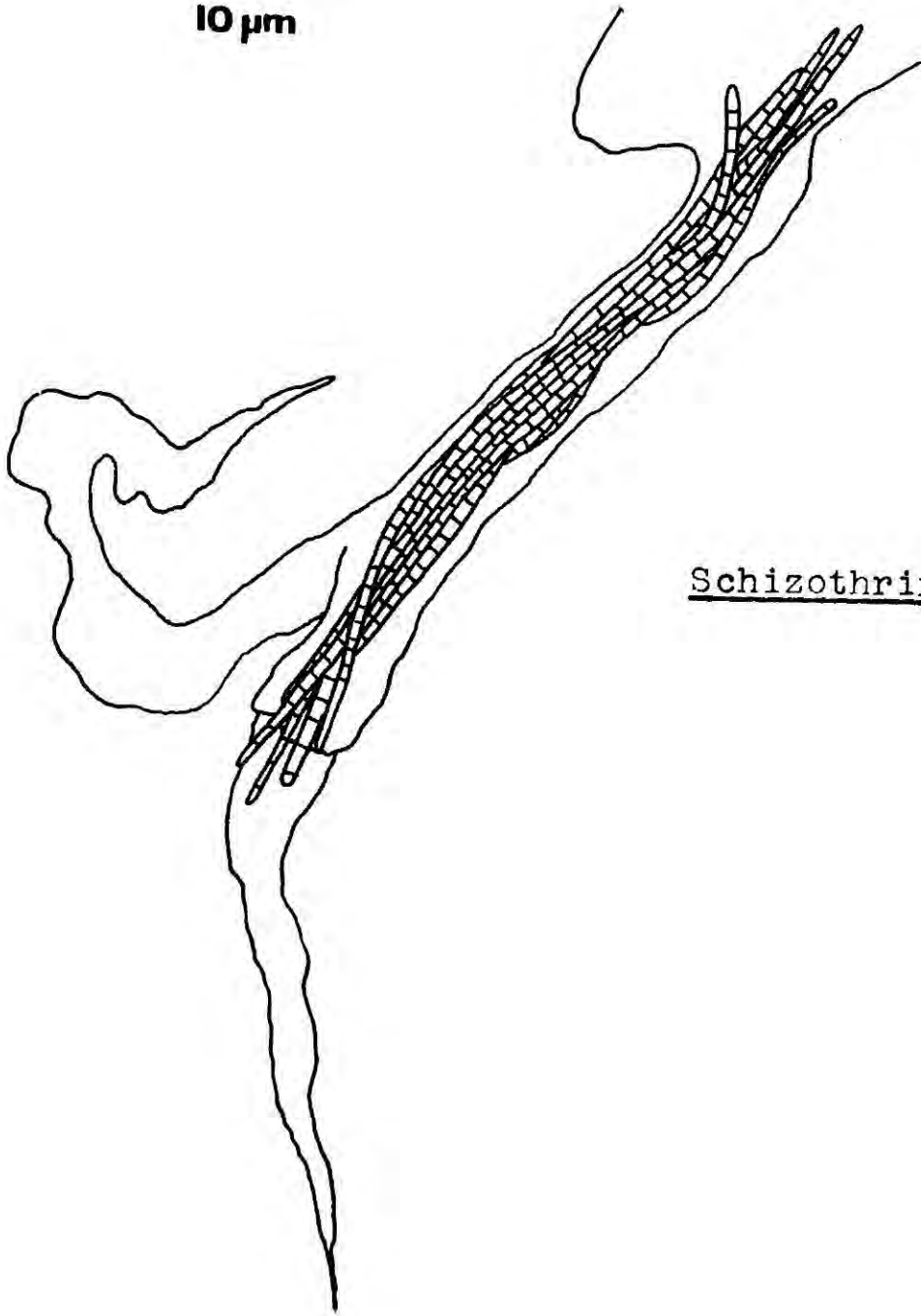
No suitable binomial can be applied to this material

C) Île Picard (058 +092); 0; 1.

D) recorded from only one location, over rocks and beachrock in front of Settlement, the seaward facing coast, Île Picard.

E) No.

—
10 μ m



Schizothrix arenaria

016602 Schizothrix arenaria (Berk.) Gomont

- A) Average cell size 1.5 x 3.0 μm , sometimes up to 3 times longer than broad, constricted, granular, end cells tapered, and/or conical, bright blue-green; sheaths branched and pointed at tips; filaments in bundles up to 8.8 μm .
- B) Cell size range 1.5 to 3.0 μm , cells up to 5.0 μm , constricted or unconstricted, end cell pointed and conical; sheath firm, pointed at ends, in lower portions thick and lamellate.
- Cosmopolitan; recorded from damp earth and rocks.
- C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937, 061 +098), Île Malabar (2705 +1099, 3138 +1187), Grande Terre (2623 +0433); L; 16.
- D) Abundant among other algal communities, especially those dominated by Schizothrix calcicola.
- E) Yes; two freshwater pools, Île Picard; rare elsewhere.

016604 Schizothrix calcicola (Agardh) Gomont

A) Average width of cells 1.8 μm , round end cell; trichomes usually indistinct.

I have extended the definition of this species to include cells up to 1.8 μm .

B) Cell size range 1.0 to 1.7 μm , unconstricted, sometimes granular, 2.0 to 6.0 μm long, bright blue-green.

Colony sometimes flesh coloured to dark green.

Recorded from damp rocks, often in greenhouses and thermal springs; cosmopolitan.

C) Île Picard (0625 +0907, 0635 +0920, 0650 +0937, 058 +092),
Île Malabar (2705 +1099, 3138 +1187, 1448 +1182, 139 +127),
Grande Terre (1858 +0287, 2623 +0433, 3770 +0620, 2623 +037),
Île Sylvestre (114 +064); L+0; 46.

D) Very abundant at Îles Moustique, forming stratiform stromatolites with Microcoleus chthonoplastes, elsewhere very abundant as the dominant species in pink coloured crusts and mats.

E) Yes; W 4 only, Île Picard.

F) Coasts of Costa Rica and Nicaragua (Dawson, 1962); littoral habitats, Oahu, Pacific (Khan, 1969); subtidal habitats, Bermuda (Sharp, 1969); supralittoral habitats, coasts near Marseille (Le Campion-Alsumard, 1969); lagoon shores, Curaçao (van den Hoek et al., 1971).

016626 Schizothrix minuta (Hansgirg) Forti

- A) Cells $\leq 1 \mu\text{m}$, pale green; forming bundles of $\approx 8.1 \mu\text{m}$;
sheaths branched, dispersed, colourless.
- B) Filament width size 0.4 to 0.7 μm , 1 to 2 times longer than
broad; bright blue-green.

Thallus slimy.

Recorded from Adriatic coasts and the Dalmatian Coast.

- C) Grande Terre (1120 +0280); L; 6.
- D) Present among a community dominated by Spirulina subsalsa,
base of a residual islet, Gros Îlot Cavalier.
- E) No.

016627 Schizothrix gracilis Golubić

A) Average cell width 1.3 μm , cells indistinct, colourless to pale blue-green.

Colonies forming globular stromatolites, up to 3 cm in diameter, purple in colour, showing distinct lamellation in section.

B) Cell size range 1.0 to 1.8 μm , slightly constricted at cross-walls, pale blue-green, 2.0 to 8.5 μm long; sheaths hyaline, firm, thick or diffluent; filaments 3.0 to 12.0 μm wide.

Thallus semi-globose, forming nodules and hollow crenules.

Described from well drained algal mats; emersion zone of hypersaline lakes at Coorong Lagoon, South Australia; intertidal zone of the Florida Keys, Bahamas, Persian Gulf.

C) Grande Terre (1120 +0280); L; 1.

D) Very abundant at one locality, intertidal carbonate mudflats, Gros Îlot Cavalier, closely associated with a surface crust of Microcoleus chthonoplastes.

E) No.

F) Coorong Lagoon, South Australia (Walter et al., 1973).

016732 Scytonema endolithicum Ercegović >8 ≤12 μm

A) Average cell size 8.1 x 3.2 μm, shorter than broad, constricted; heterocysts spherical or flattened, 6.4 μm; filament size range 9.6 to 11.3 μm, slightly swollen at ends; sheath brown or colourless, not distinctly lamellate. Thallus visible over rock surfaces as a dull brown colour, penetrating filaments visible in rock as a green colour.

B) Cell size range 8.0 to 10.0 μm, thickened towards ends of trichome, shorter than broad, cylindrical; sheath yellow, slightly lamellate; filaments epilithic and endolithic, 14.0 to 20.0 μm.

Described from rocks in the upper intertidal zone, Dalmatian Coast.

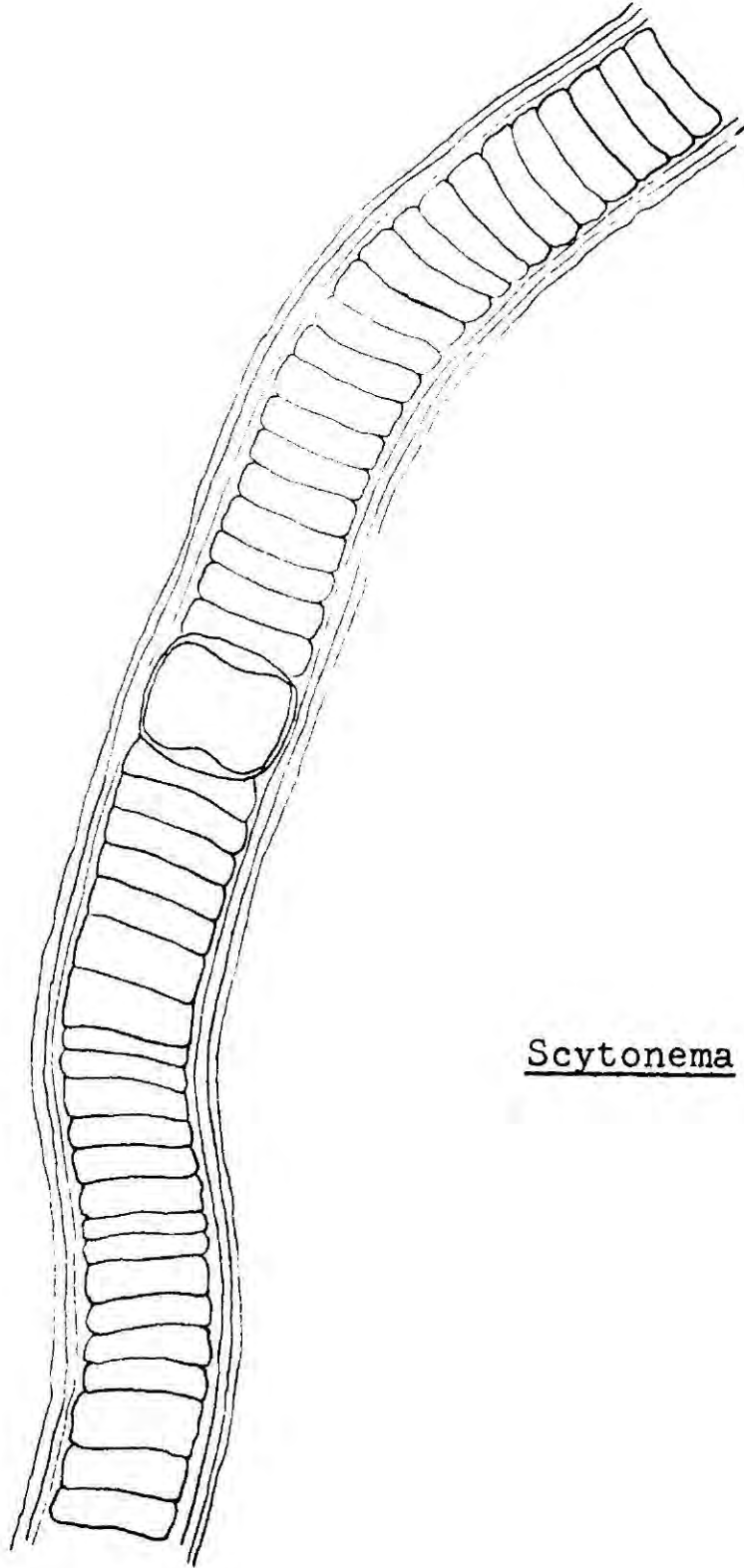
Frémy (1933) considered this species a form of Scytonema hofmanni Agardh.

C) Île Picard (0575 +0850); 0; 1.

D) Present in rocks in the upper intertidal zone of the seaward facing coast in front of the research station.

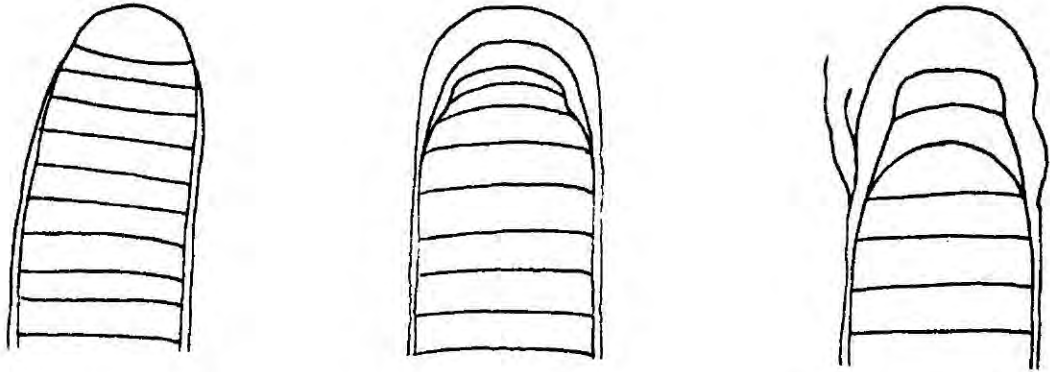
E) No.

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10 μm



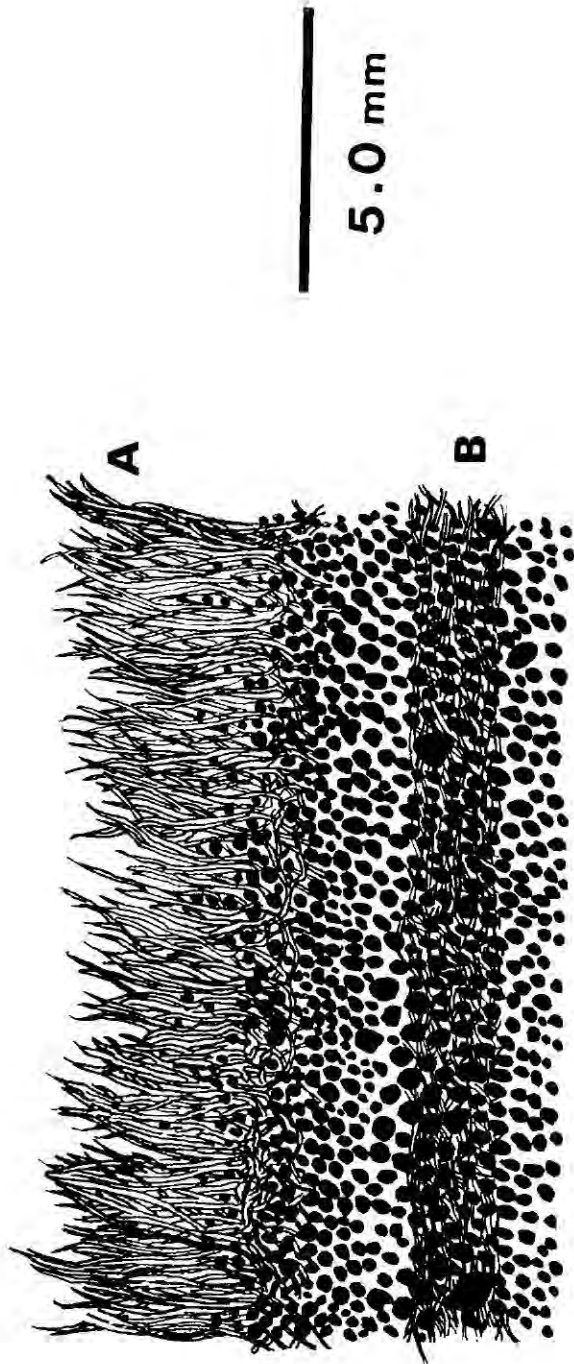
Scytonema sp.

—
10 μm



Scytonema sp.

different forms of the end cell



Section through a Scytonema mat,
binding coarse sands; A erect tufts
formed by filaments ; B single
lamination of dead filaments

016750 Scytonema sp.

A) Cell size range 20.0 to 25.0 μm , 5.0 to 10.0 μm long, shorter than broad, often slightly constricted, end cell rounded and prominent ('nipple' shaped); filament size range 25.0 to 37.5 μm , commonly 31.0 to 34.0 μm , densely entangled, irregularly bent and curved; sheath thick, up to 5.0 μm wide, commonly 4.0 μm , lamellate, colourless to brown; heterocysts quadratic, up to 25.0 μm long.

Thallus forming two distinct structures; the first being typical mats, dark olive-green, formed by erect sub-parallel tufts, 0.5 to 0.75 cm, binding sediment and forming laminated structures (Fig.4.4a); the other typical colony formation is that of 'oncolites' up to 10 cm diameter, laminated in section, only found in the bottom of tidal pools and depressions (Fig. 3.1a,c).

No binomial can be applied to this material and by all taxonomic criteria this is a new species. This has been confirmed by Dr S. Golubić (pers. comm.)

C) Île Picard (0610 +0895, 0625 +0907, 0635 +0920, 0650 +0937, 061 +098, 066 +101), Île Malabar (1448 +1182, 139 +127, 145 +126, 2705 +1099, 3138 +1187), Grande Terre (360 +113, 404 +089, 3770 +0620, 3380 +0673, 2623 +0433, 1858 +0287, 2623 +037, 1858 +013), Îles Loustique (9005 +5250); L+0; 45.

D) Very abundant in the upper intertidal zone of the lagoon, forming thick sediment binding mats and crusts, also very abundant as 'oncolites' at the tidal depression, close to the 'upside down' jellyfish pool, Île Picard. On seaward

facing coasts its form is reduced to small tufts in pits of the champignon (Figures 3.1a, b, c, e, f, 3.2b).

E) No.

F) Similar material collected from the Persian Gulf and Andros Island, Bahamas (S. Golubić, pers. comm.).

016901 Spirulina subsalsa Oersted ex Gomont

- A) Average width of cells 1.5 μm ; winds of trichome 4.0 μm , close together and tightly packed, bright blue-green; sheath thin, colourless.
- B) Cell size range 1.0 to 2.0 μm ; trichomes densely coiled, spirals 3.0 to 5.0 μm apart.
Thallus bright blue-green or yellow-green.
Described from freshwater, brackish and thermal water habitats; cosmopolitan.
- C) Île Picard (066 +101, 0625 +0907, 061 +098), Île Malabar (2705 +1099), Grande Terre (3380 +0673, 1120 +0280); L; 33.
- D) Very abundant, often forming bright blue-green sheets over the surface of silt.
- E) Yes; four freshwater pools, Cinq Cases, often becoming the dominant species in the more brackish pools.
- F) In salt-pans, Curaçao (Koster, 1963); littoral zone, Oahu, Pacific (Khan, 1969).

016932 Spirulina labrynthiformis (Meneghini) Gomont

A) Cell size range 1.0 to 1.3 μm ; spirals compact, 3.0 μm wide, 1.0 to 2.0 μm apart, pale blue-green.

The most suitable binomial here would be S. labrynthiformis, however the definition of this species would have to be extended to include cells up to 1.3 μm .

C) Île Picard (0635 +0920, 066 +101), Île Malabar (1448 +1182), Grande Terre (3770 +0620, 0810 +0505); L; 7.

D) Present among other algal communities.

E) No.

016933 Spirulina sp. $>2 \leq 4 \mu\text{m}$

A) Average cell width 2.5 μm ; spirals closely packed, bright blue-green.

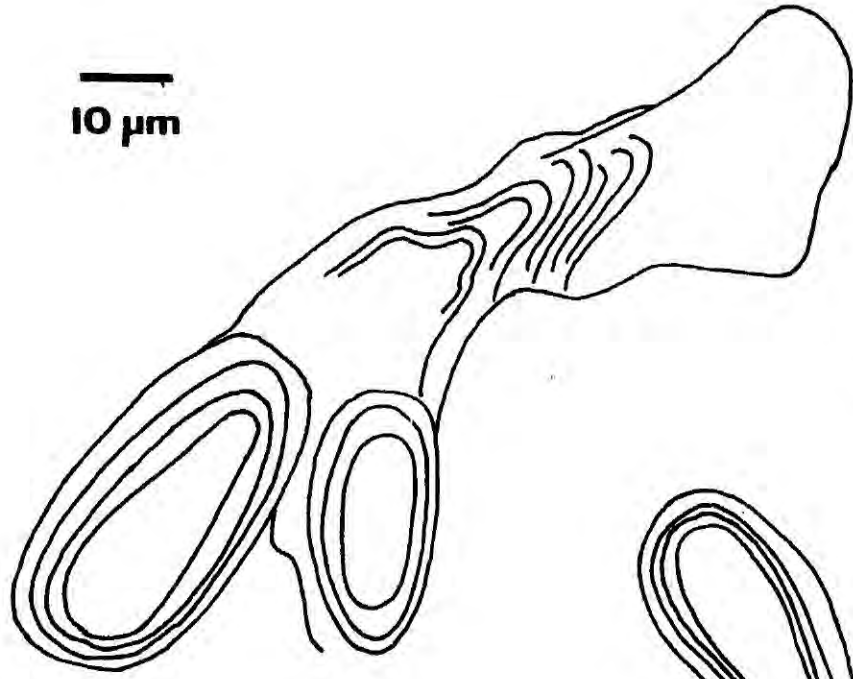
This size category includes several species.

C) Île Picard (061 +098); L; 2.

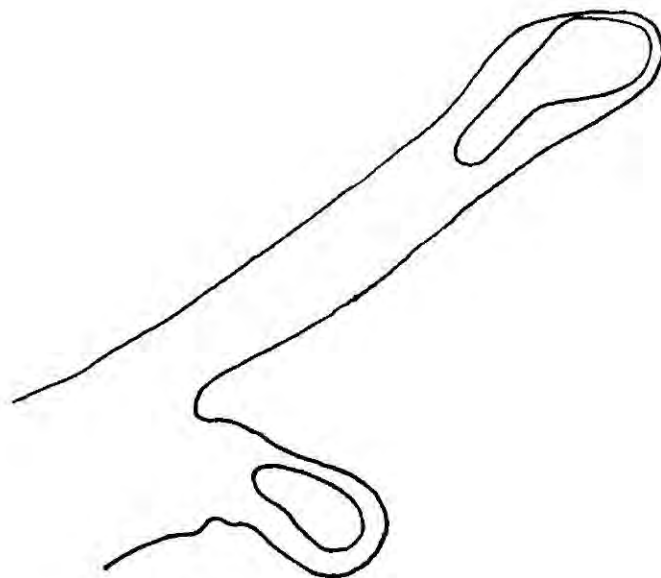
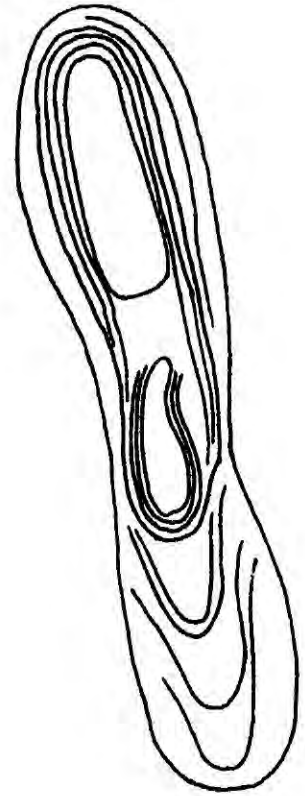
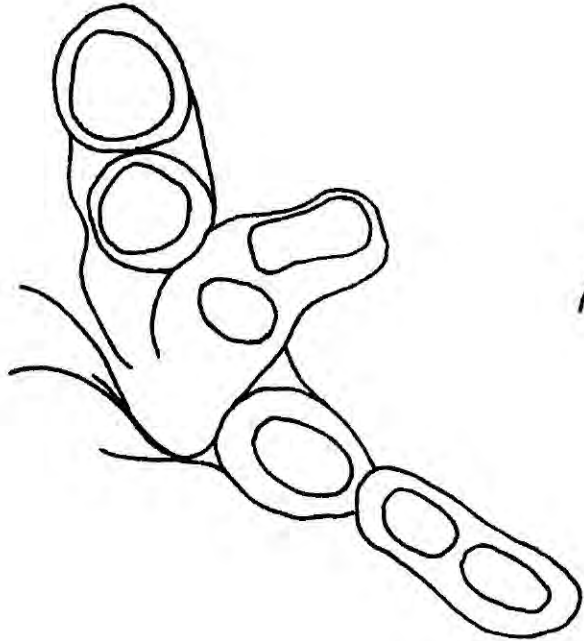
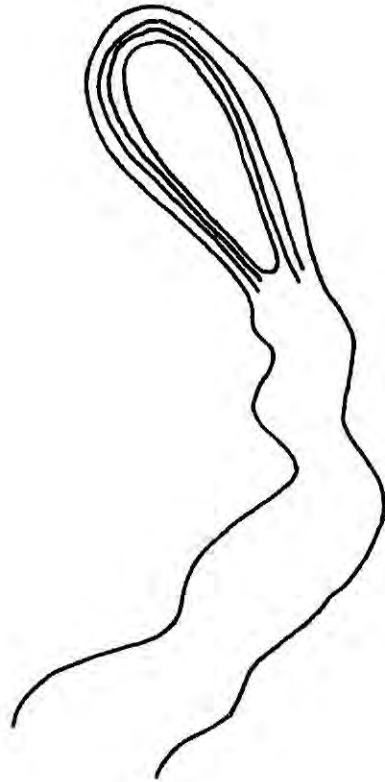
D) Present among other algal communities, tidal depressions, Île Picard.

E) No.

10 μ m



Solentia stratosa



018201 Solentia intricata Ercegović

- A) Apical cells extended, average width 5.0 x 30.0 μm , green; average width of filaments 10.0 μm ; sheath lamellate; no endospores noted.
- B) Cell size range 2.0 to 6.0 μm , and 2.0 to 30.0 μm long, very distant from one another; sheath lamellate; filament size range 3.0 to 9.0 μm .
- Described from shells and rocks, intertidal zone, Dalmatian Coast.
- C) Île Picard (0638 +0920); L; 1.
- D) Abundant in rocks of champignon islets, La Gigi.
- E) No.

018202 Solentia stratosa Ercegović

- A) Average cell size 6.3 x 11.3 μm , longer than broad, slightly clavate, olive-green or pale-green; endospores 5.0 to 7.0 μm ; filament size range 12.5 to 25.0 μm ; sheath lamellate.
- B) Cell size range 3.0 to 12.0 μm (commonly 6.0 to 9.0 μm), 4.0 to 45.0 μm long; filament size range 10.0 to 40.0 μm ;
Described from rocks on the Dalmatian coast.
- C) Île Picard (061 +098, 0638 +0920), Grande Terre (1120 +0280, 1858 +013), Îles Moustique (9005 +5250); L+0; 6.
- D) Abundant in rocks of the upper intertidal zone, inside the lagoon and also the seaward coast.
- E) No.
- F) Intertidal zone, coast near Marseille (Le Campion-Alsumard, 1969).

017434 Synechococcus brunneolus Habenhorst $>6 \leq 8 \mu\text{m}$

A) Average width of cells $6.3 \mu\text{m}$, pale green.

As can be seen from below this computer category only includes cells $>6 \leq 8 \mu\text{m}$, and the range for this species is $>5 \leq 11 \mu\text{m}$.

B) Cell size range 5.0 to $11.0 \mu\text{m}$, cylindrical, brown or blue-green.

Described from damp rocks.

C) Île Picard (066 +101); L; 1.

D) Present among other communities at Bassin Lebine.

E) No.

017602 Tolypothrix byssoidea (Berk.) Kirchner

- A) Average cell size 11.0 x 5.0 μm ; single pore heterocysts at false branches; sheath thin, yellow brown.
- B) Cell size range 9.0 to 11.0 μm , barrel shaped, a half to third long as broad; heterocysts basal, rarely intercalary; filament size range 10.0 to 15.0 μm .

Recorded from damp rocks; cosmopolitan.

- C) Île Picard (061 +098), Grande Terre (3770 +0620); L; 5.
- D) Present over rocks in the extreme upper part of the intertidal zone of tidal depressions.
- E) Yes; one of the main terrestrial algae of Aldabra; presence in freshwater pools thought to be inwash.

018401 Trichodesmium erythraeum Ehrenberg ex Gomont

- A) Average cell size 7.0 x 7.0 μm , often shorter than broad; trichomes in bundles, parallel, free floating.
- B) Cell size range 7.0 to 11.0 μm , as long as broad or third long as broad; trichomes in free swimming, purple-red bundles.

Recorded from plankton of tropical and subtropical regions; Mediterranean and Adriatic.

- C) Planktonic within the lagoon ; L; 3.
- D) As above.
- E) No.
- F) Well documented from Indian Ocean (for references, see Desikachary, 1959).

018402 Trichodesmium thiebautii Gomont

- A) Cell size range 6.9 to 8.1 x 10.9 μm , unstricted, slightly tapered at ends, granular, numerous surface epiphytes.
- B) Cell size range 7.0 to 16.0 μm , up to 2 times longer than broad, sometimes quadratic; unstricted, briefly attenuated at apices.

Trichomes free swimming in bundles.

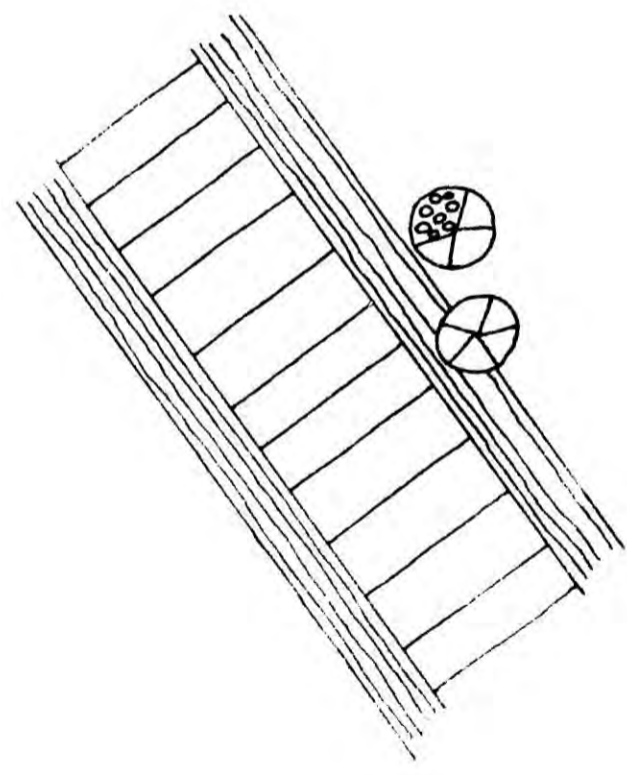
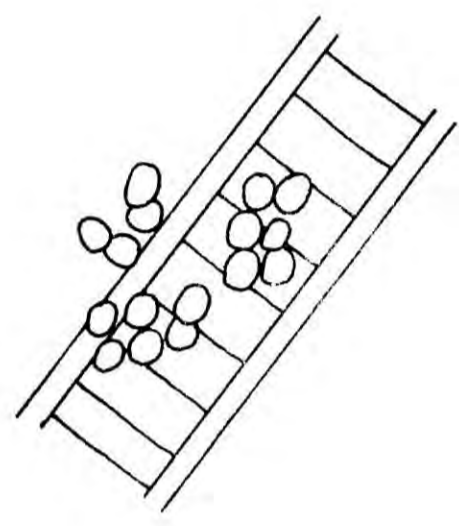
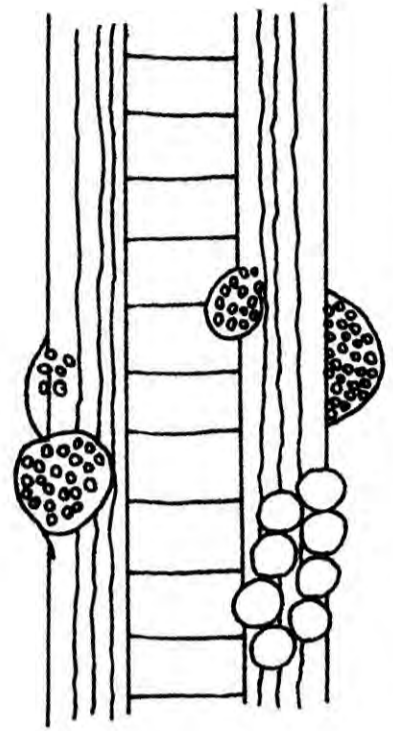
Recorded from subtropical and tropical habitats as plankton; also from the Atlantic.

- C) Île Picard (0575 +0925); 0; 2.
- D) Very abundant on the beach in front of the research station after a period of high tides, carried in from outside the reef; covering the sand as a foul smelling green scum.
- E) No.
- F) Well documented from the Indian Ocean (for references, see Desikachary, 1959).

10 μm

-228-

Xenococcus larsanensis



Xenococcus keyneri

018032 Xenococcus laysanensis Lemmermann >2 ≤4 μm

A) Cell size range 2.5 to 4.0 μm, typically 2.5 to 3.0 μm and 3.8 to 4.0 μm, bright blue-green.

The definition of this species has been extended to include cells 2.5 to 4.0 μm.

B) Cell size range 3.0 to 4.0 μm, 5.5 to 7.0 μm long, blue-green. Recorded from marine algae.

C) Île Picard (0610 +0895, 0625 +0907, 058 +092), Île Malabar (2705 +1099), Grande Terre (1858 +013, 3380 +0673, 1120 +0280) L+0; 25.

D) Abundant as epiphyte on Scytonema sp., Lyngbya aestuarii and Cladophora spp.

E) No.

018033 Xenococcus kernerii Hansgirg >4 ≤6 μm

A) Cell size range 5.0 to 5.6 μm.

B) Cell size range 3.5 to 6.0 μm, up to 10.0 μm long; endospores ≤ 3.0 μm.

Recorded from aquatic plants, mosses and algae (Cladophora, Lemanea).

C) Île Picard (0625 +0907, 0635 +0920), Île Malabar (2705 +1099, 1448 +1182); L; 9.

D) Present as epiphyte on filaments of Scytonema sp.

E) Yes; W 4, Île Picard; rare, epiphyte of Oedogonium sp. and Portulaca sp.

018034 Xenococcus schousboei Thuret >6 ≤ 8 μm
(syn; Dermocarpa schousboei (Thuret) Bornet

A) Cell size range 6.3 to 7.5 μm, pale blue-green to brown or red.

B) Cell size range 4.0 to 9.0 μm, blue-green.

The 'species' number excludes part of the size range for this species.

Recorded from other algae (especially blue-green algae; Hormogonales).

C) Île Picard (061 +098, 0635 +0920), Île Malabar (3770 +0620, 3138 +1187), Grande Terre (1858 +013); L+0; 8.

D) Abundant epiphyte on Scytonema filaments, both inside and outside the lagoon.

E) No.

F) Lagoon shores, Curaçao (van den Hoek et al., 1971).

018035 Xenococcus cladophorae (Tilden) Setchell et Gardner

>8 ≤16 μm

A) Cell size range 8.1 to 8.8 μm, or 11.5 to 15.6 μm,

spherical, pale brown; endospores 1.5 μm.

Thallus prominent, clear.

B) Cell size range 8.0 to 15.0 μm; endospores 1.5 to 2.0 μm.

Recorded from filaments of Cladophora along the coasts of British Columbia.

C) Île Picard (0635 +0920), Île Malabar (1448 +1182, 145 +126, 2705 +1099, 3138 +1187), Grande Terre (3770 +0620, 1858 +013); L+0; 19.

D) Abundant epiphyte on Scytonema filaments, particularly the older ones.

E) No.

018036 Xenococcus chaetomorphae Setchell et Gardner >16 μm

A) Average cell size 17.5 μm, bright blue-green; sheath thin, colourless.

B) Cells up to 45.0 μm, and 25.0 μm high.

Recorded from filaments of Chaetomorpha aerea along coasts of California.

C) Grande Terre (2705 +1099, 3138 +1187); L; 3.

D) Present as epiphyte on filaments of Scytonema sp.

E) No.

3.14 Summary of the number of species of blue-green algae recorded from marine and brackish water environments

Table 3.3 shows the number of species of blue-green algae, recorded from marine and brackish water environments at Aldabra Atoll, together with their taxonomic status. The use of L, L+O and O, was discussed in Section 3.12. Table 3.4 shows the number of species which were recorded both in the present study, and also by Donaldson and Whitton (1976b).

A detailed account of the distribution and abundance of photosynthetic prokaryotes within the intertidal zone of the lagoon, is given in the following chapter.

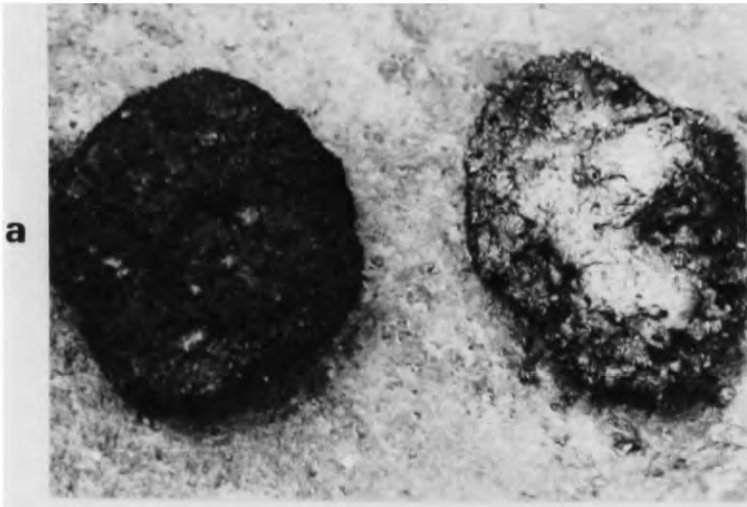
Table 3.3 The species of blue-green algae recorded from marine and brackish water environments at Aldabra Atoll

	L	L+0	0
<u>total number of species</u>	116	88	22
non-heterocystous	98	78	17
heterocystous	18	10	5
non-endolithic	105	85	16
endolithic	11	3	6
mat forming	6	2	4
<u>distribution in orders</u>			
Chroococcales	36	32	4
Chamaesiphonales	23	11	10
Hormogonales	57	45	8

Table 3.4 Comparison of species recorded by Donaldson and Whitton (1976b) from freshwater and terrestrial environments, with those recorded from marine and brackish water environments

<u>total number of species recorded from</u>				
<u>freshwater and terrestrial environments</u>	124			
non-heterocystous	105			
heterocystous	19			
<u>total number of species recorded from</u>				
<u>freshwater, terrestrial, marine and</u>		L	L+O	0
<u>brackish water environments.</u>	43	39	4	0
non-heterocystous	42	38	4	0
heterocystous	1	1	0	0
<u>distribution in orders</u>				
Chroococcales	21	19	2	0
Chamaesiphonales	3	3	0	0
Hormogonales	19	17	2	0

- Figure 3.1
- a 'Oncolites' formed by Scytonema sp., in a tidal depression, Bassin Cabri, actual size
 - b Scytonema sp. growing over the tops of knee roots of the mangrove Bruguiera gymnorhiza, out of the level of standing water, Petit Cavalier
 - c 'Oncolites' of Scytonema sp. covering the bottom of a tidal depression among prop roots of the mangrove Rhizophora mucronata, Bassin Cabri
 - d Hemispherical colonies of Rivularia sp. A, over exposed limestone in the lagoon, landing to Dune d'Messe
 - e Scytonema sp. covering the knee roots of Bruguiera, carbonate mudflat, Petit Cavalier
 - f Scytonema sp. growing attached to a prop root of Rhizophora, Île Picard



- Figure 3.2
- a Beachrock on the seaward facing coast in front of Settlement, Île Picard; Hyella balani is responsible for colouring the surface of the rock blue

 - b Tufts of Scytonema sp. in pits of champignon limestone on the seaward facing coast at Dune Jean-Louis, actual size



a



b

3.2 The taxonomy of photosynthetic bacteria

3.21 Allocation of binomials

Photosynthetic bacteria were identified using Bergey's Manual (1974). Until these species are obtained in culture, the binomials remain tentative.

3.22 Species list

Table 3.5 lists the three species recorded from marine and brackish habitats on Aldabra, all are purple sulphur bacteria.

3.23 Description of species

The same scheme as used for blue-green algae was adopted (3.13).

Table 3.5 The species of photosynthetic bacteria recorded from brackish and marine intertidal environments at Aldabra Atoll

Order Rhodospirillales

Family Chromatiaceae

Chromatium buderii Trüper et Jannasch

Thiocystis violacea Winogradsky

Thiospirillum sanguineum (Ehrenberg) Winogradsky

Chromatium sp.

- A) Cell size range 2.5 to 4.0 μm , 2.5 to 6.0 μm long, spherical, elliptical, 'bean'-shaped, rod-shaped; sulphur granules present, distributed irregularly throughout cells; mucilage absent; contains bacteriochlorophyll a which when extracted in 95 % methanol gives a A_{max} at 770 nm. Forms purple to pink 'streaks' over sand sediments. The most suitable binomial for this material is C. buderii Trüper et Jannasch (1968).
- B) Cell size range 3.5 to 4.5 μm , 4.5 to 9.0 μm long during exponential phase, 3.0 to 4.0 μm long during stationary phase; elemental sulphur evenly distributed throughout cells; colour of suspension purple-violet. Described from saltwater environments, Galapagos Islands.
- C) [^]Ile Picard (0635 +0920, 0575 +0925); L+0;15.
- D) Very abundant at La Gigi, associated with intertidal, residual pools; also very abundant under blue-green algal mats and films in mangrove creeks (Fig. 4.6). At various stages of the tidal cycle becomes abundant on the intertidal sandflat in front of the research station.
- E) No; however A. Donaldson and B.A. Whitton (pers. comm.) have both noted the colouration of freshwater pools a vivid pink colour, due to photosynthetic bacteria in parts of Cinq Cases, Grande Terre.
- F) Intertidal salt marshes and estuaries, Galapagos Islands
" Trüper and Jannasch (1968).

Thiocystis sp.

- A) Average cell size 8.8 μm diameter, spherical, highly motile, numerous sulphur granules distributed throughout the cell.

Forming crimson coloured films over the surface of silt and in standing water.

The most suitable binomial of the two species of Thiocystis in Bergey's Manual (1974) is T. violacea Winogradsky.

However the upper cell size for this species is 3.0 μm , although "larger individual cells may occur due to environmental conditions". As all cells of the populations studied were of the same magnitude of cell size, it is unlikely that this species is T. violacea.

- B) Cell size range 2.5 to 3.0 μm diameter, larger individual cells may occur due to environmental conditions, sulphur granules distributed evenly throughout the cells.

Described from mud and stagnant, fresh and saltwater, containing hydrogen sulphide and exposed to light.

- C) Grande Terre (3770 +0620); L; 12.

- D) Very abundant at Cinq Cases, forming crimson coloured films over the surface of mangrove mud in Avicennia 'parkland'; recorded only from this location.

- E) No; see comments for Chromatium sp.

Thiospirillum sp.

- A) Average width of cells 3.1 μm , up to 30.0 μm long, spiral shaped, highly motile, numerous sulphur granules distributed throughout the cells; individual cells red-orange in colour.

The most suitable binomial for this material is T. sanguineum (Ehrenberg) Winogradsky.

- B) Cell size range 2.5 to 4.0 μm , typically about 40.0 μm , with a range of 10.0 to 100.0 μm , cylindrical, attenuated at ends, individual cells rose to purple-red.

Described from mud and stagnant water, sea water exposed to light. Not in pure culture, 'type' not known.

- C) Île Picard (0650 +0937), Île Malabar (2705 +1099); L; 4.
- D) Present among other algal communities, never becoming abundant or forming growths similar to the other two species.
- E) No.

3.3 A species of endolithic photosynthetic prokaryote

A) Cell size range 1.7 to 2.0 μm , spherical, spherical after division, sheath absent, sulphur granules not visible, pale green, distributed in mucilage.

Colonies spherical (c 0.5 mm diameter), gelatinous, pink, endolithic in limestone rock, leathery when dry, gelatinous when wet.

No suitable binomial can be applied to this material

C) [^]Ile Picard (059 +091); 0; 15.

D) Abundant in the upper part of the limestone overhang, directly in front of the laboratory at the research station; small pink colonies visible when the rock surface was scratched or broken, at a depth of c 2 mm; the only record.

E) No.

At present it is not possible to state with certainty, that this is a species of blue-green algae or photosynthetic bacteria. However, studies carried out using fluorescence microscopy, indicate that the endolith is probably a species of photosynthetic bacteria. Material was studied as follows:

Rock samples were wetted with sea water and colonies of the endolith removed using fine mounted needles, manipulated under a dissecting microscope. Colonies of Aphanocapsa concharum, A. montana, Pleurocapsa fuliginosa and Entophysalis granulosa were also found on the rock surface; these were removed for comparative studies. Separate samples of the pink endolith and the blue-green algae, were mounted on glass slides (in sea water) and studied using a Leitz Wetzlar

fluorescence system. A 1.5 mm BG accessory filter was used with a barrier filter of K 530 - K510, at the 3 x 3 filter settings. These gave a blue light source of 490 nm.

When examined under this light source, cells of all the blue-green algal species mentioned previously, fluoresced strongly emitting a red light fluorescence. When colonies of the pink endolith were studied, no fluorescence was observed. Mixed material of blue-green algae and the endolith were also examined, and it was found that only the cells of the blue-green algae gave off a bright red fluorescence. It can be noted here that the dimensions of the Aphanocapsa spp. cells, and the endolith cells were approximately the same, the cells of Pleurocapsa fuliginosa and Entophysalis granulosa were of the order of twice that of the endolith cells. Material was also studied which had been wetted for three days previously; the same results were obtained, and it is unlikely that the differences between the blue-green algae and endolith were due to the latter not taking up sufficient water. It is probable that the cells of the endolith were fluorescing in the invisible region of the spectrum i.e. they are cells of a photosynthetic bacterium. Until the species is grown in pure culture, this conclusion is tentative.

4 STUDIES OF LAGOON ENVIRONMENTS

4.1 Transects of the intertidal zone

The species of blue-green algae and photosynthetic bacteria, which were recorded from intertidal habitats of the lagoon and the seaward coasts, were described in Chapter 3. It is the purpose of the present chapter, to show the distribution of dominant photosynthetic microbial communities within the lagoon intertidal zone, as well as to describe the environments in which these communities are growing.

In order to maintain a uniform system of data recording and sampling in different areas of the intertidal zone, it was decided before visiting Aldabra, to carry out standard transects in each area of study. A standard transect would include detailed information on photosynthetic microbial communities, water chemistry, lagoon sediments, and more general information on geology, animals and higher plant communities. Data collected from these transects would be used to give an account of the intertidal zone, with emphasis on the dominant communities of blue-green algae and photosynthetic bacteria.

After considering such a transect study, questions arose as to how representative these transects would be of large areas of the intertidal zone, and to what extent they could be compared, when carried out at different areas over a period of eight months. A decision was therefore taken, to visit a number of the transect sites several times during the study period, and to make many observations of important communities.

It was hoped that these more intensive studies, would help to give some indication of any cyclical changes, or seasonal variations in the communities. The problem of the representative nature of the transects was borne in mind when producing a scheme for selecting sites.

4.11 Selection of transect sites

For all the transects carried out, the following conditions apply.

- i) Transects were made at areas which differed in their sediment type, width of intertidal zone, tidal range, coastal vegetation and dominant photosynthetic microbial communities.
- ii) Sites which were less than two kilometres apart, were selected to show the uniformity or variation of the intertidal zone, along a particular stretch of coastline.
- iii) Only two sites were chosen close to major passes, otherwise transects were as truly 'lagoonal' as possible.
- iv) Sites were selected initially by examination of maps and aerial photographs (2.113), and after discussion with native Seychellois.

The sites finally visited are shown in Fig. 4.1 and Table 4.1.

4.12 Interpretation of the intertidal zone

The intertidal zone of the lagoon was discussed briefly in Section 1.33, and was interpreted as 'the zone extending from the upper limit reached by the highest spring tides, to the lower limit exposed at the lowest neap tides and the appearance of marine angiosperms'. However, it became obvious

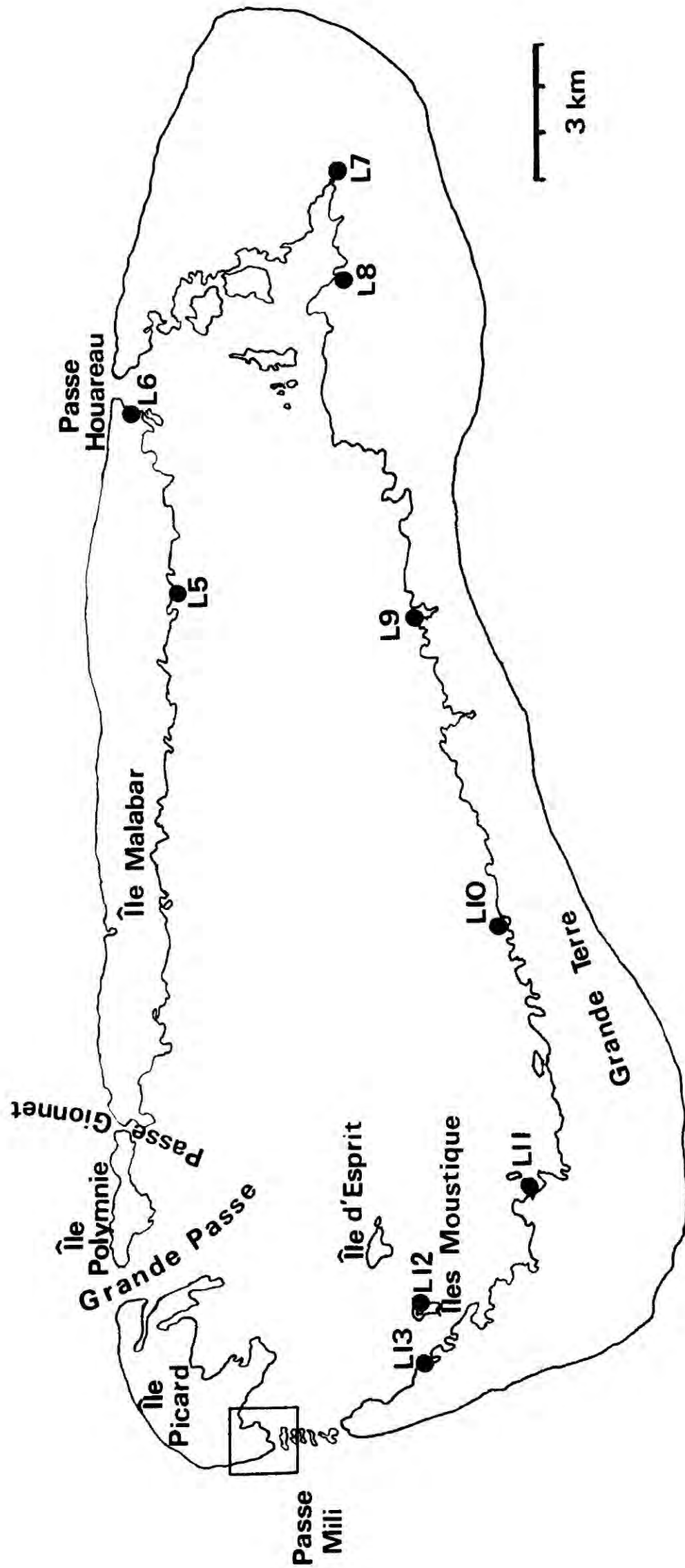
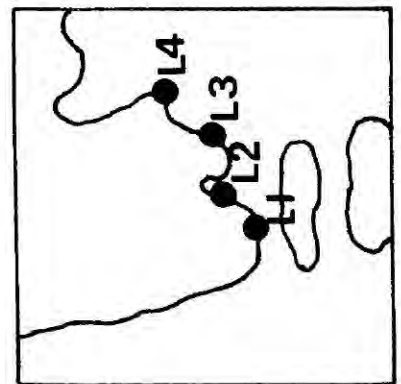


Figure 4.1 Transect sites within the lagoon



after only preliminary observations of parts of the lagoon, that to carry out transects of the intertidal zone would involve a number of problems, particularly to do with the interpretation of zonation patterns of communities within the intertidal. Littoral terminology is based upon the fact that certain types of organisms characterize certain positions upon the shore, and it is generally applied to rocky shores where the zonal divisions are sharp (Taylor, 1971). Within Aldabra Lagoon, the zonal terminology can only be applied with confidence to areas where the tidal regime is essentially vertical i.e. the limestone cliffs which form a rim around the lagoon, residual islets and inland tidal pools and depressions. The zonal divisions are less distinct in the extensive areas of flat sand and mudflats, which are exposed to varying extents at low tides . Here the tidal regime has two components, one of which is vertical, the other being horizontal. Due to the unusually high tidal range and restriction of the passes to water flow (1.32), ponding of water occurs in some areas, whereas in others, the intertidal can remain dry for several days (1.32). In addition mangrove creeks flow across many of these areas, and limestone hummocks and residuals occur at varying distances and elevations from the shore. A transect carried out at 90° to the land rim, and in a straight line towards the standing water of the lagoon, would in effect pass through a range of microhabitats, each with different tidal characteristics. For example, communities growing at the top of limestone residuals in the lower part of the intertidal,

come into contact with lagoon waters only during the highest tides, whereas communities growing at the base of the undercut land rim in the highest part of the intertidal are wetted by most tides. To overcome the problems of interpretation of the position of communities in the intertidal zone, an approach was taken in which the vertical as well as the horizontal zonation was studied. The horizontal zonation of communities was studied using straight line transects as outlined in the following section. In order to study the vertical zonation, samples were collected from different heights; in areas of the transect, from the land rim, limestone residuals and mangrove roots. For comparative purposes, data was also collected from inland tidal pools, where it was possible to observe distinct vertical zonation patterns.

It was found convenient in the collection of data, to sub-divide the intertidal into 'upper', 'mid' and 'low' zones, as suggested by Womersley and Edmunds (1952) for Australian coasts. The upper zone was that area only reached by the highest spring tides, the area subject to the greatest frequency of wetting and drying was named the mid zone, and that area only exposed during lowest neap tides, the low zone.

4.13 The standard transect

After selection of a transect site, a grid reference was allocated to the highest part of the intertidal zone, using the methods detailed in 2.113. A complete set of photographs were taken for future study, and notes made on vegetation, geological features and fauna.

The transect was then carried out in as straight a line as possible, at 90° to the lagoon coastline, and moving towards the standing water of the lagoon. As was indicated in the previous section, this was not always possible where creek beds traversed the area. In this case the bed of the creek was followed towards the low zone of the intertidal.

For data collection purposes the transect was considered as a number of 10 m square quadrats, and mangrove poles were staked out at 10 m intervals in line with the transect, each pole being considered as the centre of the quadrat square. Data was collected from adjacent quadrats when the transect appeared highly variable, and from those associated with dominant communities when the transect appeared uniform. A minimum of five quadrats were studied in each transect. Subjective estimates of percentage cover were given for the visually obvious communities of blue-green algae and photosynthetic bacteria. Bearing in mind the precautions to be used (2.17), readings of Eh, pH and temperature were taken within short intervals of one another, at many points within each quadrat. Where possible, readings of conductivity and percentage dissolved oxygen were taken from standing water and analysis of water samples was carried out in situ (2.14), and on return to Durham (2.21). Samples of rock, sediment, algal and bacterial communities were collected as discussed in 2.19.

4.14 Numbering system

Transects were carried out at 13 sites along the shores of the lagoon: four along Île Picard, two along Île Malabar and

Table 4.1 The numbering system for lagoon transects

transect number	date	lagoon shore	grid ref.
L1	16.11.74	Île Picard La Gigi	0610 +0895
L2	18.11.74	Île Picard La Gigi	0625 +0907
L3	18.11.74	Île Picard lagoon beach adjacent to Passe Femme	0635 +0920
L4	7.12.74	Île Picard lagoon beach towards Entre Deux	0650 +0937
L5	12.02.75	Île Malabar between Île Verte and Perdu Couteau	2705 +1099
L6	10.02.75	Île Malabar Passe Houareau	3138 +1187
L7	1.03.75	Grande Terre Cinq Cases	3770 +0620
L8	13.12.74	Grande Terre Takamaka	3380 +0673
L9	31.01.75	Grande Terre lagoon landing to Dune Jean-Louis	2623 +0433
L10	29.01.75	Grande Terre lagoon landing to Dune d'Messe	1858 +0287
L11	13.03.75	Grande Terre Gros Îlot Cavalier	1120 +0280
L12	27.11.74	Grande Terre Îles Moustique	9005 +5250
L13	11.12.74	Grande Terre Petit Cavalier	0810 +0505

seven along Grande Terre (Fig. 4.1). For discussion purposes these have been assigned a separate number between one and 13, prefixed by the letter L e.g. L4, L11, etc. The numbers were assigned on a clockwise basis around the lagoon, commencing with the first transect carried out near Passe Femme, Île Picard (4.161). This transect thus became L1.

4.15 Presentation of data

For presentation purposes some data are presented in tabular form, and the remainder in a standard format as shown in Table 4.2. The format is used in the following section to describe the geology and geography of the transect areas, the dominant communities of photosynthetic prokaryotes, and certain data on the eukaryotic algae, higher plants and animals. Detailed discussion of the physical and chemical nature of these environments is given in Section 4.2.

















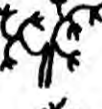




Table 4.2 Standard format for transect data

- A) Date; time; grid ref. of the top of the transect line; island; name; area.
- B) Description of the intertidal zone: topography; geology; vegetation; fauna; tidal characteristics.
- C) Description of the transect line: comments.
- D) Upper: dominant photosynthetic microbial communities, distribution, specific biological details.
- E) Mid: as (D).
- F) Low: as (D), including details of marine angiosperms.

A large number of diagrams and photographs have been included, as it was felt that they illustrate many of the

important features of geology and vegetation, as well as showing the appearance of certain communities in situ. A key to the symbols used in some diagrams is given in Table 4.3, several being those used by Womersley and Bailey (1969), van den Hoek et al. (1971), and Macnae (1971). The transect line is shown in these diagrams as a line labelled A to B. The standard abbreviations of Womersley and Edmunds (1952) are used for extreme high water springs (E.H.W.S.) and extreme low water neaps (E.L.W.N.), to give some indication of the tidal range.

Table 4.3 Standard symbols used in transect illustrations

	<u>Rhizophora mucronata</u>		limestone
	<u>Avicennia marina</u>		brown silt
	<u>Bruguiera gymnorhiza</u>		white calcareous silt
	<u>Ceriops tagal</u>		sand
	<u>Lumnitzera racemosa</u>		coral debris
	young mangrove shoot		
	marine angiosperms		
	<u>Acrostichum aureum</u>		
	<u>Pemphis acidula</u>		
	<u>Sporobolus virginicus</u>		
	<u>Cocos nucifera</u>		
	<u>Pandanus tectorius</u>		
	<u>Casuarina equisetifolia</u>		
	communities of blue-green algae		
	attached eukaryotic algae		
	<u>Cladophora 'balls'</u>		

4.16 Descriptions of transect areas and dominant communities

4.161 Transect L1

- A) 16.11.74 ; 1030 ; 0610 +0895; Île Picard; the vicinity of Passe Femme, near the anchorage for pirogues.
- B) Open sandflat, separated from Passe Femme by sand dunes and a long bar of sand and shingle; sandflat at an elevation \underline{c} 1 m below the top of the sand bar, with a slope towards the lagoon of \underline{c} 4° , width of zone \underline{c} 55 m; sand dunes surround the area on several sides, surfaces stabilized by thick (5 mm) crusts of a Microcoleus chthonoplastes - Tolypothrix byssoidea community (Fig. 4.2a), vivid green after rain showers; lagoon creek enters the area through a break in the sand dunes and sand bar; pebbles and coral debris associated with the bed of the creek, sediments of the sandflat coarse to medium coarse sand; Suriana maritima, Scaevola taccada, Tournefortia argentea, Cyperus ligularis, along sand bar, Sporobolus virginicus extending short distance into upper zone, dead and decomposing angiosperms leaves carried in by highest spring tides and deposited as a line along the top of the sand bar; mangrove forest dominated by Rhizophora mucronata and Bruguiera gymnorhiza at top of creek, Ceriops tagal, Xylocarpus sp. also present; area only covered by highest spring tides, proximity to Passe Femme reduces tidal lag \underline{c} 30 min .
- C) From below the single Casuarina equisetifolia tree at level of the line of dead angiosperm leaves, traversing sandflat for \underline{c} 30 m, to bed of creek, following creek for 15 m to its

junction with Passe Femme. Transect shown in Fig. 4.3.

- D) Well defined laminated mat dominated by Scytonema sp. and Microcoleus chthonoplastes, 2 m wide parallel to sand bar, olive-green, broken up by activities of the 'ghost' crab Ocypode ceratophthalma (Fig. 4.4a), covered by tidal water \approx 90 h over a complete lunar cycle, subject of more detailed studies (5.1); Scytonema lining the side of the creek; Calothrix crustacea among Scytonema mats as black surface crusts.
- E) Hyella balani - Schizothrix calcicola stabilizing the sediment to depth of \approx 3 mm, pale green; pennate diatoms forming a dull brown mosaic over the surface; numerous burrow entrances of Ocypode ceratophthalma visible; small shoots of Avicennia visible, numerous pneumatophores; area remains wet for long periods after retreat of the tide.
- F) Bright green films of Microcoleus chthonoplastes, when disturbed appear pink below due to Chromatium sp.; noticeable smell of H_2S when sediment disturbed; dense meadows of Thalassodendron ciliatum and Cymodocea rotundata cover sand shelf at side of Passe Femme; bottom of creek often has a depth of water of 8 cm at low springs.

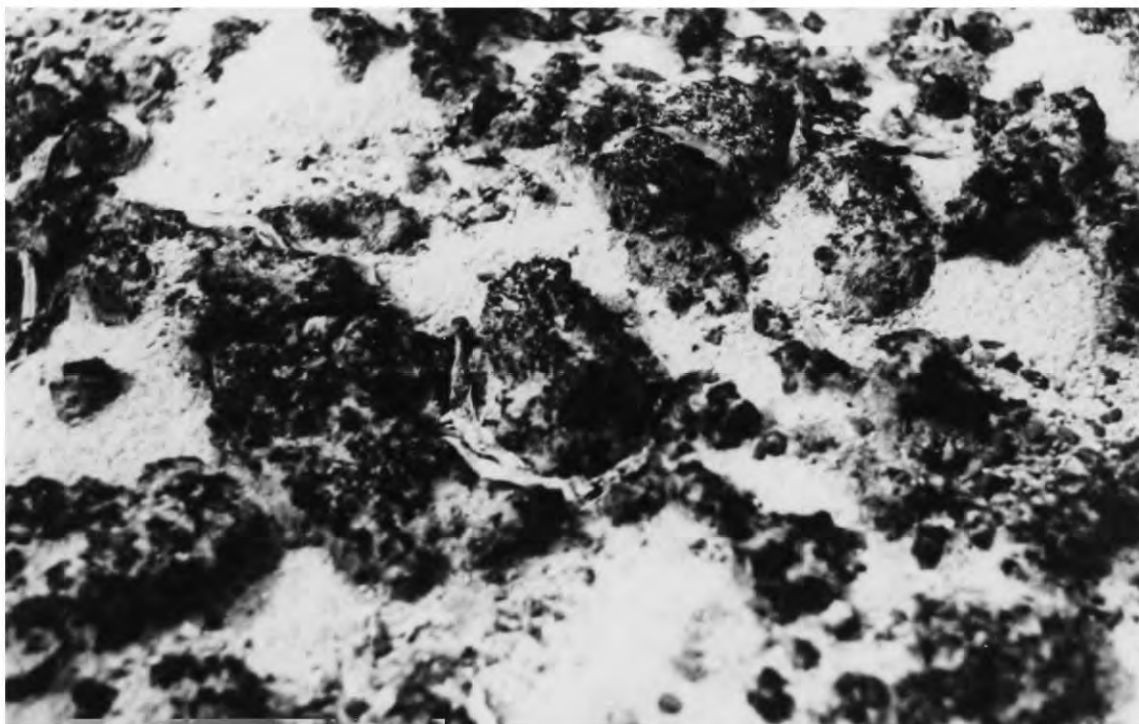
- Figure 4.2
- a Crusts of Microcoleus chthonoplastes - Tolypothrix byssoidea communities over the surface of sand dunes, among Cyperus ligularis, upper zone, L1
 - b Mid intertidal zone, L2, showing cemented sand deposits and 'scoured' pattern
 - c Cemented sand deposits in b, surface covered by mats of Scytonema sp.



a



b



c

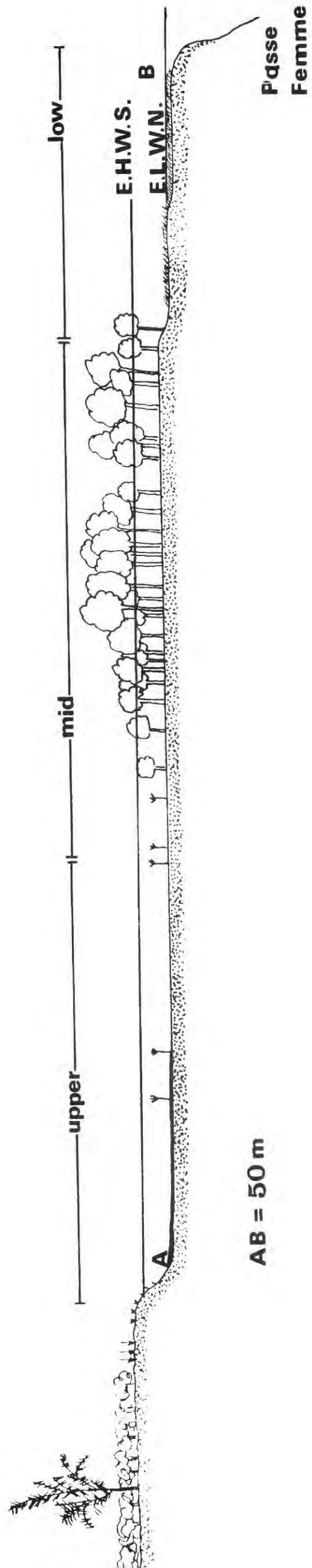
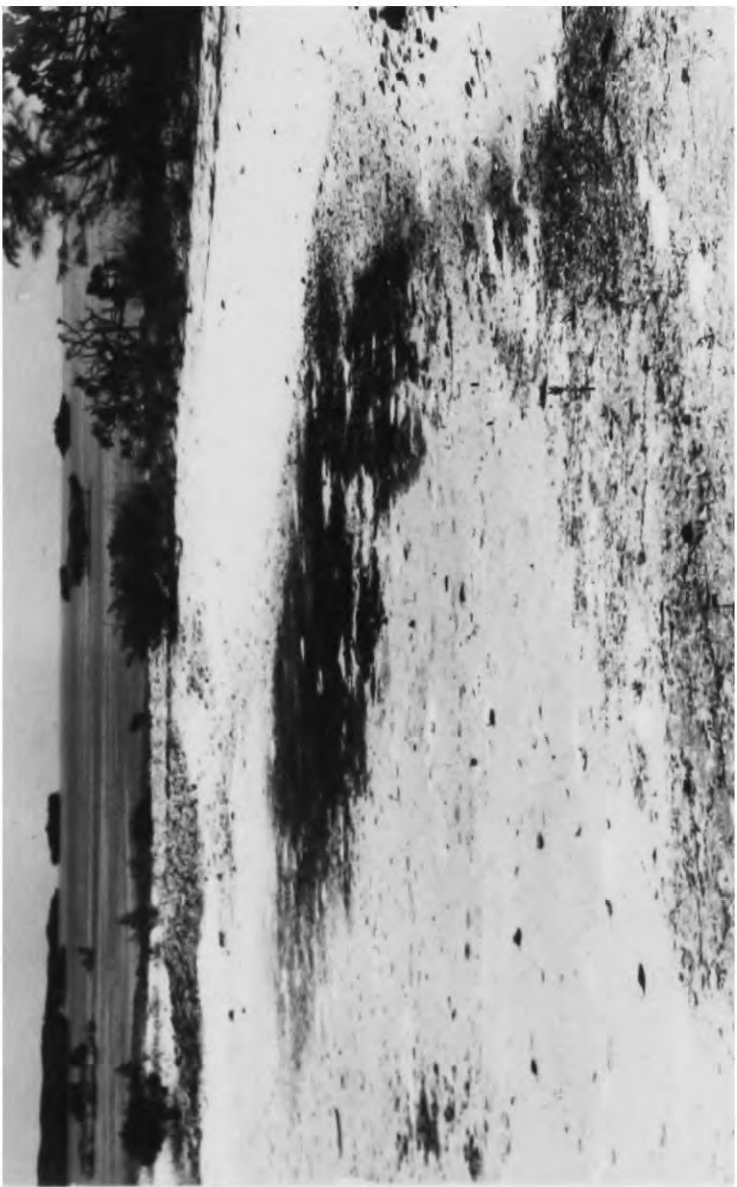


Figure 4.3 L1 La Gigi

- Figure 4.4
- a Transect area L1, near Passe Femme, showing the 'crescent' shaped community of Scytonema sp. in the upper intertidal below the sand bar, the lagoon is in the background and the creek entrance is at the extreme top left corner of the photo by the pebble deposits
 - b Transect area L8, Takamaka, Scytonema sp. covering the surface of exposed limestone in the upper zone, note the absence of Scytonema over the white silt surface; the mangrove is Rhizophora mucronata
 - c Transect area L10, lagoon landing to Dune d'Messe, thick mats of Rivularia sp.A and Scytonema sp. covering the exposed limestone hummocks, deposits of carbonate silts in background and pneumatophores of Avicennia marina are visible around the base of the tree in the right hand of the photo
 - d Transect area L13, Petit Cavalier, open carbonate mudflat, the start of the transect line was below the Cocos trees, prop roots of Rhizophora are visible in the foreground



a



b



c



d

4.162 Transect L2

- A) 18.11.74 ; 1025 ; 0625 +0907; ^AÎle Picard; La Gigi; area adjacent to headland of Passe Femme.
- B) Sandflat; separated from the lagoon by a line of mangroves, giving the enclosed sandflat a 'horseshoes-shape'; sandflat at an elevation c 2 m below the top of the sand dunes, width of zone c 250 m; exposed limestone in extreme upper part of zone, sediments coarse to medium coarse sands, pebbles and coral debris associated with the bed of a creek which connects the area with the lagoon, sand of the bed of the creek consolidated and cemented into small boulders c 10 cm diameter, easily fragmented, appearance of beachrock, sediments of creek bed in a 'scoured' pattern (Fig. 4.2b); dense scrub; Pemphis acidula on elevated limestone above the sandflat, Scaevola taccada and Tournefortia argentea on top of sand dunes; mangrove forest dominated by Rhizophora, Bruguiera and Avicennia; area often visited by large flocks of the crab plover Dromas ardeola; short coverage time even at the highest spring tides c 1.5 h, 30 to 40 min lag.
- C) From first appearance of exposed limestone and upper limit of the mangrove forest, in a straight line for c 100 m to bed of creek and followed to its confluence with Passe Femme (Fig. 4.5).
- D) Thin black crusts of Calothrix contarenii and pink crusts of Schizothrix calcicola, associated with the surface of small sand hummocks; Entophysalis granulosa - Pleurocapsa

fuliginosa community covering sediment surface among pneumatophores; thick laminated mats of Scytonema sp. (1 cm) among mangroves, perforated by pneumatophores of Avicennia.

- E) Thin black crusts of Scytonema sp. broken up by Ocypode burrows; sediment cemented to an elevation of c 10 cm above the sandflat and covered by broken mats of Scytonema sp. (Fig. 4.2b, c), much of sediment where no mats are present with a surface crust formed by evaporation of sea water and retention of salt crystals; area open with only a few shoots of Rhizophora.
- F) Bright green films of Microcoleus chthonoplastes covering sediment; standing water; when disturbed sediment gives off a noticeable smell of H_2S ; Chromatium sp. forming pink coloured layer beneath the films of Microcoleus (Fig. 4.6); large deposits of rotting angiosperm leaves; Thalassodendron ciliatum and Thalassia hemprichii over sand deposits at creek entrance; at low neaps water enters the creek to a depth of only a few centimetres.

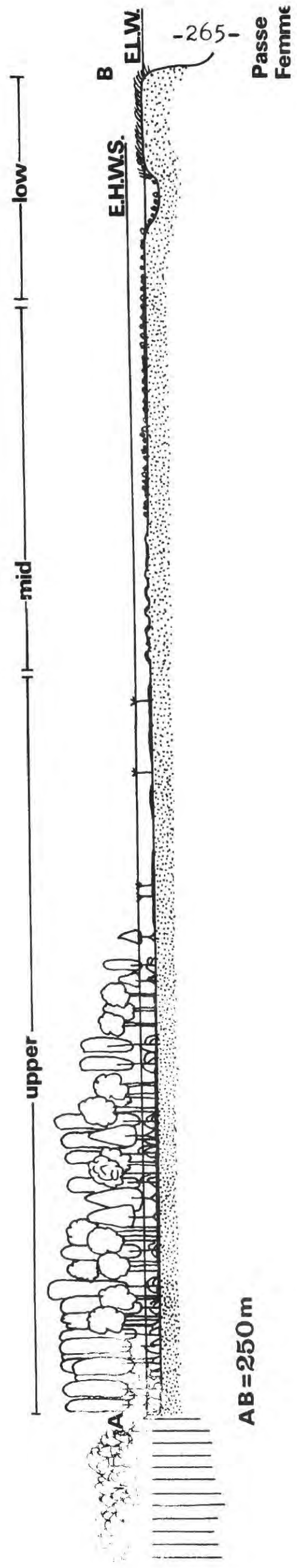


Figure 4.5 L2 La Gigi



Figure 4.6 A green surface film of Microcoleus chthonoplastes, disturbed to show the pink layer of Chromatium sp. below, L2

4.163 Transect L3

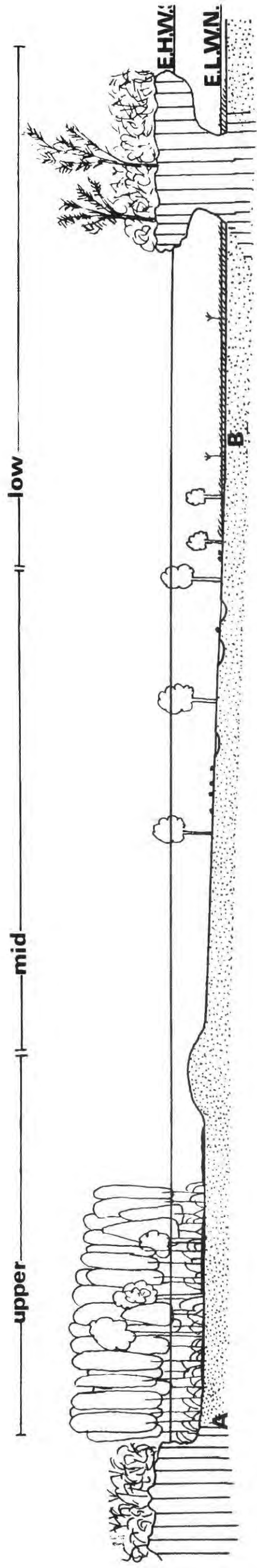
- A) 18.11.74 ; 1200 ; 0635 +0920; Île Picard; lagoon beach, parallel to coastline and adjacent to champignon islets.
- B) Sandflat; stretching from Passe Femme to the large creek adjacent to Entre Deux; large sandbar at top of beach separating the sandflat from the mangrove forest; slope towards lagoon of $\underline{c} 4^{\circ}$, $\underline{c} 200$ m ; residual champignon islets in low zone with dense vegetation of Pemphis acidula and Casuarina equisetifolia (Fig. 4.7b); sandflat exposed to lagoon, sediments coarse to medium coarse sand with basin-shaped depressions in mid zone, these retain water at low tide, subject of further study (5.21), sediments of sandflat much darker than those of the sand bar, coral debris scattered over wide area (4.7a); powerful smell of H_2S over whole area; mangrove forest dominated by Rhizophora, Bruguiera and Ceriops; Avicennia common in the low zone; large areas of standing water in the low zone and at base of residuals, lag of $\underline{c} 40$ min, tidal movements complicated by the presence of a large 'sink' hole close to the nearest residual, this hole is connected to the sea outside the land rim.
- C) From the mangrove forest, following a straight line across the sandflat for $\underline{c} 200$ m to the first champignon residual (Fig. 4.8).
- D) A Scytonema sp. - Calothrix crustacea community forming polygons (20 cm diameter) and black crusts in sheltered areas behind the sand bar, covered by water only during

high springs, remaining as dried out crusts for most of the tidal cycle.

- E) Hyella balani endolithic in sand grains and Microcystis reinboldii epilithic on grains, colouring a large area of sediment bright green, most vivid at 5 mm depth; conspicuous pink growths of Chromatium sp. associated with the residual pools; pennate diatoms in pools and giving a brown colour to the surface of sediment; one large sand hummock with a thick orange crust of Phormidium molle, laminated and bright green below the surface; Monostroma sp. attached to pebbles and coral debris (Fig. 4.7 a).
- F) Hyella balani and Microcystis reinboldii lending a green colour to the sediment; irregular patches of Chromatium sp.; diatoms and Spyridia filamentosa present in areas of standing water; Thalassia hemprichii, Thalassodendron ciliatum and Halodule wrightii in dense meadows under standing water.

- Figure 4.7
- a Sandflat adjacent to La Gigi and Passe Femme, coral debris over much of area; marine angiosperms in standing water to left of photo; the small mangrove trees are Avicennia
 - b The low intertidal zone of L3, the line of angiosperms is visible from left to right; limestone residuals are visible in the background, some with dense surface vegetation





AB = 200m

Figure 4.8 L3 La Gigi - lagoon beach

4.164 Transect L4

- A) 07.12.74 ; 1400; 0635 +0920; Île Picard; the vicinity of the creek entrance into Bassin Cabri, northeastern extremity of the beach discussed in 4.163.
- B) Sandflat exposed to the lagoon; close to the dense Rhizophora forest of Entre Deux, separated from it by a wide creek; width of zone c 100 m; medium coarse sand, brown mangrove silt in places; mangroves forming a thin fringe to sides of the creek and exposed limestone in the upper zone, Rhizophora dominant; due to large areas of standing water, much of the sediment is of a 'quicksand' nature; even during lowest neap tides, water in creek c 0.3 m; H₂S smell prevalent over wide area.
- C) From raised limestone behind mangrove fringe, across an area of standing water and open sandflat to the creek (Fig. 4.9).
- D) Hyella balani - Microcystis reinboldii associated with loose sediments; Calothrix scopulorum forming brown films on stilt roots of Rhizophora; Lyngbya confervoides and Spirulina sp. forming bright green films on stilt roots of Rhizophora; Vaucheria sp. - Microcoleus chthonoplastes community forming thick green felts over sediment among mangroves; Bostrychia tenella covering lower portions of stilt roots.
- E) Hyella balani, Chromatium sp. and pennate diatoms the dominant species associated with sediment.
- F) Bright green films of Microcoleus chthonoplastes in standing water, Chromatium sp. below these films; Ulva sp.,

Monostroma sp., Gracilaria sp. and Spyridia filamentosa
frequent in standing water; Halodule sp. and Syringodium sp.
also in standing water; this area very rarely dries out.

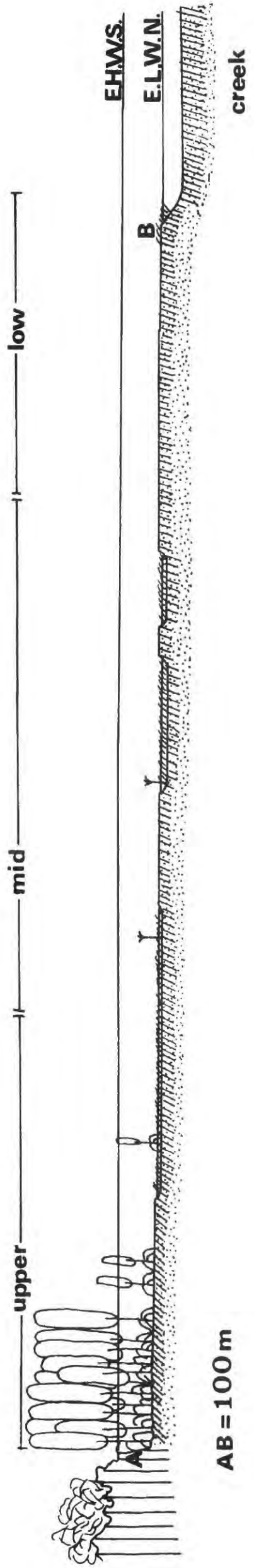


Figure 4.9 L4 Creek entrance to Bassin Cabri

4.165 Transect L5

- A) 12.02.75 ; 1300; 2705 +1099; Île Malabar; between Île Verte and Perdu Couteau.
- B) Mudflat; undercut limestone of land rim raised 2 m above the mudflat, numerous small residuals close to the shore; relatively deep (38 cm) deposits of brown silts covering a wide area, give only a 'web'-like cover to exposed limestone, brown silts only a 2 mm cover to pale coloured silts below, limestone hummocks in upper zone; dense, tall mangrove forest close to the shore, Rhizophora and Bruguiera dominant, several small shoots found away from the shoreline; burrows of Uca spp. and other crabs visible in the sediment; many creeks cut into the mangroves along the coast; incoming tide advances rapidly, only exposed for c̄ 2 h at each low spring tide, low tide level well delimited, shallow for long distances into the lagoon.
- C) From the head of a creek in dense mangrove forest, across the mudflat towards the lagoon for c̄ 100 m (Fig. 4.10).
- D) Thick olive-green mats of a Scytonema sp. - Vaucheria sp. community covering exposed limestone hummocks and knee roots of Bruguiera; Scytonema sp.-Microcoleus chthonoplastes among roots of mangroves.
- E) M. chthonoplastes forming bright green films in the standing water of depressions in the silt.
- F) Spirulina subsalsa in standing water; Thiospirillum sp. among many of the algal communities; Caulerpa sp., Halimeda spp. present at the low tide level; Cladophora sp.

Boodleopsis sp. and Rhizoclonium sp. forming 'cushion'-like colonies at the base of the limestone undercut;

Bostrychia sp. and Heterosiphonia sp. in clumps at the base of the residuals.

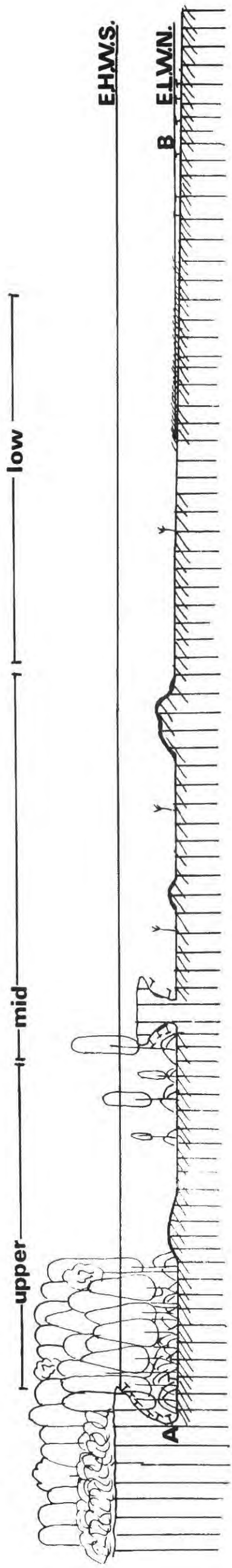


Figure 4.10 L5 Area between Île Verte and Perdu Couteau

4.166 Transect L6

- A) 10.02.75 ; 0930 ; 3138 +1187; Île Malabar; Passe Houareau; 30 m behind the camp.
- B) Narrow intertidal zone, tidal regime essentially vertical, flat limestone pavé with several large, shallow depressions containing sediment, adjacent to an area of Pandanus tectorius scrub, Nostoc commune colonies visible among the Sporobolus virginicus ground vegetation; c 50 m from the scrub, the pavé drops abruptly 1 to 2 m to an open expanse of water; Rhizophora fringe the pavé undercut; deposits of brown silt associated with the mangroves, coarser sediments and sands in the depressions and close to the Pandanus scrub, otherwise the limestone pavé is completely exposed; area completely submerged only at high spring tides, limestone dries out quickly after exposure, sediment in depressions remains wet.
- C) From the mixed Pandanus scrub, across the open pave for c 50 m to the Rhizophora fringe (Fig. 4.11).
- D) Black crusts of a Scytonema sp. - Tolypothrix byssoidea community associated with the sand deposits close to the Pandanus scrub; thin crusts of Scytonema sp. and Lyngbya aestuarii in shaded depressions of the limestone pavé.
- E) Sediment in depressions covered by Phormidium molle, sediment white when disturbed; Beggiatoa sp. among the Phormidium molle community.
- F) Schizothrix calcicola, Lyngbya confervoides and Microcoleus chthonoplastes forming bright green films over sediment at

base of stilt roots among mangroves; Thalassodendron
ciliatum in standing water.

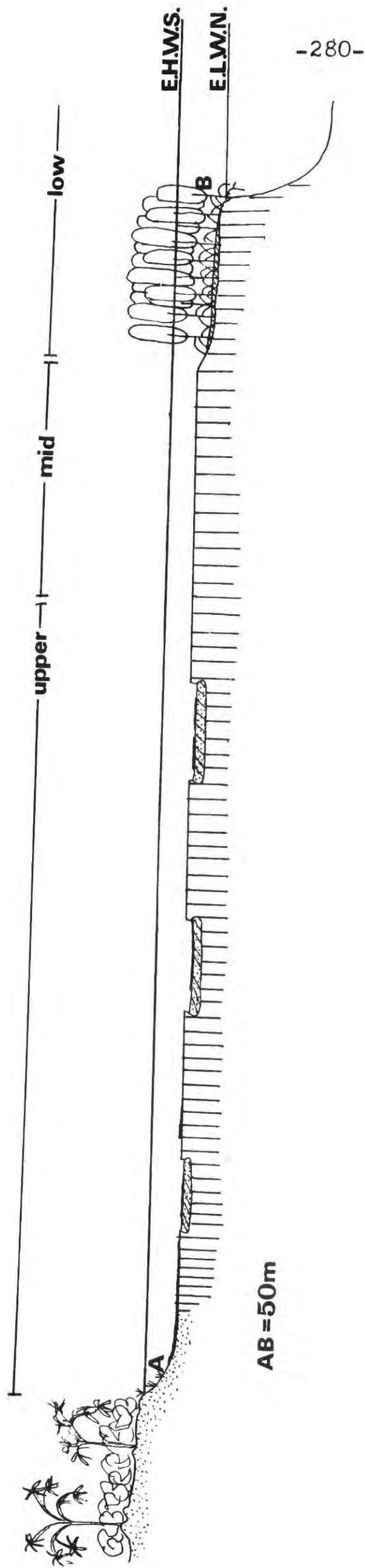


Figure 4.11 L6 Passe Houareau

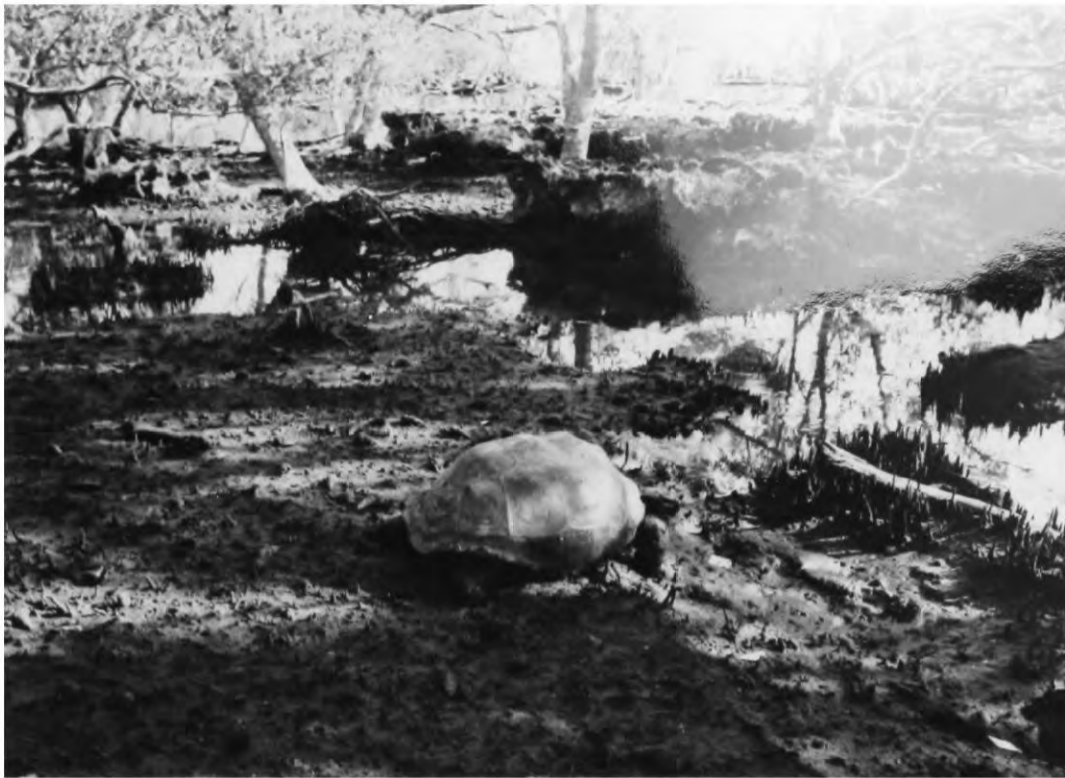
4.167 Transect L7

- A) 01.03.75 ; 0745 ; 3770 +0620; Grande Terre; Cinq Cases; vicinity of boat landing, following track inland.
- B) Wide mangrove mudflat, stretching from Bras` Cinq Cases to the first appearance of Lumnitzera racemosa; exposed limestone c 0.5 m above mud surface in low and mid zones; numerous sediment filled depressions, with relatively deep (0.5 m) grey silts, black below the surface; flat plain with light coloured sediment in upper zone, many of sediments especially in depressions with noticeable smell of H_2S ; a dense mangrove forest of Rhizophora, Bruguiera and Cerriops, lines the sides of the main creek, used by large flocks of birds for roosting; low density Avicennia 'parkland' covers several square kilometres in low zone, vegetation sparse in mid zone with few plants of Lumnitzera racemosa and Acrostichum aureum, merging into Pandanus scrub in the upper zone; the giant tortoise Geochelone gigantea Schweigger disturbs much of the sediment in the mid and low zones, the black tracks that they leave being clearly visible (Fig. 4.12c); large numbers of the gastropod Terebralia palustris Linnaeus are found on the surface of the silt in the low zone (Fig. 4.12a); a wide, deep creek drains the area and often contains water even at the lowest tides due to 'ponding' effects (1.32); longest lag in tides in the lagoon are found here (4.5 h), highest springs reach the Pandanus scrub, tide advances over the parkland sediment at a rate of 0.3 m sec^{-1} at certain stages of the

tide, when dried out the area may remain dry for several days during low neap tides.

- C) From standing water in the Avicennia 'parkland' to the first appearance of Pandanus in the upper zone, 300 m wide transect (Fig. 4.13).
- D) Sediment in depressions covered by dark brown, rubbery films of Dichothrix rupicola, often blistered in appearance (Fig. 4.12b); Microcoleus chthonoplastes - Aphanocapsa grevillei communities form bright green films over the sediment; Thiocystis sp. found in irregular, pink coloured patches; Calothrix scopulorum - Aphanocapsa montana - Spirulina sp. and Lyngbya martensiana - Beggiatoa sp. communities found in sheltered parts of tidal depressions, usually towards the perimeters.
- E) Films of Calothrix pulvinata cover the sediment and Tolypothrix byssoidea associated with the surfaces of exposed limestone.
- F) Thiocystis sp. visible as bright crimson films in standing water; Beggiatoa sp. forming white sheets, also in standing water; Cladophora sp. attached to rocks in deeper water of the creek and Enteromorpha sp. often floating on water surface; Cymodocea sp. covering large areas at entrance to the creek.
- Scytonema sp. mats found in the low zone, but associated with raised hummocks of mud adjacent to the creek.

- Figure 4.12
- a The giant tortoise Geochelone gigantea Schweigger; large numbers of Terebralia palustris Linnaeus are visible over the mud surface; photosynthetic bacteria found in the standing water of this area of the low intertidal zone, Cinq Cases
 - b A depression in the platin, upper intertidal zone, Cinq Cases, blistered films of Dichothrix rupicola are visible under the overhang at the left of the photo
 - c 'Tracks' left in sediment by a giant tortoise, the black sediment below the surface is exposed; Cinq Cases



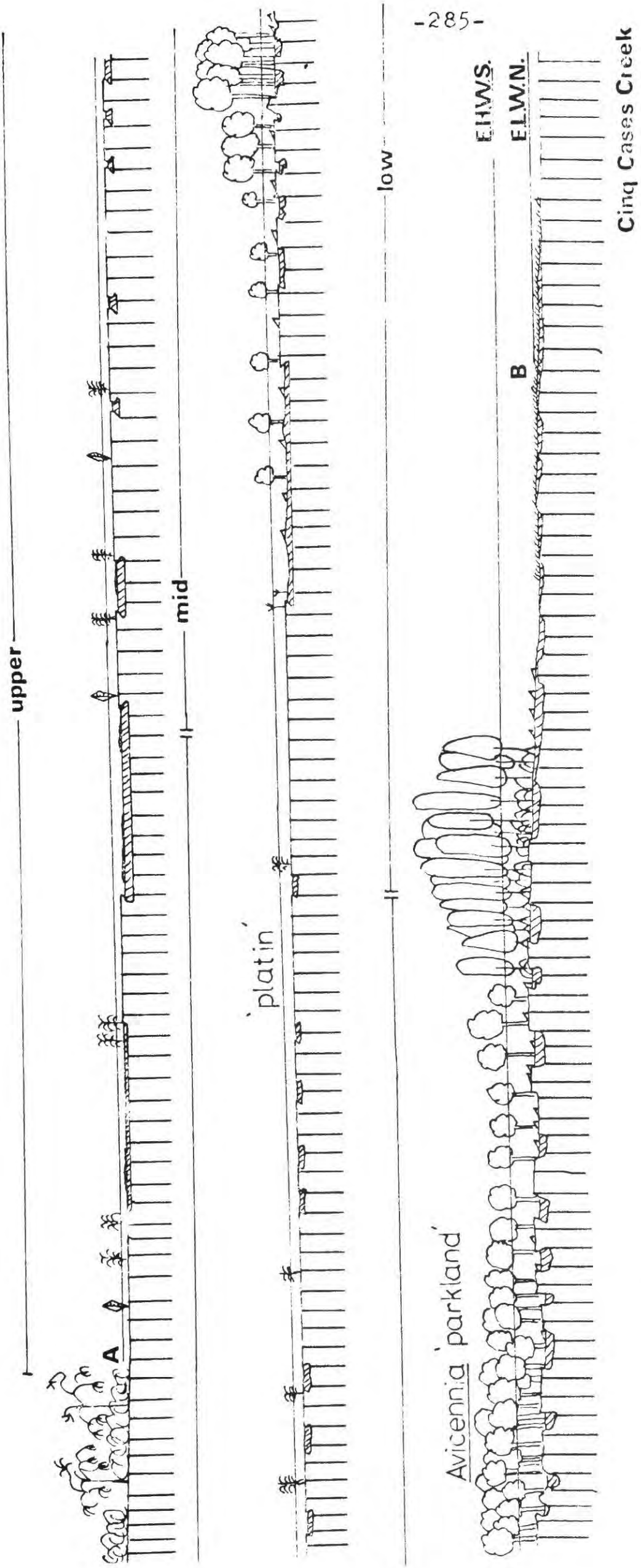
a



b



c

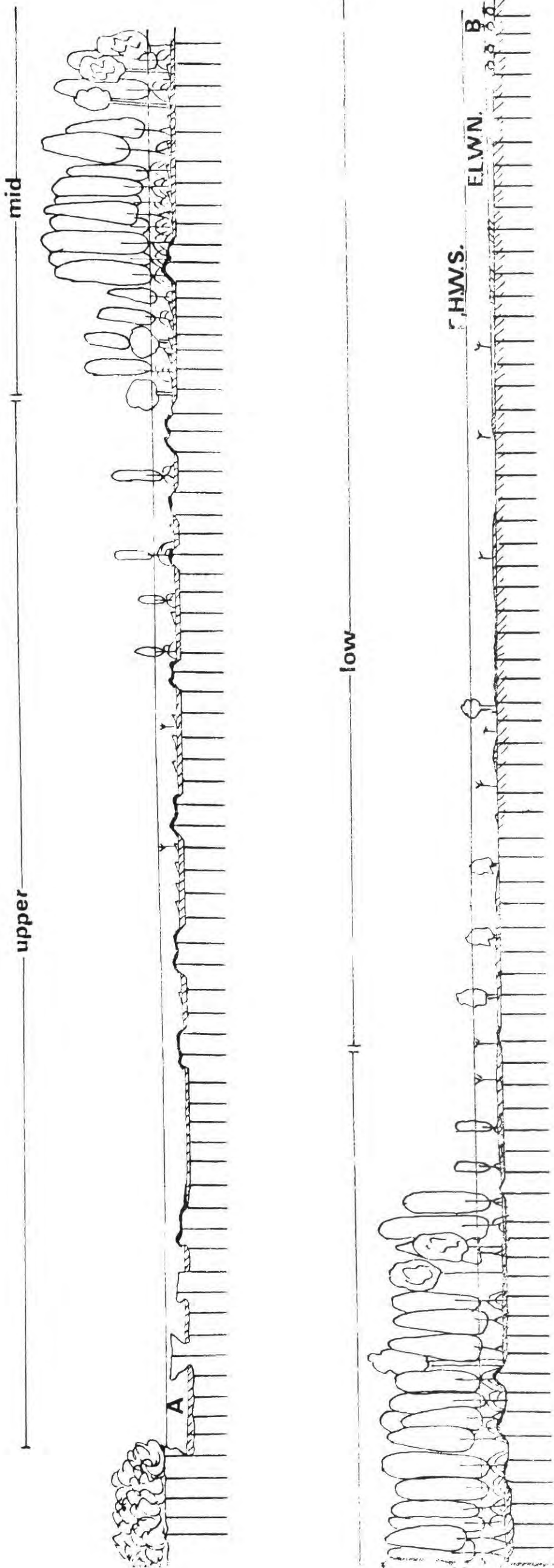


AB = 300m

Figure 4.13 L7 Cinq Cases

4.168 Transect L8

- A) 13.12.74 ; 1100 ; 3380 +0673; Grande Terre; Takamaka creek; vicinity of the boat landing.
- B) Carbonate mudflat, 300 m wide; limestone of the land rim c 0.5 m above the mudflat, limestone hummocks in upper zone; white silts deep in places (0.3 m), not covering the exposed limestone hummocks; tall mangrove forest of relatively low density, dominated by Avicennia and Rhizophora; large numbers of Terebralia palustris over the sediment surface; areas of standing water left after high tide, lag up to 3.5 h.
- C) From the limestone undercut in a straight line towards Bras Takamaka, 250 m (Fig. 4.14).
- D) Thick (1 cm) olive-green mats of Scytonema sp. covering the exposed limestone hummocks, not found over the silt surface (Fig. 4.4b); Lyngbya aestuarii - L. confervoides community frequent over the silt surface among pneumatophores.
- E) Hemispherical colonies of Rivularia sp. A over the sediment, Beggiatoa sp. often found among these colonies
- F) Bright green polygons, several centimetres in diameter at sides of creek, formed by Microcoleus chthonoplastes, laminated in section; Cladophora sp. 'balls' 3 to 5 cm diameter on creek bottom, each associated with a single cerethid gastropod shell, moved about freely with each tide; Cymodocea sp. covering large areas in Bras Takamaka.



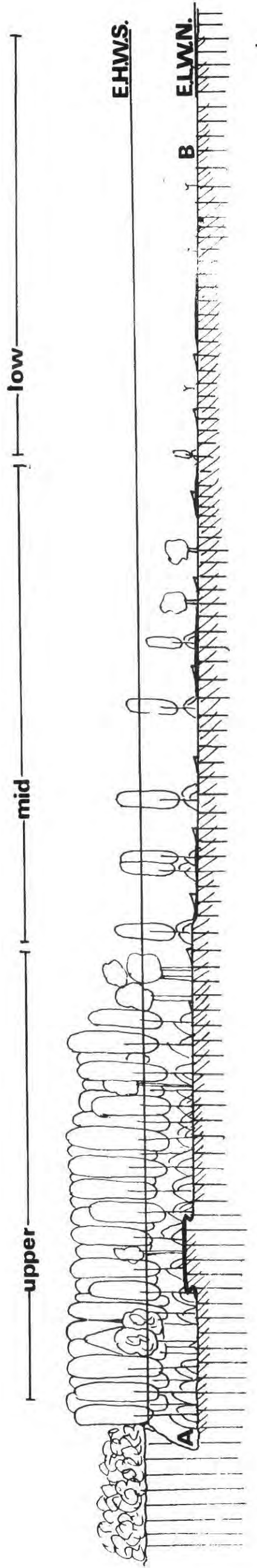
A Δ = 250m

Figure 4.14 L8 Takamaka Creek

4.169 Transect L9

- A) 31.01.75 ; 1400; 2623 +0433; Grande Terre; vicinity of the lagoon landing joining the track to Dune Jean-Louis.
- B) Carbonate mudflat, enclosed by mangroves and forming a corridor leading to the landing; limestone undercut 1 to 1.5 m above mudflat, residual limestone hummocks present only in the upper zone; deepest silts recorded within the lagoon found here, mud in the corridor raised \approx 0.3 m above the sides of the creek; dense Pemphis scrub growing to edge of the limestone; mangrove forest as a fringe to the coast and lining the corridor; Rhizophora and Avicennia dominant; Uca spp. burrows numerous in sediment, large numbers of crabs advance with the incoming tide; waters here milky white, dark brown at the bottom of the crab burrows; 3.5 h lag in tides at the top of the creek, height of the highest tides visible as a white 'tide' mark on the mangrove trees.
- C) From the Pemphis scrub, in a straight line through the corridor and across the mudflat to standing water (Fig. 4.15).
- D) Schizothrix calcicola - Lyngbya confervoides communities forming pink crusts over the limestone hummocks; green coarse filaments of Rhizoclonium sp. visible over the silt surface.
- E) Microcoleus chthonoplastes sheets over the surface of silt in the creek; Vaucheria sp. - Rhizoclonium sp. communities lining the sides of the corridor, together with Scytonema sp.

F) Bright green sheets of Microcoleus chthonoplastes over the silt surface but highly broken up by the activities of Uca spp.



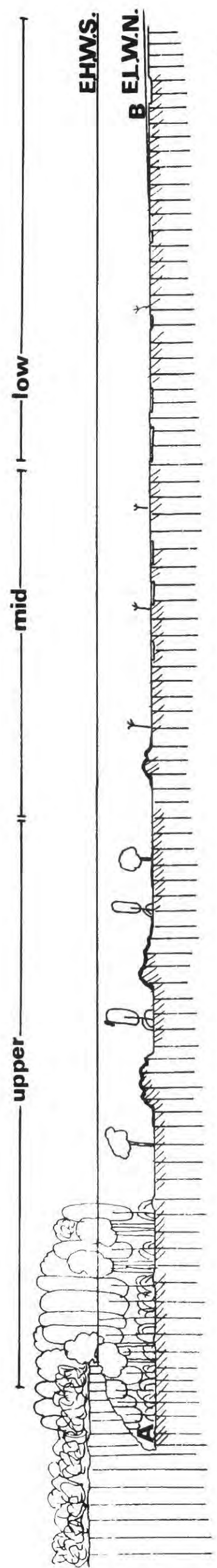
AB = 250 m

Figure 4.15 L9 Lagoon landing to Dune Jean-Louis

4.170 Transect L10

- A) 29.01.75 ; 1230; 1858 +0287; Grande Terre; vicinity of the lagoon landing joining the track to Dune d'Messe.
- B) Carbonate mudflat, representative of much of the south coast of the lagoon; residual hummocks of limestone close to the shore; lagoon floor soluted and eroded, many depressions from a few centimetres to one metre diameter; white-grey silts, deep in places, lagoon floor visible, sediment forming a crust when exposed to the sun for several hours; numerous crab burrows, few Terebralia; mangroves forming a thin fringe to the shore, Rhizophora, Cerriops and Bruguiera dominant, small shoots of Rhizophora far out into the lagoon; milky coloured water in depressions; 2 to 2.5 h lag, water advances rapidly with each tide.
- C) From landing in straight line towards the lagoon, c 200 m (Fig. 4.16).
- D) Yellow-brown gelatinous colonies of Placoma vesiculosa in small pits of the limestone overhang; exposed lagoon floor and some small residuals blue in colour due to Hyella balani; Rivularia sp. A - Scytonema sp. forming thick mats over exposed limestone hummocks (Fig. 4.4c), not over silt; Schizothrix calcicola - Microcoleus chthonoplastes binding sediments over the surface of some hummocks.
- E) Pale blue laminated sediments of Microcoleus chthonoplastes; coarse green filaments of Rhizoclonium sp. over the surface of the silt.

F) Hyella balani lending a blue colour to much of the exposed rock and Microcoleus chthonoplastes binding sediment.

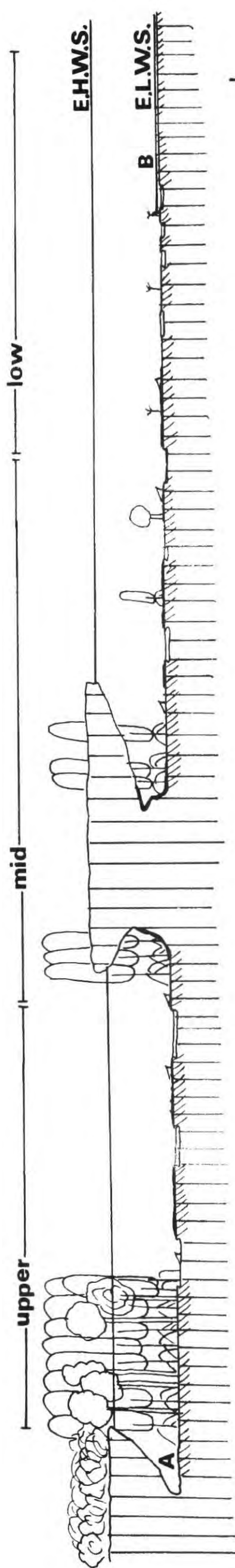


AB = 200m

Figure 4.16 L10 Lagoon landing to Dune d'Messe

4.171 Transect L11

- A) 13.03.75 ; 1400; 1120 +0280; Grande Terre; vicinity of Gros [^]Îlot Cavalier.
- B) Carbonate mudflat; several large residual islets close to the shore with dense surface scrub of Pemphis; lagoon floor visible in places, soluted and eroded with an irregular cover of pale grey silt, often forming large drifts; mangroves in a thin line to the shore, many dead and fallen, Avicennia and Rhizophora dominant; at low tide a large area remains under water of 3 to 4 cm depth for a long distance into the lagoon, lag of 2 h, low water lasting a very short time during springs.
- C) From mangrove line to the first residual islet offshore, and a small stand of Rhizophora, c 250 (Fig. 4.17).
- D) Scytonema sp. forming broken mats among mangroves.
- E) Pale blue laminated sediments of Microcoleus chthonoplastes, bright green below surface, covering a wide area; globular stromatolites of Schizothrix gracilis, 2 to 3 cm diameter, purple in colour, irregularly distributed over a wide area.
- F) Microcoleus chthonoplastes and Lyngbya confervoides covering the silt surface as films.



AB = 250m

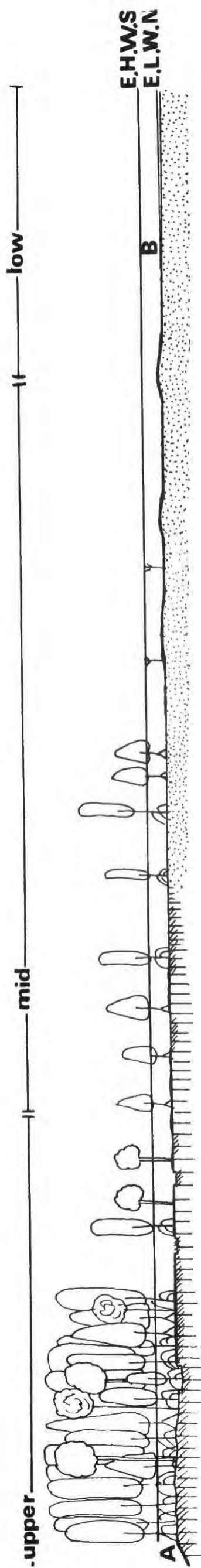
Figure 4.17 L11 Gros îlot Cavalier

4.172 Transect L12

- A) 27.11.74 ; 0830; 9005 +5250; Grande Terre; in the 'mini' lagoon of Îles Moustique, a mangrove colonizing sandbank off the coast of Grande Terre.
- B) Carbonate mudflat merging into sandflat, stretching from an open circular area in Îles Moustique to a wide extensive sandflat between Îles Moustique and Île d'Esprit (Fig. 4.1); small amount of exposed limestone in upper zone, silt and sand hummocks in upper and mid zone, shallow white silts in upper zone, in places cemented by heating and evaporation of sea water forming thin surface crusts (2 to 3 cm), fine sand in hummocks and ripples in low zone; Rhizophora and Bruguiera enclose the mini lagoon in the upper zone, lower down the zone Bruguiera, Cerriops and Rhizophora are dominant; water a milky colour in the mini lagoon, draining rapidly here after retreat of the tide, area connected to the lagoon proper by a narrow creek, lag of 2.5 h, advancing rapidly with incoming tide.
- C) From the mini lagoon, following the creek to the sandflat in a straight line towards the lagoon, 275 m (Fig. 4.18).
- D) Small gelatinous colonies of Entophysalis granulosa spread over a wide area of the surface crust of the mudflat; Scytonema sp. and Scytonema sp. - Microcoleus chthonoplastes communities covering a wide area as broken crusts; Pleurocapsa fuliginosa - Entophysalis granulosa community among the sediment.
- E) Stratiform stromatolites of Microcoleus chthonoplastes -

Schizothrix calcicola community covering extensive areas as orange coloured crusts, hummocks orientated 90° to the direction of tides.

F) Stratiform stromatolites as above, becoming more broken up.



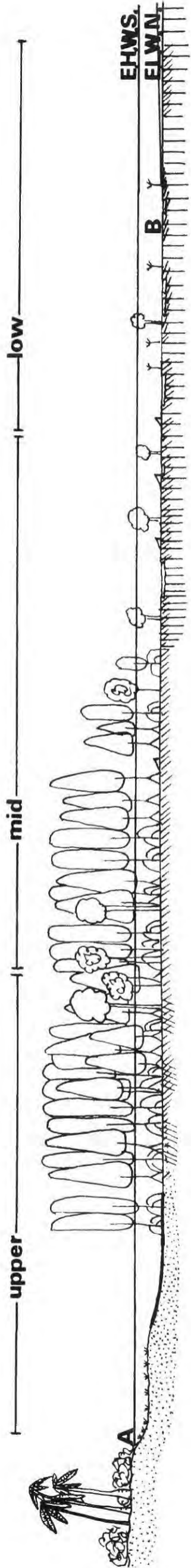
-298-

AB = 275 m

Figure 4.18 L12 Îles Moustique

4.173 Transect L13

- A) 11.12.74 ; 0830; 0810 +0505; Grande Terre; vicinity of Petit Cavalier, close to the boat landing by the Cocos trees.
- B) Carbonate mudflat; lagoon floor visible in large areas, pits and depressions common, towards the low zone, limestone becomes acute and jagged, no limestone overhang visible at the land rim; deposits of sand merge into dense Pemphis scrub behind the Cocos trees, grey silts over much of the intertidal zone; mangrove forest tall, Bruguiera dominant, Rhizophora, Cerriops and Avicennia also present; long exposure times here, lag 2 h.
- C) From Cocos trees across the mudflat in a straight line towards the standing water of the lagoon, 175 m (Fig. 4.19).
- D) Scytonema sp. covering the sand deposits as thick crusts.
- E) Pale blue laminated sediments of Microcoleus chthonoplastes over much of the deeper deposits of sediment; Scytonema sp. attached to knee roots of Bruguiera (Fig. 3.1b, e, 4.4d); Beggiatoa sp. among both communities above.
- F) Microcoleus chthonoplastes over much of sediment surface; orange flocks of Lyngbya aestuarii in water filled depressions of lagoon floor.



-300-

AB = 175 m

Figure 4.19 L13 Petit Cavalier

4.18 Revisits to selected transect sites

As was discussed in 4.1, a decision was made to visit a number of transect areas several times during the study period, with the purpose of obtaining information on any apparent cyclical or seasonal variations in important communities. Transects L1, L2 and L3 (4.161, 4.162, 4.163) were chosen because they were in relatively close proximity to one another, which meant they could all be visited on the same day. Communities in these areas were found in many of the other transects and several were felt to be ecologically important. In addition, one of the two visually conspicuous communities of photosynthetic bacteria recorded in the intertidal zone, were found in the area of L3.

4.181 Transect L1

A description of transect L1 was given in 4.161. This area was first visited on 16.11.74, and then subsequently on 04.12.74, 08.02.75, every day from 28.03.75 to 20.04.75 and 28.05.75.

The dominant community in this area was a Scytonema mat in the upper intertidal (Fig. 4.4a), and at least in area, was found to change little during the time of study. During high spring tides the community appeared as a relatively flat, olive-green mat, remaining damp from one tide to the next. However, during neaps the mat became broken up into polygonal crusts, curled at the edges and separated from the sediment of the sandflat. Microscopic examination of samples of the mat indicated no major changes

in species composition; Scytonema sp. and Microcoleus chthonoplastes remained the two dominant species.

A community dominated by Aphanothece microscopica and Hydrocoleus sp. was noted on 28.03.75, and formed a pale green film over the surface of sand hummocks at the sides of the creek. This community was not recorded on previous visits, and after the spring tides in March, it was not recorded again. Pink growths of Chromatium sp. became conspicuous in the creek after high spring tides, and were always found covering the sand at the side of the creek closest to the mangrove forest. The other dominant communities described in 4.161 underwent no observable changes in eight months.

4.182 Transect L2

The dominant communities in this area were described in 4.162, and were visited on the same days as L1 (see previous section).

Apart from the appearance of new burrows of ghost crabs in mats and crusts, the extent and species composition of these communities did not change appreciably. The community dominated by Microcoleus chthonoplastes in the low intertidal, increased in area by c 0.5 m², at the sides of the creek, where it was associated with Chromatium sp. (Fig. 4.6). As in L1, repeated observations of the pink growths of Chromatium sp., indicated that they were always associated with creeks and sediments close to mangroves.

4.183 Transect L3

This area was first described in detail in 4.163, and was visited on the dates specified in 4.181.

When first visited on 18.11.74, the Hyella balani - Microcystis reinboldii community lent a bright green colour to a large area of the intertidal sandflat (4.163). After low neap tides, the sediment always appeared to dry out to such an extent that the surface formed a crust c 4 mm thick. With the onset of spring tides, sediment was deposited over this crust, and within a few days it lost its rigidity and the sediment remained wet even at low spring tides. With the increased exposure times at neaps, the crust again began to form.

The most dramatic changes observed in this area, were in the distribution and extent of the community of Chromatium sp. During neap tides, vivid pink growths of this species were found associated with intertidal residual pools, but only at the sides of the pools closest to the mangrove forest. After high spring tides, the pink growths covered large areas of the beach and a pronounced smell of hydrogen sulphide was evident.

The communities of Calothrix and Scytonema in the upper part of the zone (4.163), as in L1 and L2, appeared to change little over the eight months.

4.19 Regeneration time of Scytonema mats

It became apparent after several weeks of study of the intertidal zone, that mats of Scytonema sp. were widespread

and in places abundant. It was therefore decided to make an area of Scytonema mat at La Gigi, the subject of a long term study over six months. It was hoped that this would help in interpreting some of the factors influencing the abundance and distribution of this species in the lagoon.

The area selected for study was the Scytonema mat in the upper part of the intertidal zone of transect L2 (4.162). The mat grew in open 'glades' in mangrove forest, and was perforated by numerous pneumatophores of Avicennia. Only a few cerethids were visible over the surface of the mat. The mat was thickest in the open mangrove forest and was absent under the shaded areas of large mangrove trees.

A 1 m² area was removed from the mat to a depth of 10 cm, but the pneumatophores were left intact. Numerous 1 cm² samples (2.19), were taken from the sediment surface at regular intervals over six months for microscopic examination.

The sequence in species composition and abundance over 25 weeks is shown in Table 4.4. Abundance is indicated on a scale from 0 to 5 as discussed in Section 2.19. Before the start of the experiment, the dominant species in the mat were Scytonema sp., Hormathonema violaceo-nigrum and Calothrix scopulorum. After a week, the surface of the sediment was pale green in colour, and formed a very thin crust. A little sediment had been washed into the depression by tides. Filamentous species first appeared between one and two weeks after the start of the experiment, and the surface

of the sediment was still of a crust nature, and quite different to the loose beach sand out of the mangroves. The general appearance of the sediment surface remained the same during the 25 weeks of the study, only after approximately six months were a few isolated patches (1 cm diameter) of Scytonema 'tufts' visible over the surface. There was minimal infill of the depression during this time, and the depth at 25 weeks was c 9 cm.

Table 4.4 Regeneration time of a Scytonema mat community, L2

species	0	1	2	4	10	22	25 weeks
<u>Aphanocapsa grevillei</u>	1		1		3	3	2
<u>Aphanothece microscopica</u>					4	2	1
<u>Calothrix scopulorum</u>	3		1			4	3
<u>Chroococcus turicensis</u>	1				1	2	2
<u>Dermocarpa olivacea</u>		3		2		3	2
<u>Entophysalis granulosa</u>	1		2			2	2
<u>Gloeothece palea</u>					4	1	
<u>Hormathonema violaceo-nigrum</u>	4		3			4	2
<u>Hvella balani</u>			2			3	3
<u>Lyngbya aestuarii</u>				1		3	1
<u>Lyngbya digueti</u>			1			2	3
<u>Lyngbya martensiana</u>				5	2	2	3
<u>Lyngbya pusilla</u>			1				1
<u>Microcoleus chthonoplastes</u>	1				2	3	4
pennate diatoms			1	2		2	2
<u>Pleurocapsa crepidinum</u>	2	1	1			3	3
<u>Pleurocapsa fuliginosa</u>		3			3	3	3
<u>Radaisia epiphytica</u>		2	1			1	1
<u>Schizothrix calcicola</u>	2			3		2	2
<u>Scytonema</u> sp.	5		1	2	1	4	4

4.110 The distribution and abundance of communities of photosynthetic prokaryotes within the intertidal zone of the lagoon

The extent to which transects could be considered as being representative of large areas of the lagoon was discussed in Section 4.1. Table 4.5 shows the distribution within the 13 transect areas of the most abundant species in the dominant communities interpreted from the collection of 1 cm² samples (2.19). Scytonema sp., Microcoleus chthonoplastes, Lyngbya confervoides and Schizothrix calcicola, were the most frequently occurring species, and were recorded from the greatest number of transects. The colourless, gliding bacteria Beggiatoa spp. were also recorded in more than half the transects.

Scytonema sp. was found in all but one of the transects, and Microcoleus chthonoplastes in all but two. These two species were dominant in the communities of mats and recent stromatolites, which covered large areas of the intertidal zone along the south coasts of the lagoon (4.170). Along the north coasts, the area covered by these communities was reduced to a narrow zone close to the shore. Rivularia sp. 'A', which was found with the thick mats of Scytonema sp. over limestone hummocks along the south coast, was not recorded as forming abundant communities elsewhere in the lagoon. Schizothrix calcicola and Microcoleus chthonoplastes formed stratiform stromatolites, covering a large area of the sandflat between Îles Moustique and Île d'Esprit (Table 4.11).

Visually conspicuous communities of photosynthetic bacteria were found at only two localities within the intertidal zone (4.163, 4.167).

The problems involved in the interpretation of the distribution of communities within different zones of the intertidal, were discussed in Section 4.12. Tables 4.6 and 4.7, show the distribution of the dominant species recorded from communities in the upper, mid and low zones of the intertidal, as interpreted from straight line transects. Four species formed dominant communities in all the zones, and of these, Microcoleus chthonoplastes and Schizothrix calcicola were important mat forming species (Table 4.11). The most conspicuous community in the upper zone of 12 transects was one dominated by Scytonema sp., which formed thick mats in a narrow zone parallel to the shore, usually over exposed limestone, and at an elevation above that of the sand or mudflat. Communities of photosynthetic bacteria were found only in the mid or low zones, together with communities of Beggiatoa sp. and diatoms. Photosynthetic bacteria were never recorded from higher up the intertidal zone. A list of the most frequently recorded species from marine and brackish water environments is given in Table 4.8.

Table 4.9 shows the abundance of species dominating communities at different vertical heights on limestone substrata, and Fig. 4.20 shows two representative examples of substrata from the lagoon, and an inland tidal depression. As mentioned in 4.12, vertical zonation was studied to help

interpret the true distribution of communities within the intertidal zone. The position of Scytonema sp. is lower than expected, considering its association with the extreme upper part of the zone in transects. Entophysalis granulosa, Hormathonema violaceo-nigrum, Pleurocapsa fuliginosa and Tolypothrix byssoidea were only associated with the upper limit of the tidal influence, and Spirulina sp. and Mastigocoleus testarum with its lower limit. A number of species were found to be abundant in more than one zone e.g. Lyngbya spp.

When Table 4.7 is compared with Table 4.9, it is possible to produce a clearer zonation pattern, and this is illustrated in Table 4.10. Non-filamentous species, such as Entophysalis granulosa and Pleurocapsa fuliginosa are characteristic of the upper part of the intertidal, and moving lower down the zone, filamentous species become more common. Microcoleus chthonoplastes and Schizothrix calcicola are found in both the mid and low zones, and Scytonema sp. is restricted to the upper intertidal zone. The most frequently recorded species from marine and brackish intertidal environments of the lagoon and seawards were shown in Table 4.8.

Table 4.6 Number of transects in which species were recorded in different zones

	heterocysts	upper	mid	low
<u>Aphanocapsa grevillei</u>	-	0	0	1
<u>Aphanocapsa montana</u>	-	0	1	0
<u>Beggiatoa</u> spp.	-	0	4	4
<u>Calothrix contarenii</u>	+	2	0	0
<u>Calothrix crustacea</u>	+	1	0	0
<u>Calothrix scopulorum</u>	+	2	0	0
<u>Chroococcus spelaeus</u>	-	1	0	0
<u>Chromatium</u> sp.	-	0	2	3
pennate diatoms	-	0	2	2
<u>Dichothrix rupicola</u>	+	1	0	0
<u>Entophysalis granulosa</u>	-	2	0	0
<u>Hormathonema violaceo-nigrum</u>	-	1	0	0
<u>Hyella balani</u>	-	1	3	1
<u>Lyngbya aestuarii</u>	-	2	0	0
<u>Lyngbya digueti</u>	-	0	0	1
<u>Lyngbya confervoides</u>	-	2	1	3
<u>Lyngbya martensiana</u>	-	1	0	0
<u>Lyngbya majuscula</u>	-	1	0	0
<u>Lyngbya pusilla</u>	-	0	1	1
<u>Microcoleus chthonoplastes</u>	-	5	7	10
<u>Phormidium molle</u>	-	0	2	0
<u>Pleurocapsa fuliginosa</u>	-	4	0	0
<u>Rivularia</u> sp. A	+	1	2	0
<u>Schizothrix arenaria</u>	-	0	1	0
<u>Schizothrix calcicola</u>	-	2	3	3
<u>Schizothrix gracilis</u>	-	0	1	1
<u>Scytonema</u> sp.	+	12	0	0
<u>Spirulina labyrinthiformis</u>	-	0	1	1
<u>Spirulina subsalsa</u>	-	0	0	1
<u>Thiocystis</u> sp.	-	0	1	1
<u>Tolypothrix byssoidea</u>	+	1	1	0

Table 4.7 Species associated with different zones

species which are dominant only in the upper zone of transects

Calothrix contarenii
Calothrix scopulorum
Chroococcus spelaeus
Dichothrix rupicola
Entophysalis granulosa
Hormathonema violaceo-nigrum
Lyngbya aestuarii
Lyngbya martensiana
Lyngbya majuscula
Pleurocapsa fuliginosa
Scytonema sp.

species which are dominant only in the mid zone of transects

Aphanocapsa montana
Phormidium molle
Schizothrix arenaria

species which are dominant only in the low zone of transects

Aphanocapsa grevillei
Lyngbya digueti
Spirulina labyrinthiformis
Spirulina subsalsa

species which are dominant only in the upper and mid zones

Rivularia sp. A
Tolypothrix byssoidea

species which are dominant only in the mid and low zones

Beggiatoa spp.
Chromatium sp.
pennate diatoms
Lyngbya pusilla
Schizothrix gracilis
Thiocystis sp.

species which are dominant in all zones of transects

Hyella balani
Lyngbya confervoides
Microcoleus chthonoplastes
Schizothrix calcicola

Table 4.8 The 10 most frequently recorded species from marine and brackish water environments at Aldabra Atoll

Entophysalis granulosa
Hormathonema violaceo-nigrum
Hyella balani
Lyngbya confervoides
Mastigocoleus testarum
Microcoleus chthonoplastes
Pleurocapsa fuliginosa
Pleurocapsa crepidinum
Schizothrix calcicola
Scytonema sp.

Table 4.9 Abundance of species of blue-green algae at different heights on limestone substrata
(heights in centimetres)

	cm	base	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
<u>Brachytrichia dalmatica</u>															2	2	3	5	4	3
<u>Entophysalis granulosa</u>																2	3	4	4	5
<u>Hormathonema violaceo-nigrum</u>											2	4	5	4	2					
<u>Hyella balani</u>														1						
<u>Lyngbya confervoides</u>		3	3	3	3	3	3	4	5	5	3	3								
<u>Lyngbya majuscula</u>		3	3	3	4	4	2	2												
<u>Lyngbya martensiana</u>		3	3	3	4	4	4	4	3	2										
<u>Mastigocoleus testarum</u>		3	5	5	4	2	2													
<u>Microcoleus chthonoplastes</u>		4	5	5	4	1	1													
<u>Oscillatoria nigro-viridis</u>						2	2	3	5	4	3									
<u>Phormidium submembranaceum</u>				3	3	4	5	5	3	2										
<u>Pleurocapsa fuliginosa</u>								2	3	3	4	5	4	3	2					
<u>Schizothrix calcicola</u>										2	3	4	5	5	2	2				
<u>Scytonema sp.</u>										2	2	4	5	4	2					
<u>Solentia stratosa</u>																				
<u>Spirulina subsalsa</u>		4	4	5	3	3	2													
<u>Tolypothrix byssoidea</u>																	2	2	4	5

Table 4.10 The zonation of the dominant species of blue-green algae within the lagoon intertidal zone
+ indicates occurrence in a particular zone

	upper	mid	low
<u>Tolypothrix byssoidea</u>	+		
<u>Entophysalis granulosa</u>	+		
<u>Hormathonema violaceo-nigrum</u>	+		
<u>Pleurocapsa fuliginosa</u>	+		
<u>Scytonema</u> sp.	+		
<u>Hyella balani</u>	+	+	
<u>Solentia stratosa</u>		+	
<u>Schizothrix calcicola</u>		+	+
<u>Lyngbya confervoides</u>		+	+
<u>Lyngbya martensiana</u>		+	+
<u>Lyngbya majuscula</u>		+	+
<u>Microcoleus chthonoplastes</u>		+	+
<u>Spirulina subsalsa</u>			+
<u>Mastigocoleus testarum</u>			+

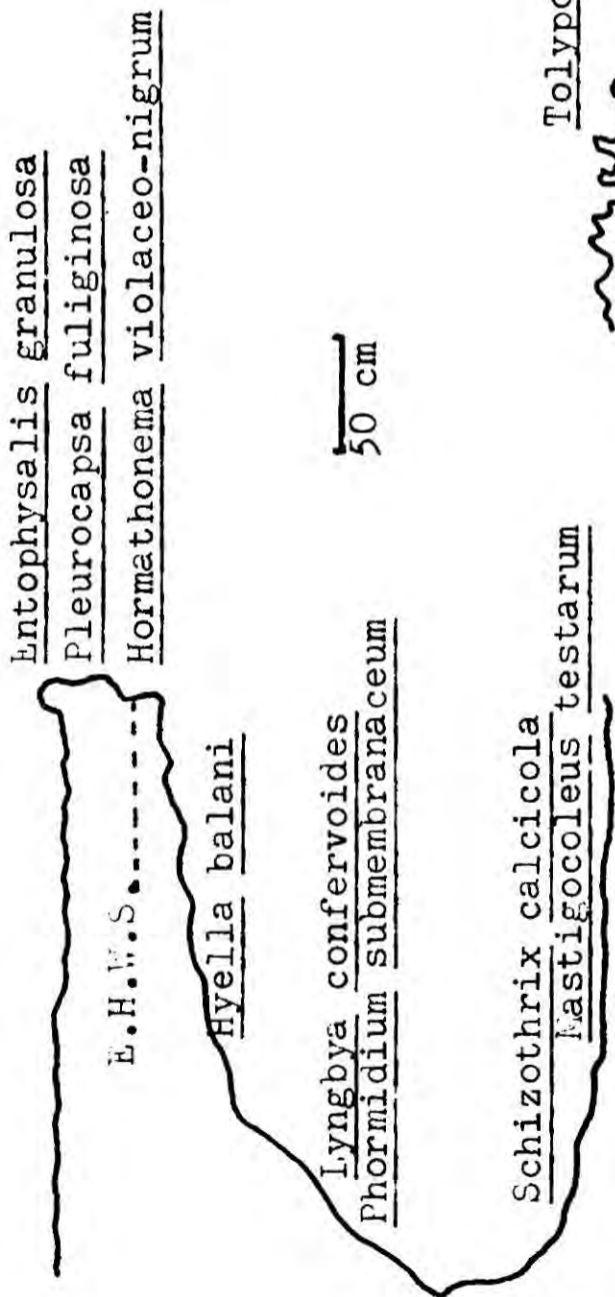


Fig.4.20a Vertical zonation on a residual islet, Ia Gigi

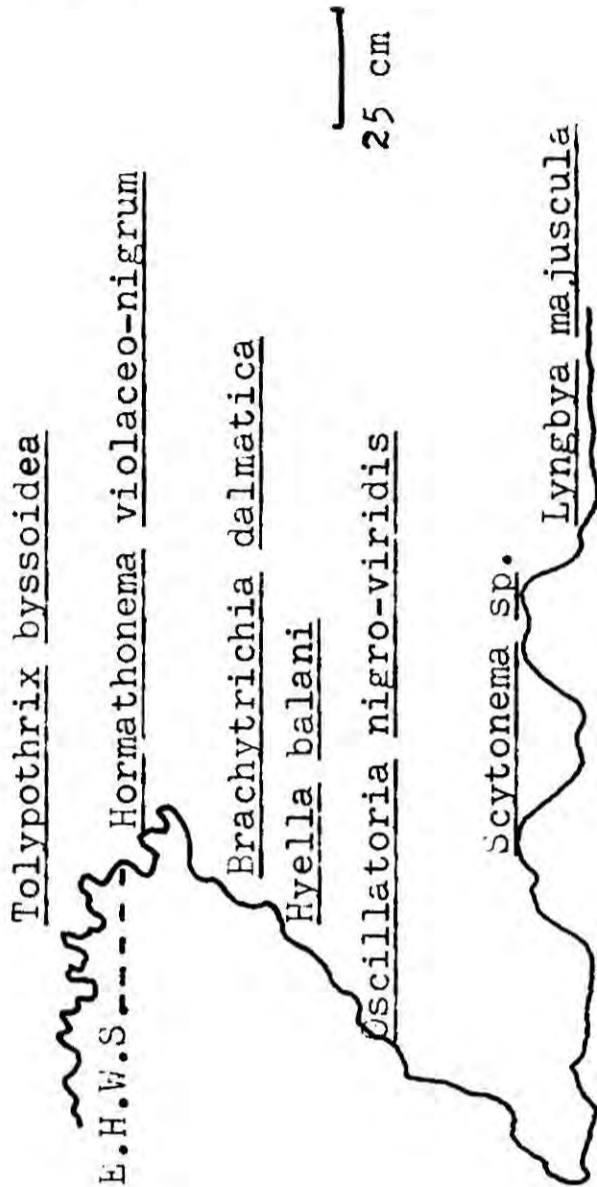


Fig.4.20b Vertical zonation in a tidal depression, Bassin Cabri

Table 4.11 The most abundant communities of blue-green algae within the intertidal zone of the lagoon (excluding endoliths)

description of community	dominant species	area
stratiform stromatolites; orange coloured crusts over sand, 2 to 3 cm thick, over sandhummocks, elevated above sandflat	<u>Microcoleus chthonoplastes</u> <u>Schizothrix calcicola</u>	extensive sandflat between Iles Moustique and Ile d'Esprit, c 0.5 to 1.0 km ²
thick mats; olive-green, covering exposed limestone hummocks, 50 cm above mudflat, hemispherical colonies among mats, 2 cm thick	<u>Scytonema</u> sp. <u>Rivularia</u> sp. A	stretches of the south coast, from Takamaka to Gros Îlot Cavalier, close to the shore c 20 x 0.02 km
stratiform stromatolites; pale blue surface crusts, bright green below surface, 3 to 4 cm thick, associated with mud deposits	<u>Microcoleus chthonoplastes</u>	large areas of the intertidal zone along the south coast, from Petit Cavalier to Takamaka c 30 x 0.04 km
thick mats; olive-green, covering limestone hummocks, 1 to 2 cm thick	<u>Scytonema</u> sp.	narrow zone close to shores of Île Malabar c 12 x 0.01 km

4.2 Physical and chemical analyses

A discussion was given in 4.1, on the distribution and abundance of the dominant communities of photosynthetic prokaryotes, in the 13 transect areas of the lagoon intertidal zone. More general information on the geology and geography of these areas was also discussed. This section presents physical and chemical data collected from the 13 transects, as well as from a number of intertidal habitats at Île Picard and other areas of the lagoon.

4.21 Light intensity

As mentioned in 2.11, the methods used in the estimation of light intensity could only give rough estimates of the actual field values. Nevertheless, values from different habitats may be used for comparative purposes. Table 4.12 gives average values of light intensity from a number of different habitats within the lagoon. All measurements were taken between 1000 and 1300 h, on a number of days over the period November 1974 to May 1975. Weather conditions for this period have been included in Table 4.12. When taking readings, the meter was orientated to give the highest reading in each particular location i.e. held up directly to the light.

The lowest values were of the order of 800 lx, obtained from among dense knee roots of Bruguiera in mangrove forest. The highest values were found in the open carbonate mudflats of the south coast, where values >30000 lx were common. The average values in mangrove forest were of the order 10000 lx.

Table 4.12 Average values of light intensity from various intertidal habitats
 (cloud cover is given in eighths e.g. 3 indicates 3/8 cover)

area	mean intensity (lx)	date	time (h)	n	cloud cover
<u>Rhizophora</u> forest, La Gigi	5500	26.11.74.	1100	8	3
open glades in mangrove forest, La Gigi	7500	10.02.75.	1230	10	3
among dense knee roots, <u>Bruquiera</u> forest, Île Verte	800	12.02.75.	1300	20	5
open sandflat, La Gigi	>30000	07.04.75.	1200	15	1
open mudflat, Grande Terre	>30000	20.05.75.	1330	23	1

4.22 Relative humidity

During the tidal cycle, mats of blue-green algae were often exposed for long periods, and the length of time they remained wet or moist after exposure, varied according to the shade and local weather conditions. It was decided to measure the relative humidity in the vicinity of several important communities of blue-green algae, from three transect areas at Île Picard. Several other important communities were included for comparative purposes.

All measurements were taken on 12.05.75, between 1415 and 1600 h. No rain had fallen within the previous three days, and the moist mats had been exposed for three hours prior to the readings being taken (Table 4.13).

The highest value of 96.0 % was taken at the bottom of a tidal depression, and this was 11 % higher than ambient air values. For the moist mats of Scytonema sp. and Calothrix crustacea, the values at the surface were approximately the same as the ambient air values, but for the dried out mats the values at the surface were somewhat lower. It is difficult to draw any positive conclusions from much of the data, but it appears that the relative humidity dropped with increasing vertical height above moist mats, and rose with increasing height above dry mats. The lowest value of 49.0 %, was recorded from the surface of Sporobolus virginicus vegetation in the Cocos nucifera grove at the research station. This value was almost 44.0 % lower than the ambient air value. Communities of the

Table 4.13 Relative humidity measurements at different vertical heights above communities at Île Picard

community	relative humidity above community (%)			
	0 cm	1.0 cm	10 cm	100 cm
dried out <u>Scytonema</u> mat, La Gigi, L1	64	67	75	78
dried out <u>Scytonema</u> mat, La Gigi, L1	73	73	72	75
moist <u>Scytonema</u> mat, C2	76	79	76	78
moist <u>Scytonema</u> mat, C2	84	82	80	77
dried out <u>Scytonema</u> mat, L2	76	73	75	80
moist <u>Calothrix</u> mat, C1	80	77	74	72
moist <u>Calothrix</u> mat, shaded	84	82	79	75
dried out sand dune crusts, C7	70	69	69	77
bottom of tidal depression, back path	96	92	93	93
out of depression, above pool	65			
standing water, mangrove forest, Anse Chauv	88	91	92	89
dried out <u>Nostoc commune</u> colonies, <u>Cocos</u> grove, research station	49	52	66	69
exposed beachrock, seaward coast, Settlement	83			
ambient air value, meteorological site	87			

terrestrial blue-green alga Nostoc commune were found over the ground surface among the Sporobolus.

4.23 Sieving analysis of lagoon sediments

Three different intertidal environments were discussed in 1.33, each characterized by a different sediment type. The results of sieving analyses of sediments collected from transects are shown in Table 4.14. The relationship between the phi (ϕ) class and the sieve size was given in Table 2.4.

Finest sediments were associated with transects carried out along the south coast of the lagoon, from Takamaka to Petit Cavalier. These sediments all had greater than 94% of their dry weight comprised of particles $\leq 250 \mu\text{m}$. The finest sediment was found lining the creek at Takamaka (L8). Coarsest sediments were all associated with passes (Passe Femme, Passe Houareau), from transects L1, L2, L3, L6. Brown silts collected from transects L4, L5, and L7 had the highest percentage of grains in the lower size classes. In transect L7 (Cinq Cases), sediment collected from three different areas down the intertidal zone showed little variation in size composition.

On a percentage dry weight basis the ranges for each ϕ class were:

-1.0	0.55 to 17.5%
0.0	0.39 to 6.5%
+1.0	0.16 to 27.9%
+2.0	0.69 to 64.9%
>+2.0	10.9 to 97.9%

In general the order for finest sediments (considering

Table 4.14 Analysis of sediments from lagoon transects

transect	% dry weight (per ϕ class)					description
	-1.0	+1.0	+2.0	>+2.0		
L1	12.9	16.8	38.7	26.5		medium coarse sand
L2	5.63	14.6	64.9	10.9		medium coarse sand
L3	0.550	27.9	51.4	13.7		medium coarse sand
L4	3.40	2.60	16.1	80.0		fine sand - brown silt
L5	6.20	1.90	15.2	74.3		brown silt
L5	16.3	2.74	11.2	68.1		brown silt
L6	10.8	12.5	38.3	32.3		medium coarse sand
L7	16.6	7.80	14.0	56.3		brown silt
L7	12.8	8.20	17.0	57.4		brown silt
L7	17.5	9.90	11.0	55.1		brown silt
L8	0.670	0.210	0.740	97.9		white silt
L8	1.94	0.160	1.20	94.3		white silt
L9	0.420	1.30	1.33	96.4		white silt
L10	1.22	1.24	0.690	96.0		white silt
L11	0.670	0.500	2.60	95.4		white silt
L12	6.69	7.30	13.3	69.2		very fine sand - white silt
L13	1.05	4.82	14.9	77.2		fine sand - white silt

particles ($\leq 500 \mu\text{m}$) were in transects L8, L9, L10, L11, L12, L13, L4, L5, L7, L1, L2, L3, L6.

The importance of mats of blue-green algae in the trapping and binding of sediments was discussed in 1.11, and the distribution and abundance of recent stromatolites in the lagoon was summarised in Table 4.11. Figures 4.21, 4.22, 4.23 show the size weight distribution in sediments associated with six communities of blue-green algae, from three transects at Île Picard, and one transect at Îles Moustique. With one exception the highest percentage of grains in each sediment class were those in the ϕ class range +2.0 to +1.0 ($>250 \leq 500 \mu\text{m}$). For the Microcoleus chthonoplastes - Schizothrix calcicola community, forming stratiform stromatolites at Îles Moustique (4.172), the highest percentage of grains were those $\leq 250 \mu\text{m}$.

4.24 Eh and pH

4.241 Lagoon sediments

Figures 4.24 and 4.25 illustrate the Eh-pH characteristics of lagoon sediments in 13 transect areas. Because of the shallow nature of some sediments it was not always possible to take readings at 40 mm depth, and there are fewer readings from this depth. The precautions and methods adopted in the measurement of Eh and pH were discussed at length in 2.17.

In general readings of pH and Eh tended to be lower at 40 mm than at 10 mm depth. At 10 mm white carbonate silts had higher values of pH than brown silts. Carbonate silts also had higher mean values of Eh, although the distinction was not as

Figure 4.21 The size weight distribution of
sediments associated with mats
of Scytonema sp., Île Picard

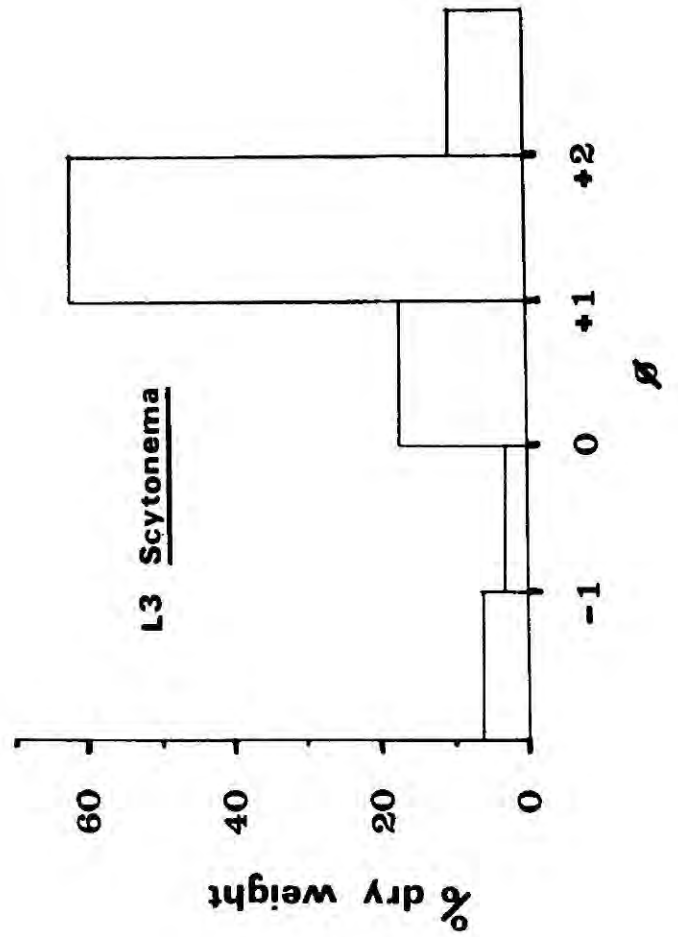
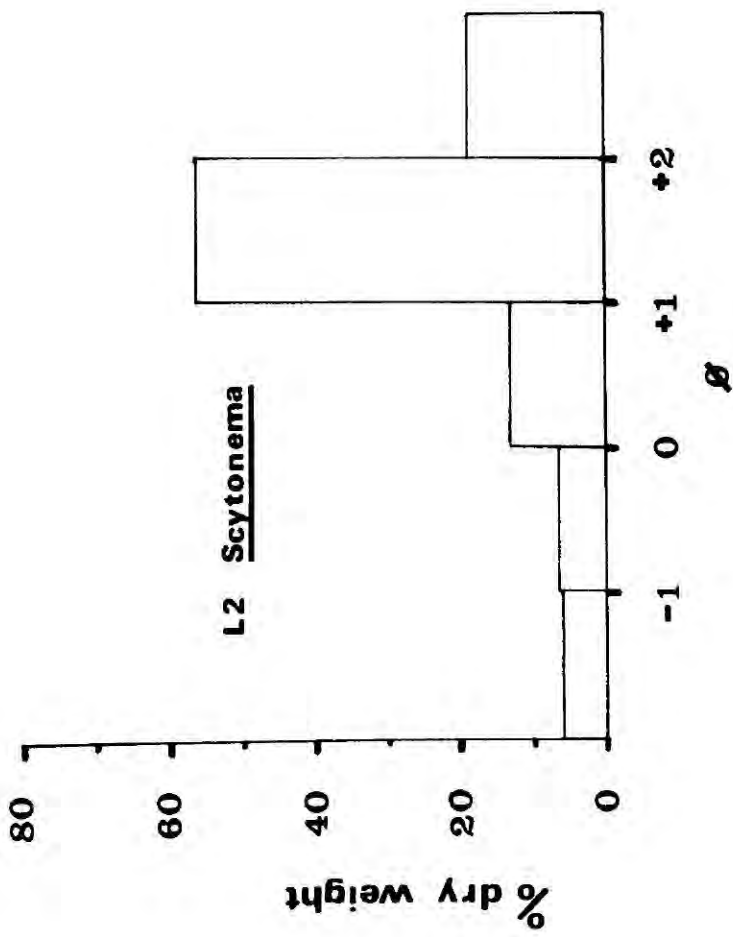
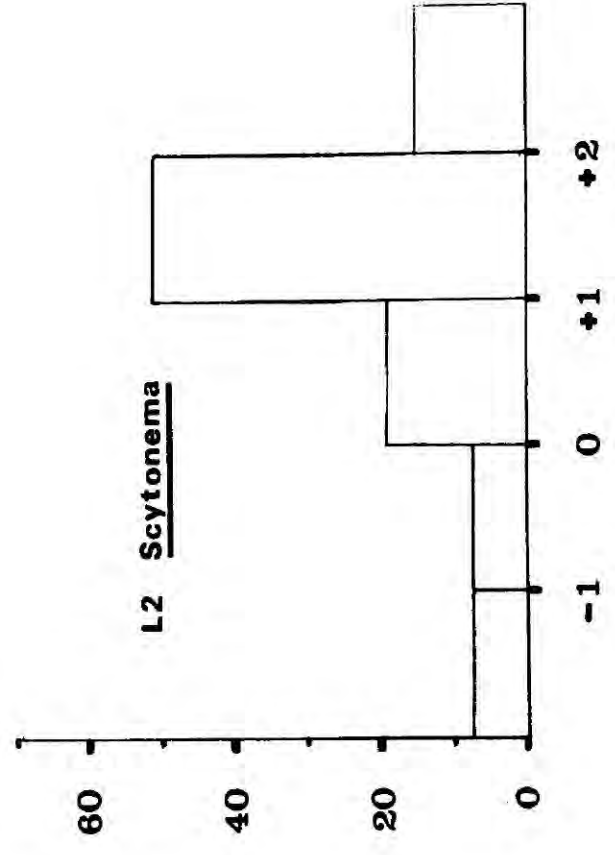
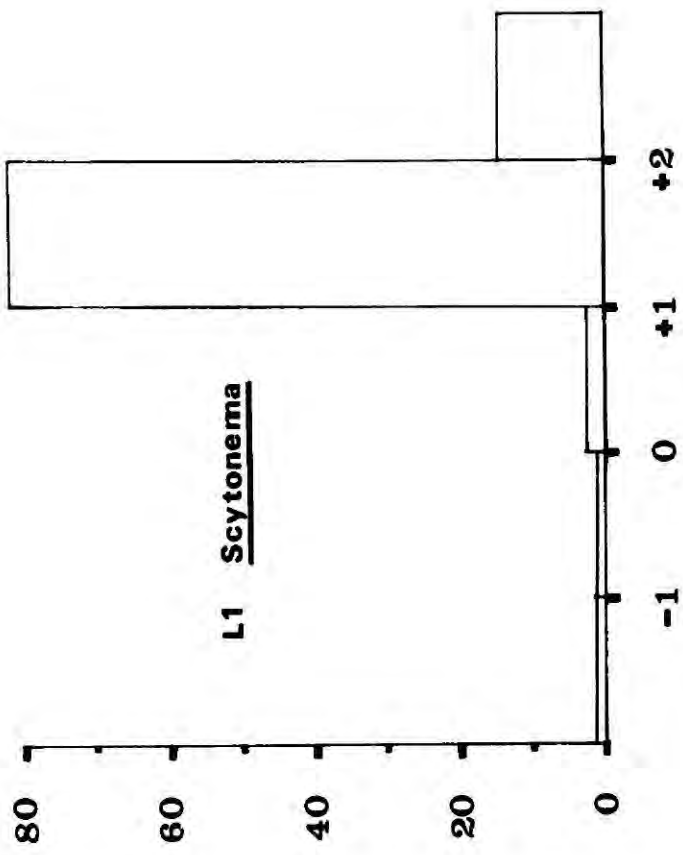


Figure 4.22 The size weight distribution of sediments associated with different communities of blue-green algae, Île Picard and Îles Moustique

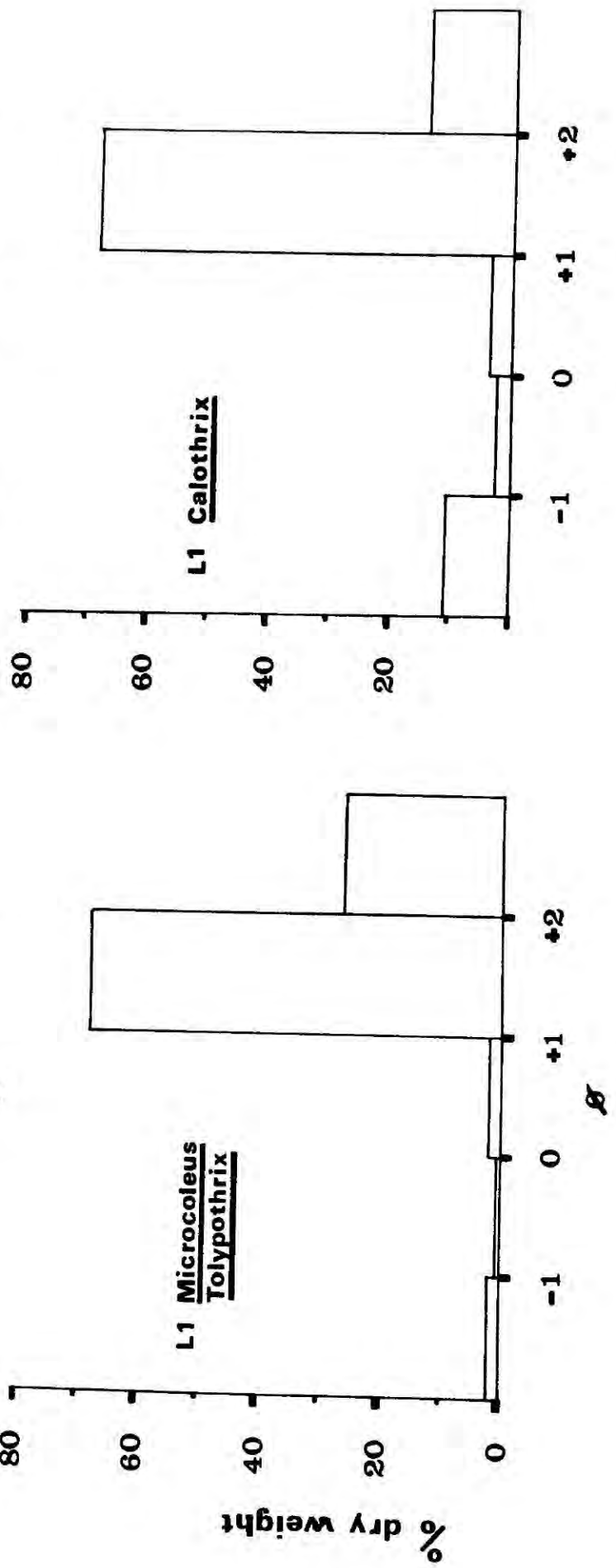
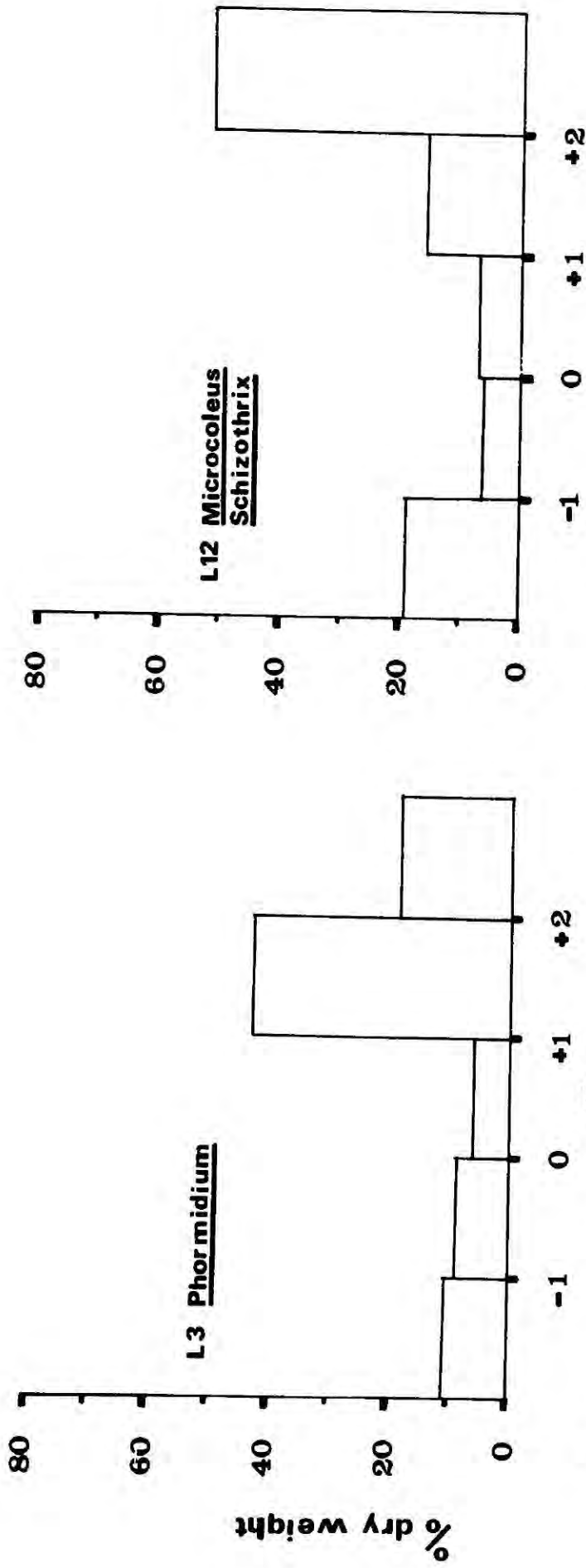


Figure 4.23 The size weight distribution of sediments associated with different communities of blue-green algae, Île Picard

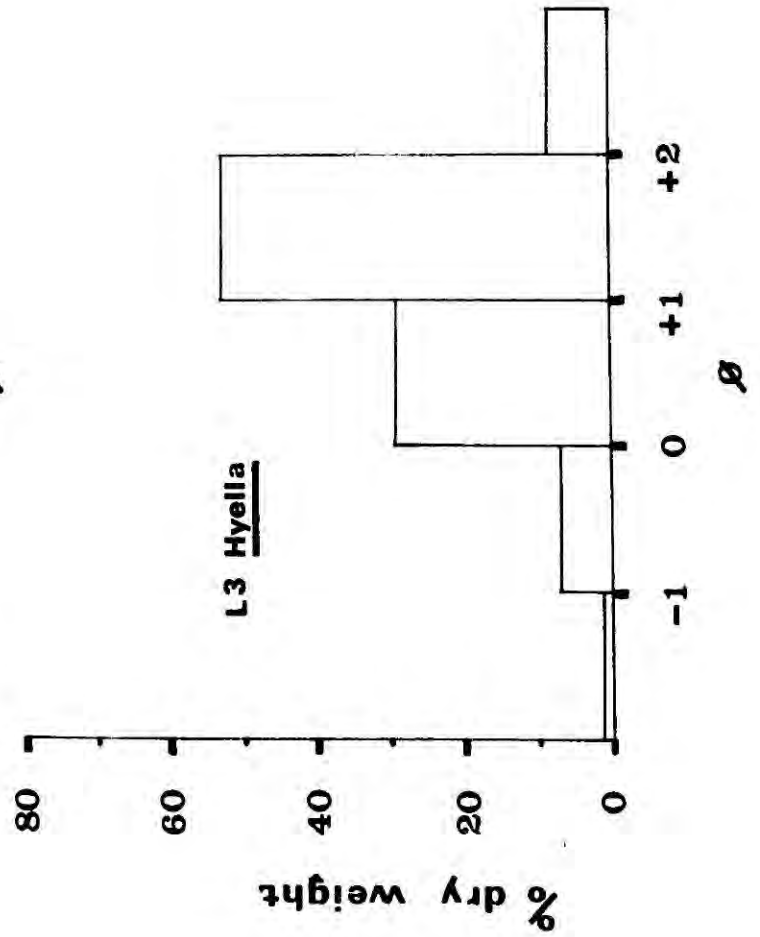
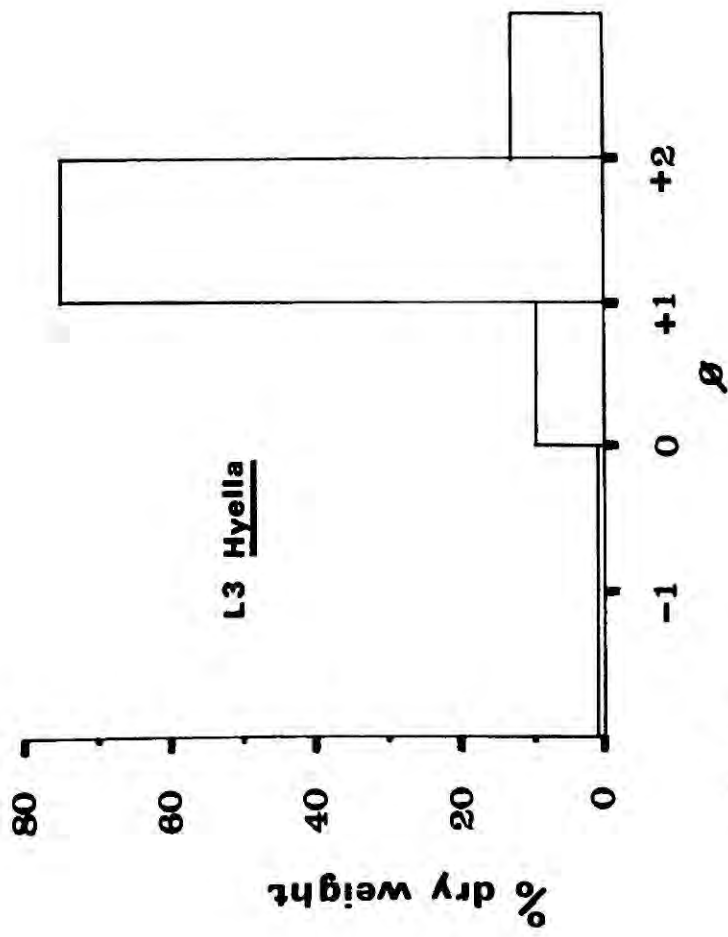
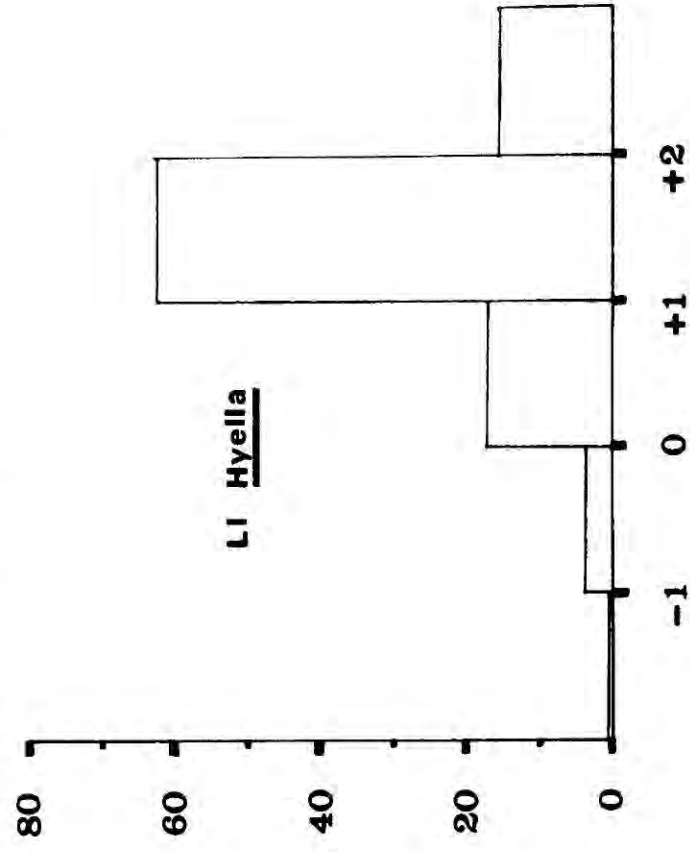
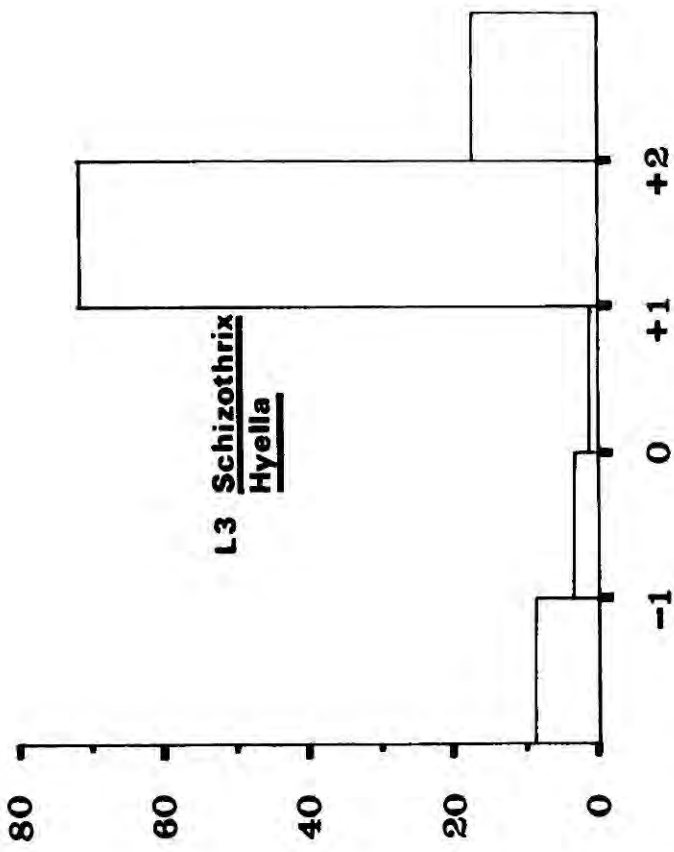
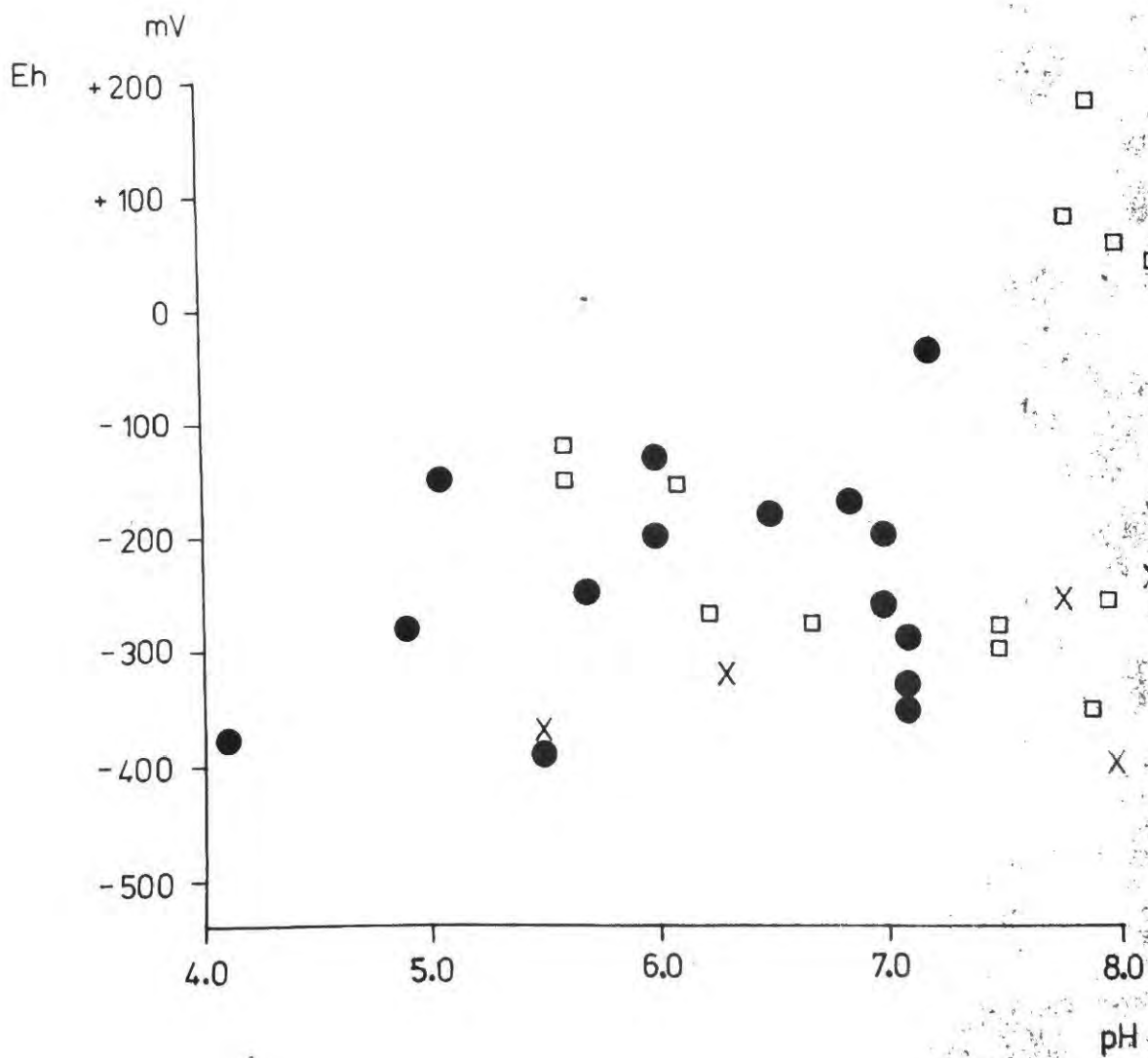
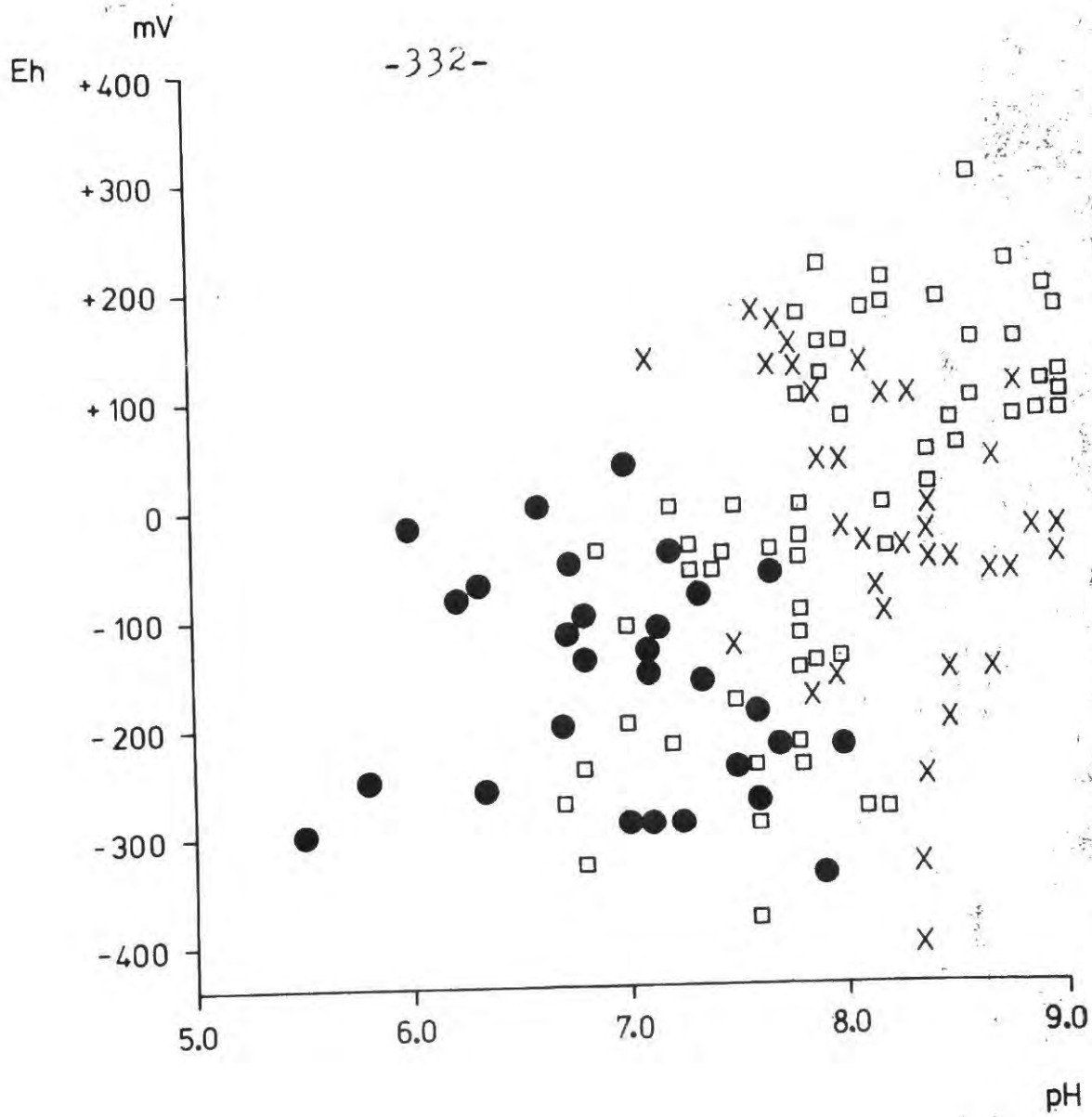


Figure 4.24 Eh-pH characteristics of lagoon
sediments at 10 mm depth
□ sands
x whitish silts
● coloured silts (grey or red-brown)

Figure 4.25 Eh-pH characteristics of lagoon
sediments at 40 mm depth
□ sands
x whitish silts
● coloured silts (grey or red-brown)



clear as for pH. Sands exhibited a wide range in Eh as well as pH values. At 10 mm as well as 40 mm, the Eh values for sands were generally higher than those for both silt types. For all sediments there was a wide range in both pH and Eh at 10 mm and 40 mm (5.5 to 9.1, -410 to +300 mV; 4.1 to 8.35, -400 to +179 mV).

4.242 Sediments associated with photosynthetic microbial communities

Fig. 4.26 shows the Eh-pH range of sediments associated with five algal communities and one photosynthetic bacterial community.

The Chromatium sp. community clearly differs from the algal communities in the range of Eh and pH (5.75 to 8.3, -330 to -80 mV). The algal communities all fall within the ranges 6.9 to 9.2 and -160 to +275 mV. Within this broad range, the ranges for individual communities are: Scytonema sp. (7.1 to 9.2, -66 to +275 mV) a range of 341 mV, 81% of the readings being positive; pennate diatoms (7.4 to 8.6, -65 to +155 mV) a range of 220 mV, 71% of the readings being positive; Microcoleus chthonoplastes (7.2 to 9.1, -75 to +183 mV) a range of 258 mV, 71% of the readings being positive; Schizothrix calcicola (7.0 to 8.3, -50 to +50 mV) a range of 100 mV, 50% of the readings being positive; Hyella balani (6.9 to 8.7, -160 to 0.0 mV) a range of 160 mV, all readings being negative. For the Chromatium sp. dominated community, the range in Eh is 250 mV, all the Eh readings being negative.

In order of the probability of being associated with positive Eh values the communities are: Scytonema sp.;

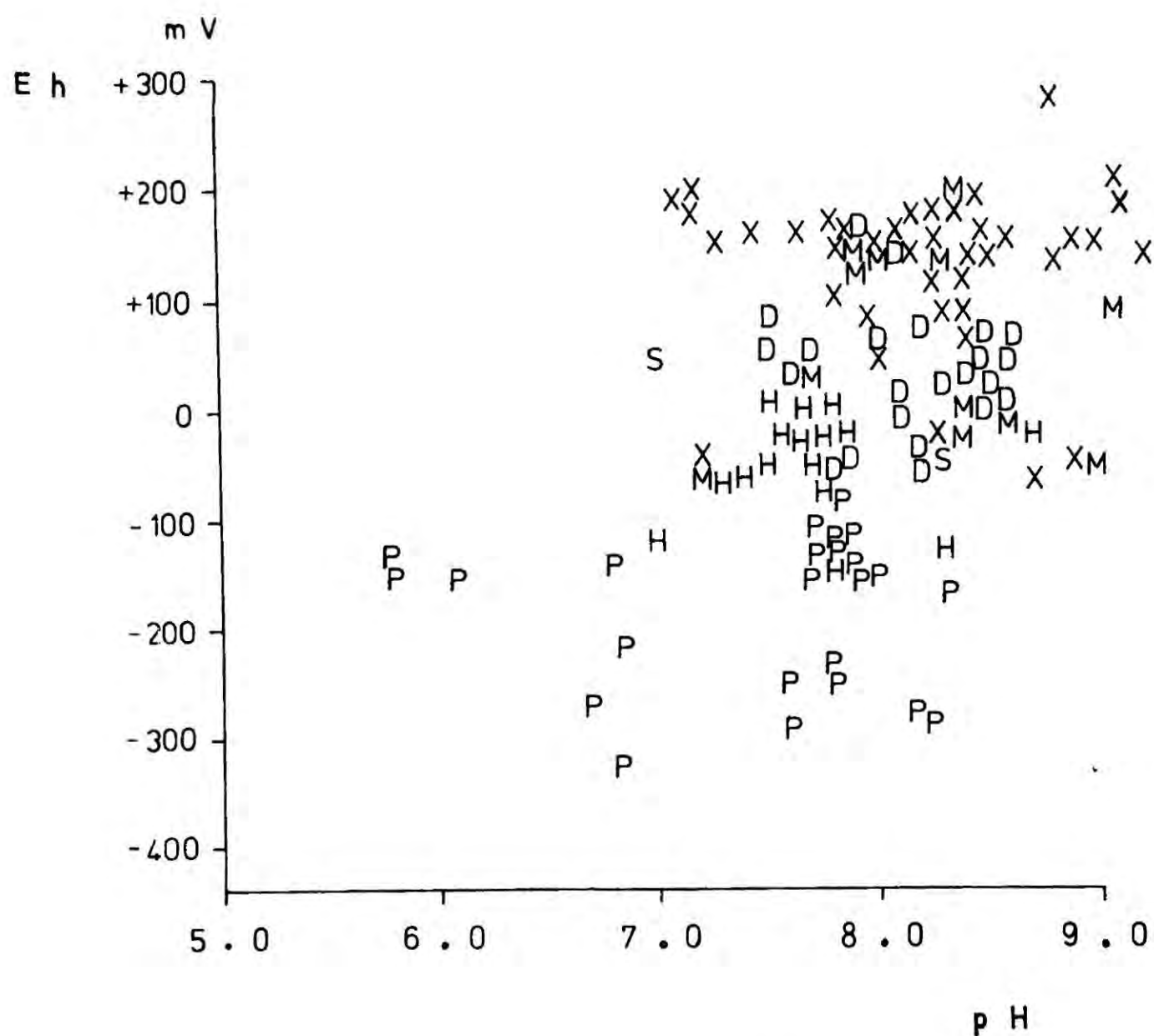


Figure 4.26 Distribution of photosynthetic communities occurring on or near the surface in relation to Eh-pH found in sediment at depth of 10 mm

- x Scytonema sp.
- D pennate diatoms
- S Schizothrix calcicola dominated
- M Microcoleus chthonoplastes
- H Hyella balani
- P purple sulphur bacteria

pennate diatoms; Microcoleus chthonoplastes; Schizothrix calcicola; Hyella balani; Chromatium sp.

4.25 Chemistry of marine and brackish waters

4.251 Waters from transects

Table 4.15 summarises the data for waters collected from the 13 transects. Standard deviations have been omitted where less than four samples were collected from a particular transect.

The widest range in pH (7.1 to 8.6) was found in waters lying over white carbonate silts, collected from transects along the south coast of the lagoon. The smallest range was from waters lying over brown silts (7.37 to 7.95), collected from transects L4 (Île Picard), L5 (Île Verte) and L7 (Cinq Cases). Waters collected from transects in which the dominant sediments were sands, showed the highest pH values (7.9 to 8.89).

Waters from transects along the south coast also showed the widest range in Eh values (-133 to +170 mV) and also the lowest values. Waters collected from over sands never exhibited negative values, the values being the highest among the waters (+119 to +189 mV). Waters above brown silts had a range intermediate between the two above (-33 to +122 mV).

Waters from the south coast had the highest range in temperature, and highest values of salinity (29.3 to 34.1°C; 47.3‰). Those collected from transects made along the shores of Île Picard, and other areas where the main sediment type was sand, had the highest range in salinity and highest values of

Table 4.15 Chemistry of marine and brackish waters collected from transect areas

transect	n	pH		Eh		Eh ₇		°C		‰		Na		K		Mg		Ca	
		\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s
L1	10	8.74	0.392	+189	33.2	+318	36.9	29.3	2.48			11390	261	381	38.2	1432	85.3	458	60.0
L2	3	7.90		+150		+202		42.7				14100		560		1720		531	
L3	11	8.89	0.452	+177	75.5	+261	83.1	33.8	4.62	0.52	11772	1030	403	57.6	1468	122	467	36.3	
L4	3	7.95		- 33		+ 22		30.8				9885		389		1216		469	
L5	6	7.80	0.327	+122	57.8	+168	41.7	26.1	0.54			8760	1775	325	22.6	1103	194	345	43.0
L6	5	8.50	0.697	+119	41.6	+207	41.6	34.1	2.03	3.60	9003	3149	310	95.4	1094	449	358	123	
L7	12	7.37	0.501	+ 76	105	+103	129	28.7	1.52	1.56	6936	837	255	29.1	888	109	292	37.6	
L8	13	8.55	0.349	-133	45.5	+ 77	63.4	32.3	1.03	6.08	15767	2361	545	69.6	1667	109	515	67.9	
L9	3	8.30		+100		+171		33.1		40.1	14660		461		1403		492		
L10	3	8.06		+113		+174		31.4			11135		380		1338		435		
L11	4	8.60	0.141	+107	65.9	+200	57.5	31.3	0.81		12500	108	410	10.0	1586	57.1	479	11.3	
L12	3	7.51		+170		+222		27.7		47.3	15300		590		1792		603		
L13	3	7.10		- 55		- 49		29.0		35.8	13450		498		1476		461		

temperature. Waters from the Cinq Cases area, Île Verte and Entre Deux, where brown gelatinous silts were the dominant sediments had the lowest range and lowest values of temperature (27.7 to 33.0°C).

The highest values of cation concentrations were from waters from the south coast, Na (14100 mg l⁻¹), K (560), Ca (531), Mg (1720). The lowest were from those areas associated with brown silts, Na (9855), K (389), Ca (469), Mg (1216).

4.252 Lagoon waters between Passe Femme and Point Tanguin

The chemistry of waters collected from transects at Île Picard was summarised in 4.251. As waters from areas of silt and sand appeared to have different chemical characteristics, it was decided to study lagoon waters at Île Picard in more detail. From Passe Femme to Grande Passe, there was a transition in sediment type, from sands associated with the passes to the large areas of mangrove silts at Entre Deux (Fig. 4.1). Measurements of pH, Eh and temperature were taken from surface waters between Passe Femme and Point Tanguin in what was virtually a 'transect' across the lagoon. All measurements were made during 1300 and 1500 h on an ebb tide in January 1975. The results are presented in Table 4.16, and the sampling points in Fig. 4.27.

The range in pH and Eh of these waters was 7.15 to 8.7, and +165 to +450 mV. The range in temperature was 30.0 to 36.1°C. pH values increased when moving along the coast of Île Picard towards Entre Deux, whereas the Eh values dropped.

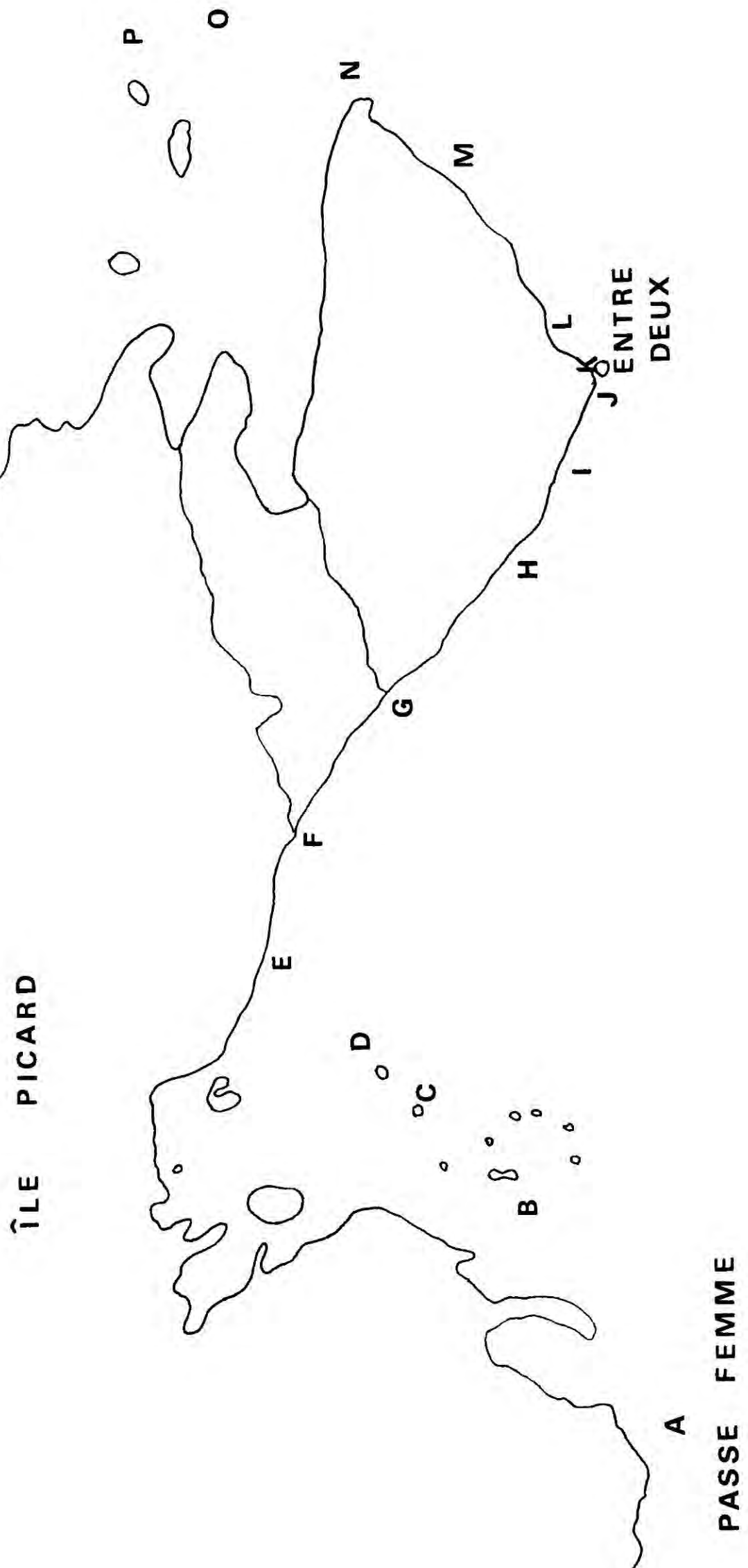


Figure 4.27 Sampling points between Passe Femme and Point Tanguin
(not to scale)

Table 4.16 Analysis of lagoon waters between Passe Femme and Point Tanguin (values are the mean of three readings)

sampling point	°C	pH	Eh	Eh ₇
a (Passe Femme)	31.2	8.1	+450	+514
b (Petit Aldabra)	31.9	8.02	+330	+389
c	31.7	8.22	+300	+371
d	34.2	8.20	+225	+296
e (Entre Deux coast)	33.4	8.50	+200	+287
f (Bois des Rats)	33.0	8.70	+200	+299
g	32.9	7.65	+220	+258
h	32.5	8.30	+204	+279
i	32.6	8.09	+218	+281
j	32.2	7.90	+224	+276
k (Entre Deux)	34.3	8.59	+165	+257
l	36.1	8.36	+200	+279
m	31.5	7.60	+228	+263
n (Point Chauve-Souris)	31.2	7.50	+230	+259
o	31.0	7.20	+235	+247
p	30.9	7.30	+240	+257
q	30.9	7.20	+238	+250
r (Point Tanguin)	30.0	7.15	+230	+239

The greatest change in pH was noticed adjacent to a wide mangrove creek (8.75 to 7.65). The pH continued to fall past Entre Deux and Point Chauve-Souris, where it fell to its lowest value of 7.15. The Eh values remained fairly constant from site G to site R (Fig.4.27). Temperatures tended to rise when moving into the lagoon and drop towards passes.

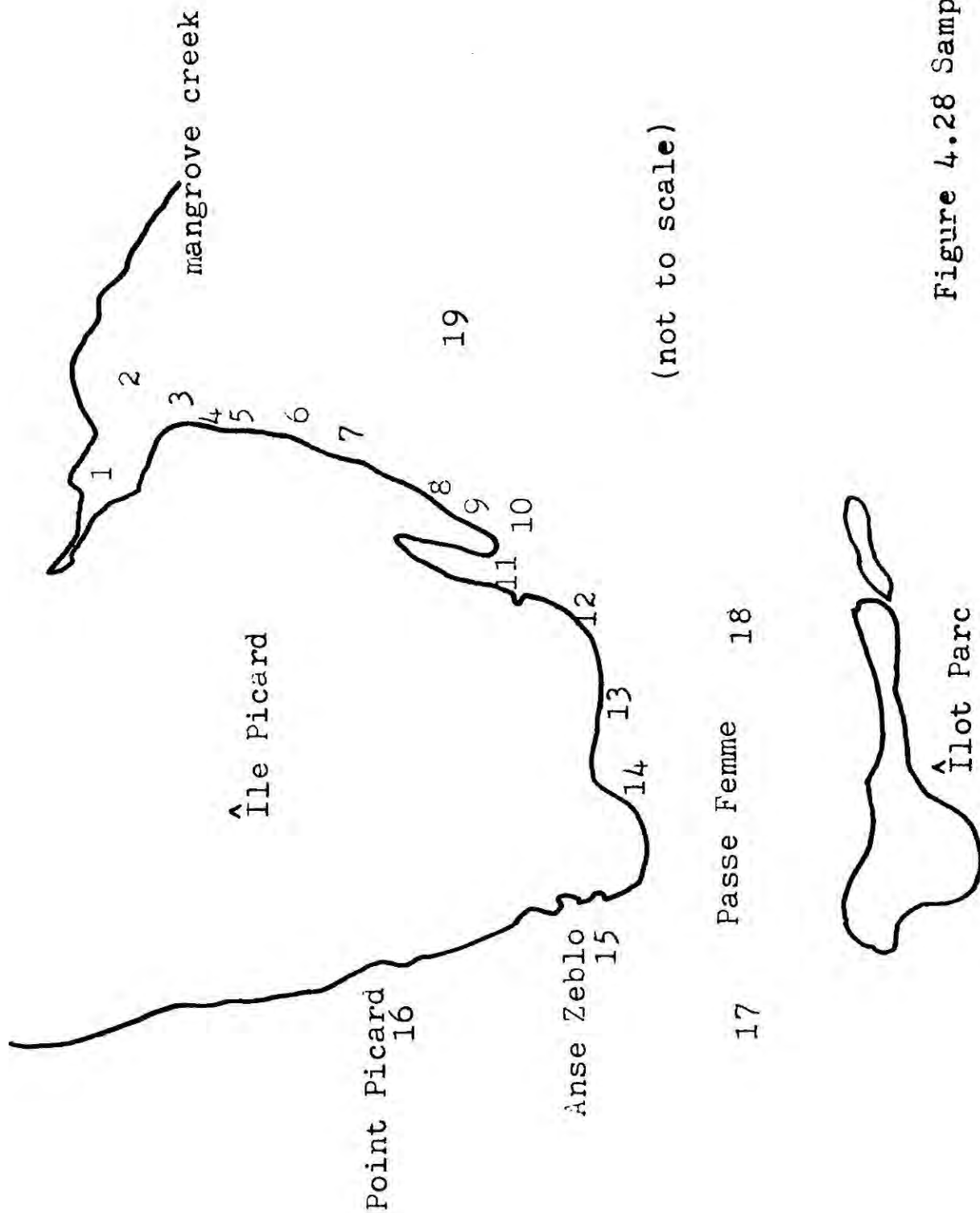
4.253 Measurement of percentage dissolved oxygen from inside the lagoon and on the seaward coast of Île Picard

Large volumes of water entered and left the lagoon through the passes, at different stages of the tide (1.32). As these waters passed over extensive communities of algae, marine angiosperms and large areas of mangrove silts, it was decided to carry out measurements of dissolved oxygen at many points within the lagoon, passes and reef flats on the seaward coast near the research station. The points at which the sampling was carried out are shown in Fig. 4.28. All measurements were taken between 0800 and 0930 h on 16.05.75. Measurements at points 1 to 16 were taken during the end of an ebb tide, and measurements 17 to 19 were taken on the flood tide entering the lagoon. Weather conditions at the time were dull and overcast. The values of percentage dissolved oxygen, temperature and salinity are summarised in Table 4.17.

The lowest values of dissolved oxygen were found associated with waters in the large creek within the lagoon (1), and on the lagoon beach in the vicinity of the residual pools described in transect 4.163. The values remained low in

Table 4.17 Sampling points and values of dissolved oxygen, temperature and salinity

comments	% O ₂ dissolved	°C	‰
1 creek in vicinity of transect L4	44.0	27.5	35.3
2 mouth of creek	47.0	27.0	34.8
3 sand bar near <u>Avicennia</u> forest	48.0	26.9	34.9
4 shallow, slow moving water	50.0	26.2	35.2
5 <u>Chromatium</u> in places	46.5	26.9	35.3
6 H ₂ S smell prevalent	48.0	26.8	34.3
7 area of transect L3	45.0	26.8	34.0
8 pools associated with <u>Chromatium</u>	44.0	26.7	35.0
9 " " "	50.0	26.8	33.0
10 off La Gigi beach	50.0	26.8	35.1
11 in vicinity of transect L1	49.0	26.7	34.6
12 vicinity of beds of <u>Cymodocea</u>	44.5	27.9	34.8
13 in Passe Femme	45.0	27.0	35.0
14 close to entrance	48.0	26.5	34.3
15 Anse Zeblo on reef flat	45.0	27.0	35.0
16 Point Picard on reef flat	48.0	27.0	35.1
17 entrance to Passe Femme	78.5	33.1	35.3
18 in Passe Femme	76.5	33.5	36.1
19 near Petit Aldabra	79.1	36.8	36.2



(not to scale)

Figure 4.28 Sampling points for measurements of dissolved oxygen

Passe Femme and in standing water on the seaward coast reef flat (15, 16). The complete range in percentage dissolved oxygen on the ebb tide in the areas 1 to 16 was 44.0 to 50.0 % (Table 4.17). There was negligible change in either temperature or salinity for the waters. On the flood tide the values of dissolved oxygen were almost twice as high as found on the ebb tide. The temperature of the water was also 5°C to 6°C higher, although there was no marked change in salinity.

4.254 Chemistry of Aldabra waters

The lagoon is connected to the sea by four passes, as well as through the honeycomb nature of the land rim (1.31), and two of the passes drain a large area of the lagoon (1.31). It seemed appropriate to compare the chemistry of lagoon waters, with that of waters in passes and on the sea ward coast, and to study any changes in the chemistry of waters on entering the lagoon. Because many intertidal communities were influenced by freshwater during the rains of the monsoon season (1.21), it was also felt necessary to compare lagoon waters with rainwater and waters from several freshwater habitats due to the possibility of land drainage into the lagoon.

Table 4.18 summarises the water chemistry of marine and brackish habitats on the atoll; data for rainwater and several freshwater pools has been included for comparative purposes. The Eh-pH characteristics for marine waters are represented in Fig. 4.29.

Table 4.18 Chemistry of marine, brackish and freshwater habitats on Aldabra atoll

water type	n	pH		EH		Eh ₇		°C		‰		Na		K		Mg		Ca		σ PO ₄ -P		poly-PO ₄ -P		org-PO ₄ -P		NH ₄ -N		
		\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	
rainwater	2											6	2.30	0.80	2.90													
freshwater pools	12	8.13	0.722	+47	52	+111	60	36.0	4.26	1.20	0.720	254	166	19.9	8.79	33.3	30.7	97.9	35.9	0.56	1.00	1.62	0.79	1.71	1.12	1.64	2.10	
brackish pools	13	8.50	0.794	-177	150	-82	153	30.9	4.28	13.1	10.7	3086	2970	137	101	308	307	154	105	0.67	0.57	0.73	0.49	0.25	0.13	3.16	1.93	
lagoon water over brown silt	11	7.79	0.475	+56	138	+90	138	27.9	1.71	30.5	5.51	7948	2026	297	81.2	1005	232	325	68.9							1.01	0.29	
lagoon water over white silt	10	8.15	0.729	+51	110	+118	122	30.9	1.38	42.6	5.02	12438	699	474	71.2	1562	487	446	196							1.02	0.69	
lagoon water over sand	58	8.45	2.810	+149	94	+238	148	30.5	5.51	37.7	4.59	11506	3062	394	71.2	1439	172	455	63.7									
lagoon water (central)	4	7.56	0.460	+224	12	+257	15	31.3	0.900	38.0	7.04	10718	2064	368	58.6	1338	253	451	15.6									
inland tidal pools	13	7.96	0.169	+220	46	+275	53	28.2	0.810	35.6	0.120	10683	1759	368	49.4	1318	197	423	60.1									
reef front by research station	2	8.15		+92		+160																						
oceanic 1 km off shore	3	8.06		+258		+314		31.3		34.8		11600	400	1477				458										

The range in pH and Eh for these habitats is wide, whereas the mean pH values for each are relatively close (7.56 to 8.50). The mean Eh values differ greatly (-177 to +258 mV).

Brackish pools have the highest mean pH and lagoon waters the lowest mean pH. Water samples collected from several hundred metres outside the reef front had the highest positive values of Eh. In decreasing order the mean pH values for all habitats are: brackish water; lagoon waters; reef front waters; lagoon waters (over white silts); freshwaters; oceanic waters; inland waters of tidal pools; lagoon waters (over brown silts); lagoon waters (central).

For Eh the order of mean values is: oceanic waters; lagoon waters (central); tidal pools waters; lagoon waters (over sand); reef front waters; lagoon waters (over brown silt); lagoon waters (over white silt); freshwaters; brackish waters.

The salinity range is wide (1.19 to 42.6%), small residual pools in white carbonate silts along the south coast having the highest values.

Concentrations of cations are all very similar for oceanic, lagoon (central), tidal pool and lagoon waters (over sand). The highest values are for lagoon waters associated with white silts.

The highest values of $\text{NH}_4\text{-N}$ were found in brackish pools (3.16 mg l^{-1}). The mean value for freshwater pools was c half this value. Lowest detectable values were from waters associated with silts, there being no significant difference between the values for white or brown silt waters (1.01 and 1.02 mg l^{-1} respectively).

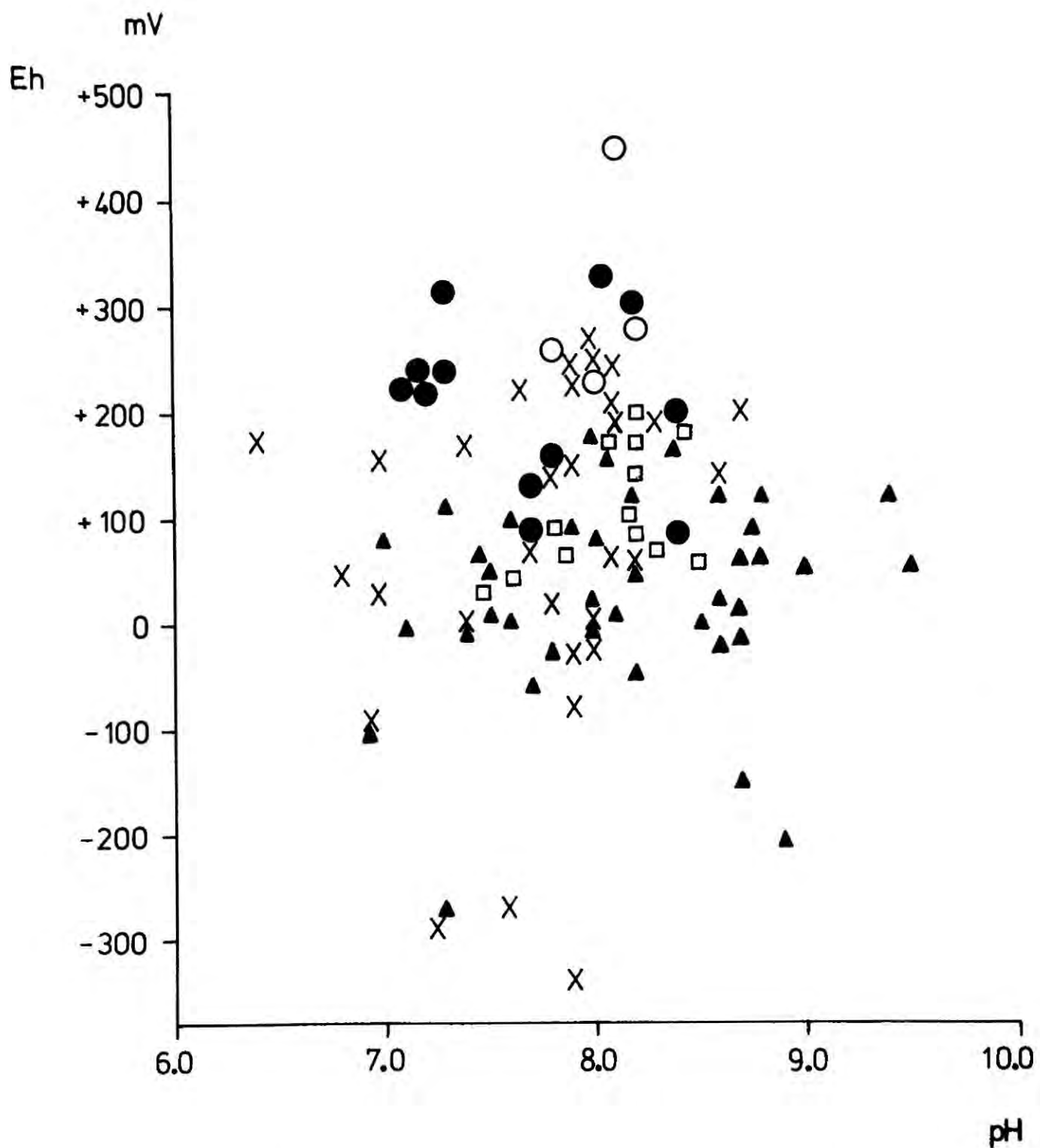


Figure 4.29 Eh-pH characteristics of marine waters

- ± oceanic (ocean or channel into lagoon during inflowing tide)
- shore (outside atoll), residual waters left at low tide
- main lagoon
- ▲ residual pools
- x creek waters

5 STUDIES OF SELECTED PHOTOSYNTHETIC PROKARYOTIC COMMUNITIES

5.1 Blue-green algae

In many areas of the lagoon, blue-green algae form sediment binding mats, often covering large areas (4.172). One species, Scytonema sp., formed thick crusts and mats in the upper intertidal zone, and a study of one community was discussed in 4.19. Because of the widespread distribution of these mats in the lagoon, and their possible ecological importance, a detailed study was carried out on one community of Scytonema sp. from transect L1, Île Picard (4.161).

The mat was visited on 28.03.75, during a period of high spring tides, when it was completely covered by tidal water twice during the 24 hours of the study. Readings of pH, Eh, temperature, salinity and water chemistry were taken at 15 minute intervals, and water samples collected when possible.

The complete ranges in the different parameters are shown in Table 5.1. The range in pH was 7.3 to 9.28; Eh (+100 to +240 mV); % dissolved oxygen (52.5 to 74.8 %); Na (10950 to 12000 mg l⁻¹); K (364 to 402 mg l⁻¹); Ca (369 to 580 mg l⁻¹); Mg (1343 to 1620 mg l⁻¹).

The lowest values of pH were taken from the mat and water pipetted from the mat during 2200 to 0455 h. There was a rise in the pH of the sea water of the incoming tide standing above the mat on day one, from 1555 to 2000 h. The water in Passe Femme had a pH of 8.65 at 1540 h, and 9.28 at 2200 h, after standing over the mat for c 4 h. After the mat was exposed, the pH dropped from 9.28 to 7.30 during 2200 to

Table 5.1 Physical and chemical measurements of a Scytonema mat over a period of 24 hours (values for Na, K, Ca, Mg in mg l⁻¹)

time (h)	comments	°C	pH	Eh	Eh ₇	%O ₂	Na	K	Mg	Ca
1500	exposed, dried mat	38.8	8.72	+240	+340	74.0	11500	384	1500	463
1530	"	40.8	8.65	+200	+295	74.0				
1540	advancing tidal water	34.0	8.80	+200	+304	74.8	11300	377	1454	436
1555	"	34.1	8.80	+150	+254					
1600	water over mat	34.7	8.80	+170	+274	74.8	11200	371	1420	442
1600	readings in mat	34.7	8.80	+150	+257					
1615	water	33.9	8.80	+170	+274					
1615	mat	34.5	8.90	+150	+257					
1630	water	32.6	8.70	+195	+294	72.0				
1700	water (1 m deep)	30.2	8.95	+210	+323	65.2	11500	384	1405	398
1730	"	29.9	8.80	+212	+316	63.0				
1800	1818 high tide	29.6	9.15	+225	+349	61.8	11250	378	1350	369
1830	"	28.9	9.14	+210	+334	57.4				
1900	water	28.5	9.09	+233	+354	57.0	11500	386	1343	386
1930	"	28.0	9.15	+235	+359	59.3				
2000	"	28.1	9.28	+180	+312	52.5	11300	381	1385	375
2030	upper part of mat exposed	28.1	9.25	+235	+365	60.4				
2040	pipetted water from mat	29.0	9.10	+180	+302		11200	364	1343	555
2100	all mat exposed	27.4	9.10	+193	+315		11250	378	1420	506
2130	"	27.0								
2145	"	28.3								
2200	"	28.0	7.90	+ 50	+102					
2300	"	27.3								
0100	"	25.4								
0300	"	24.6								
0400	"	24.5								
0415	"	24.0	7.45	+150	+176					
0423	advancing tidal water	24.0	7.30	+130	+147					
0440	0430 mat first touched	26.5	7.80	+130	+176					
0455	all mat covered	27.9	7.80	+150	+196					
0455	mat	27.8	7.80	+200	+246	50.0	11450	386	1567	486
0500	water in Passe Femme	27.8	7.80	+100	+146					
		26.9	8.00	+110	+168					

0415 h. With the second tide, the pH of the passe water was 7.80 at 0423 h which rose to 8.50 at 0800 h, after standing over the mat. After exposure, readings of pH taken from the mat, and water pipetted from the mat, rose from 8.50 at 0800 h to 9.2 at 1000 h, at which time the mat became completely dry.

Changes in Eh values were less clearly defined. In general the readings dropped in the water standing over the mat, and in the mat itself, the lowest readings being taken from the exposed mat at night. Readings from the mat were usually lower than from the lagoon water. The pH and Eh of the incoming tidal water in the passe were quite different at night than during the day, 8.00 and +110 mV, 8.72 and +240 mV respectively.

The mat underwent a wide range in temperature during the 24 hours, from 24.0 at 0415 h to 42.0 at 1500 h. Highest values being recorded during the day, when the mat was exposed.

The values of dissolved oxygen from the lagoon water over the mat dropped during the night from 1630 to 2030 h, and rose again during the day, 0455 to 0820 h.

5.2 Photosynthetic bacteria

5.21 Communities associated with intertidal residual pools

Visually conspicuous communities of photosynthetic bacteria were found at only two localities in the intertidal zone of the lagoon (4.163, 4.167). This was in contrast to the widespread distribution of blue-green algae, and suggested that the abundance of photosynthetic bacteria, was possibly controlled by certain environmental conditions. At La Gigi,

Chromatium sp. formed pink growths associated with intertidal residual pools, formed by depressions in the sand (4.163).

Six pools were chosen at random for study. These were all at different distances from the standing water of the lagoon, and all were of different sizes with varying depths of water.

Horizontal polarity distinguished two zones in each pool. The first was the pink colour attributable to the Chromatium sp., and the other a dull brown colour due to communities of pennate diatoms. Hyella balani was endolithic in the sand grains, but the green colour was somewhat masked by the other two communities. The results of sampling of Eh, pH and temperature of these pools is shown in Table 5.2.

The range in pH and Eh for the pool waters at the surface and immediately above the sediment was small (7.75 to 8.09, +26.2 to +45.8 mV; 7.98 to 8.16, +27.0 to +43.2 mV). There was a slight increase in the pH range at the surface of the sediment (7.56 to 8.21), and a marked increase in the Eh range (-179 to +49.4 mV). At 10 mm depth in the sediment, the range in pH and Eh was 7.34 to 8.09, and -256 to +16.2 mV, the values of Eh becoming more negative with depth. There was thus a marked horizontal zonation in sediments, in terms of their pH and Eh. The lowest pH and Eh values were associated with visually obvious communities of Chromatium sp., and the higher pH and Eh values with the diatom communities. The change in Eh values was rapid within a small horizontal distance (Fig. 5.1), and with depth (Table 5.3).

Table 5.2 Eh-pH characteristics of the different zones found in residual pools at La Gigi

	n	OC		pH		Eh		Eh7	
		\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s
photosynthetic bacteria zone									
water	27	32.9	1.29	7.75	0.529	+ 26.2	39.9	+ 92.8	30.3
water over sand	26	33.3	1.15	8.16	0.443	+ 27.0	34.6	+ 94.6	24.0
surface of sand	58	33.4	0.809	7.56	0.454	-179	81.0	-165	80.9
10 mm depth in sand	60	33.6	1.04	7.34	0.685	-256	53.4	-237	79.5
transition zone									
water	13	33.0	1.21	8.09	0.455	+ 36.0	41.8	+101	23.2
water over sand	22	33.4	1.09	7.98	0.313	+ 34.6	43.6	+ 92.2	31.7
surface of sand	34	33.9	0.939	7.93	0.408	+ 43.8	34.5	+ 94.6	24.1
10 mm depth in sand	30	34.2	0.828	7.45	0.468	- 11.6	30.4	+ 12.0	30.9
diatom zone									
water	15	33.1	1.02	7.95	0.397	+ 45.8	34.9	+101	22.6
water over sand	12	33.6	1.08	7.99	0.285	+ 43.2	36.1	+101	23.8
surface of sand	45	34.1	1.08	8.21	0.331	+ 49.4	22.6	+118	16.8
10 mm depth in sand	36	34.2	0.714	8.09	0.383	+ 16.2	52.8	+ 79.2	57.6

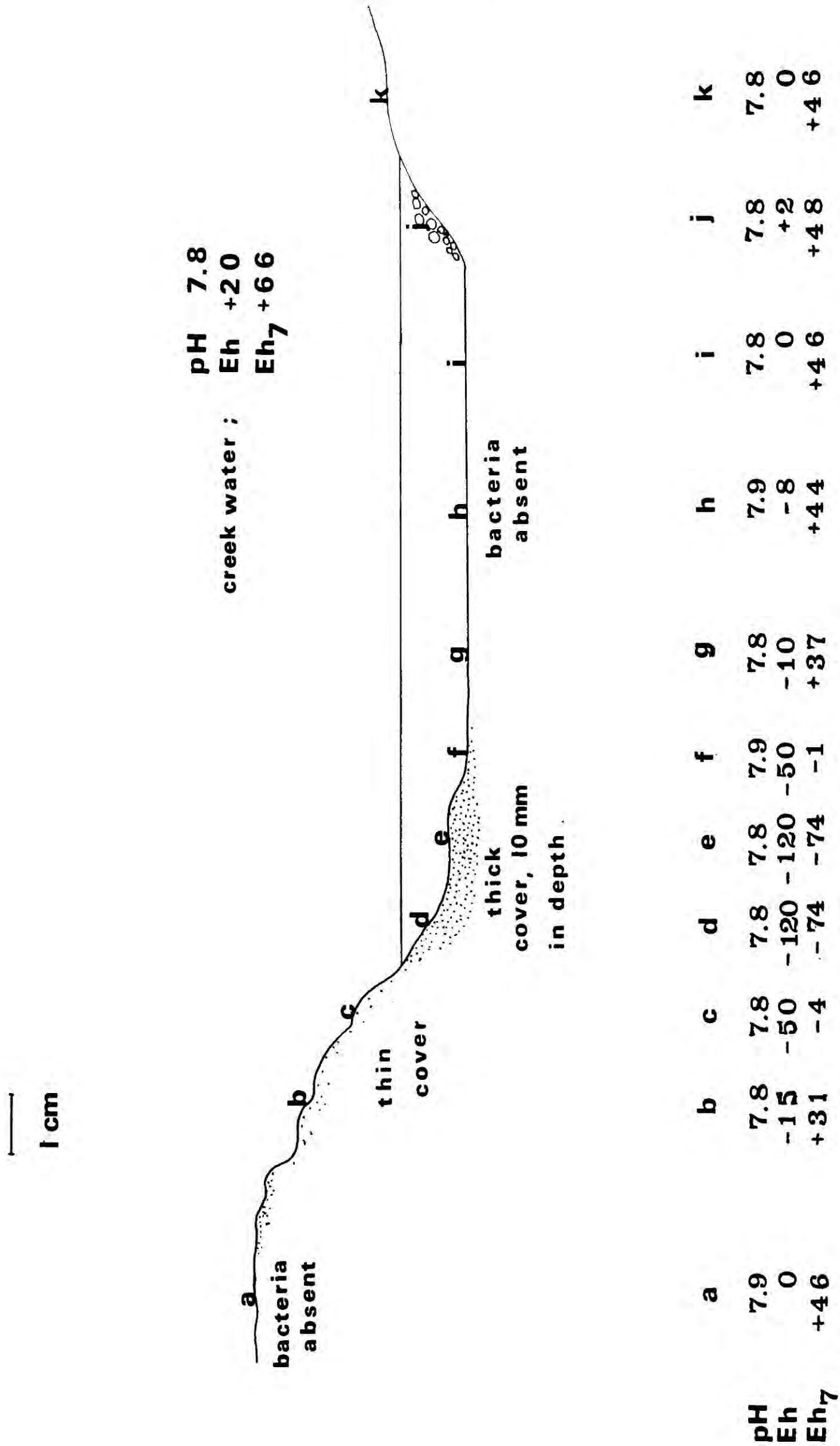


Figure 5.1 Changes in pH and Eh in a horizontal transect of a residual pool

Table 5.3 Eh-pH profile of sediment associated with a community of Chromatium sp. (values the mean of three readings)

depth (mm)	pH	Eh	Eh ₇
1	8.3	- 70	+ 5
2	8.3	- 75	0
3	8.3	- 78	- 4
4	8.3	-110	- 35
5	8.3	-120	- 46
6	8.3	-135	- 60
7	8.3	-140	- 65
8	8.1	-142	- 75
9	8.0	-150	- 92
10	8.0	-150	- 92
50	8.0	-250	-192

5.22 24 hour survey of a residual pool

One of the pools was selected for a more detailed study over a 24 hour period. The results are summarised in Table 5.4.

Over 24 hours the range in pH and Eh was 7.70 to 9.00, and +110 to +330 mV. After recession of the tide on day one, the pH and Eh values of the pool water were 8.09 and +100 mV. The pH rose steadily during the day until at 1500 h it was 9.00; the Eh values also rose from +100 mV at 0755 h, to +330 mV at 1130 h, after which they steadily fell to +20 mV at 1700 h. On covering by the tide, the pH of the lagoon water was 8.3, and the Eh +250 mV; the Eh values remained fairly constant during the period 1500 to 0800 h, the pH values dropping slightly.

The highest value of dissolved oxygen in the pool was 76.0 at 1050 h, this dropped to its lowest value during the night (49.9 at 0200 h).

The salinity of the pool remained constant over the 24 hours.

Temperature varied considerably, rising from 25.5°C in the morning, to 39.0°C in the exposed pool at 1530 h. The temperature again dropped during the night.

Table 5.4 Physical and chemical measurements of an intertidal residual pool over a period of 24 hours

time (h)	°C	pH	Eh	Eh ₇	‰	%O ₂
0755	25.5	8.09	+100	+163	34.4	74.0
0801	26.1	8.25	+250	+323		
0815	26.6	8.15	+240	+304		
0825	27.0	8.23	+230	+301		74.5
0830	27.0	8.27	+230	+300		
0837	27.2	8.30	+210	+285		
0845	27.9	8.30	+208	+283		
0900	28.0	8.25	+220	+293	35.0	74.0
0920	28.8	8.29	+206	+281		
1015	30.8	8.20	+220	+290		
1030	32.5	8.27	+200	+270		
1050	32.3	8.60	+250	+343		76.0
1100	33.1	8.50	+270	+357	54.6	
1115	33.0	8.50	+320	+407		
1130	33.7	8.60	+330	+423		
1145	34.0	8.65	+275	+391		
1200	35.0	8.65	+240	+336	35.0	
1400	38.7	8.65	+180	+276	35.6	
1430	39.2	8.70	+180	+279		
1445	39.4	8.80	+150	+254		
1500	39.5	8.80	+145	+249		
1515	39.5	8.82	+135	+241		
1530	39.0	8.80	+130	+234		
1545	38.8	8.85	+120	+227		
1600	38.5	8.90	+110	+220	34.8	
1700	37.0	9.00	+120	+236		
2000	29.6	8.30	+250	+325	34.5	
2200	28.5	8.21	+240	+310		
2400	27.4	8.00	+220	+278		
0200	27.0	7.80	+230	+276	34.5	49.9
0400	27.0	7.75	+250	+294	35.1	50.0
0600	27.1	7.70	+251	+291	36.2	66.3
0800	27.2	8.30	+230	+305	35.1	75.4

6 STUDIES OF STANDING CROP

6.1 Communities of blue-green algae at Île Picard

The reasons for studying communities of blue-green algae growing in the intertidal zone of the lagoon at Île Picard, were discussed in 4.1 and 4.18, and a number of studies on these communities were presented in 4.19 and 5.1. Microscopic examination of many of these communities showed them to have relatively high proportions of dead material. Because of their abundance in certain areas (e.g. 4.170), and their possible significant contribution to algal carbon fixation within the intertidal zone of the lagoon, it was decided to estimate the standing crop of various representative communities at Île Picard.

Communities were selected from a wide range of habitats and these are summarised in Table 6.1. The subjective delimitation of communities, and the methods used in the selection and collection of random samples were discussed in 2.111. The methods used in chlorophyll a extraction, and the estimation of chlorophyll a and phaeophytin a , were discussed in 2.221 and 2.222.

The standing crop of eight communities are shown in Table 6.2. There is great variability in the weights of the 100 cm² samples; this is almost certainly due to the variable amount of sediment associated with samples, and the broken up nature of some communities. The weights of the 1 cm² samples for the Hyella balani and other crust forming communities are similar, the range being 1.25 to 1.52 g. The

Table 6.1 Blue-green algal communities on which standing crop estimates were made

	community	details	location	area (m ²)
C1	<u>Calothrix crustacea</u> - <u>Microcoleus chthonoplastes</u>	thin crust	creek, L1	25
C2	<u>Scytonema</u> sp.	thick mat	L2	15
C3	<u>Scytonema</u> sp.	thick mat	tidal pool	10
C4	<u>Hyella balani</u>	endolithic	L1	50
C5	<u>Hyella balani</u>	endolithic	L3	100
C6	<u>Hyella balani</u> - <u>Scytonema</u> sp.	thin crust	L3	40
C7	<u>Microcoleus</u> sp. - <u>Tolypothrix byssoidea</u>	thick crust	sand dunes	15
C8	<u>Phormidium molle</u>	thick crust	L3	10

Table 6.2 Standing crop of eight communities of blue-green algae (values in the final column have been calculated using the subjective estimates of community area given in Table 6.1)

community	n	g 100 cm ⁻²		sample weight		g cm ⁻²		μg chl a cm ⁻²		mg chl a 100 cm ⁻²		community g chl a \bar{x}
		\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	
C1	24	59.5	22.0	0.347	0.161	37.2	26.1	3.72	9.30			
C2	24	97.2	23.8	0.501	0.191	75.8	44.5	7.58	11.4			
C3	24	11.1	10.7	0.262	0.178	159	74.4	15.9	15.9			
C4	5	76.7	6.36	1.25	0.087	25.9	3.84	2.59	12.9			
C5	24	113	22.8	1.25	0.114	27.6	8.02	2.76	27.6			
C6	5	218	25.0	1.52	0.053	7.55	6.78	0.755	3.02			
C7	5	77.8	4.87	1.46	0.126	12.5	6.01	1.25	1.88			
C8	5	235	40.5	1.37	0.117	25.9	6.43	2.59	2.59			

Table 6.3 Phaeophytin a as a percentage of total pigments (phaeophytin a + chlorophyll a) for samples from eight communities of blue-green algae ND = non detectable

community	n	phaeophytin <u>a</u> μg		% total pigments	
		\bar{x}	s	\bar{x}	s
C1	24	8.19	18.2	11.8	17.9
C2	24	33.7	32.7	28.9	21.1
C3	24	29.7	25.1	13.4	9.40
C4	5	ND	ND		
C5	24	1.18	4.64	3.43	4.64
C6	5	ND	ND		
C7	5	ND	ND		
C8	5	ND	ND		

weights are higher than the 1 cm^2 weights for the mat forming communities, the range here being 0.262 to 0.501 g. The Scytonema community C3 had the lowest mean 1 cm^2 weights; this community grew as a thick mat over exposed limestone in a tidal depression at Bassin Cabri, and samples had very small amounts of associated sediment.

On a 1 cm^2 basis, the mat forming communities contained more chlorophyll a (Table 6.2), the range being 37.2 to $159 \mu\text{g chl a cm}^{-2}$. The communities associated with loose sediment *i.e.* Hyella balani and Phormidium molle had a range of 7.55 to $27.6 \mu\text{g chl a cm}^{-2}$. The total range in chlorophyll a, from a loose sediment bound community to a thick mat was 7.55 to $159 \mu\text{g chl a cm}^{-2}$, the mat having 95.3% more chl a cm^{-2} than the loose sediment.

Table 6.3 shows the percentage of phaeophytin a of total pigments, where the total pigments are interpreted here as chlorophyll a + phaeophytin a. The mat forming communities have the highest values of chlorophyll a on a 1 cm^{-2} basis, and also can be seen to have the highest percentages of phaeophytin a (Table 6.3). The range for the three mat forming communities is 11.8 to 28.9%; only one Hyella balani community had detectable phaeophytin a (3.43%). For the mat forming species, the lowest values of phaeophytin a are from mats collected from shaded localities *i.e.* Calothrix crustacea in shaded mangrove forest, and Scytonema sp. in a shaded tidal depression (Table 6.1).

7 STUDIES OF NITROGEN FIXATION

7.1 Acetylene reduction assays in situ

7.11 Studies on communities of blue-green algae

The decision to study nitrogen fixation by communities of blue-green algae within the lagoon intertidal zone, was taken for several reasons (see Section 1.5).

It was intended originally that only heterocystous communities should be studied, but after carrying out transect studies within the lagoon (Chapter 4), it became apparent that communities dominated by non-heterocystous species were widespread, and in places abundant. It was therefore decided to extend the studies to include these communities.

Table 7.1 summarises the results of acetylene reduction assays carried out on 18 communities of blue-green algae at Île Picard.

In 31 experiments the rates of acetylene reduction, estimated as $\text{nM C}_2\text{H}_4$ produced $\mu\text{g chl a}^{-1} \text{min}^{-1}$, were higher in the light than in the dark. For 20 of the experiments the rates were significantly higher, as estimated by non-parametric statistics (2.24). The range in the percentage of the dark rate of the light rate in these experiments was 1.0 to 83%, for the remaining 11 experiments the range was 33 to 94%. There was no significant difference between the rates in brackish water or sea water for any of the communities (Fig. 7.1).

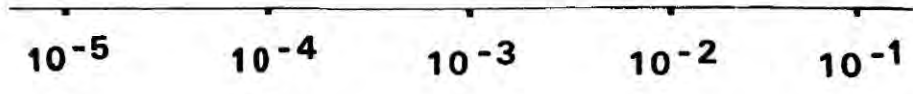
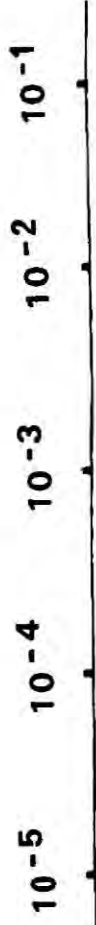
Using the Kruskal-Wallis non-parametric test (2.24), the light rates for the nine Scytonema populations differed significantly.

Table 7.1 Rates of C₂H₂ fixation by communities of blue-green algae in the lagoon intertidal zone. The communities are shown in order of maximum rate recorded for a particular community. L = light, D = dark. (Note that if the chlorophyll a content of an alga (per µg chl a) = 1% dry weight then 1 µg chl a cm⁻² = 1 g dry weight m⁻²). A + sign by a particular rate indicates that the light rate is significantly higher than the dark rate. The rate given in column 6 is nM C₂H₄ min⁻¹ cm⁻²

community	whether with heterocysts	morphology	environment	sea water				brackish water			
				µg chl a cm ⁻²	rate min ⁻¹	nm C ₂ H ₄ µg chl a ⁻¹ min ⁻¹		µg chl a cm ⁻²	rate min ⁻¹	nm C ₂ H ₄ µg chl a ⁻¹ min ⁻¹	
						L	D			L	D
<u>Hyella balani</u>	-	endolithic	medium coarse sand	10.7	0.364	0.034	0.032	0.049	0.028	+	
"	-	"	"	8.87	0.045	0.0051	0.00015				
<u>Scytonema sp.</u>	+	juvenile mat	"	13.2	0.396	0.030	0.028	0.035	0.022		
"	+	mature mat	among mangroves	287	2.12	0.0074	0.00095				
"	+	"	medium coarse sand	185	1.018	0.0055	0.0020	0.0031	0.0011	+	
"	+	"	"	207	0.724	0.0035	0.0019	0.0045	0.0019	+	
"	+	"	"	233	0.619	0.0027	0.0016	0.0025	0.0007	+	
"	+	"	"	293	0.703	0.0024	0.0016	0.0030	0.0018		
"	+	"	among mangroves	179	0.430	0.0024	0.00065	0.0023	0.00076		
"	+	"	on rock, sheltered	231	0.438	0.0019	0.0015	0.0017	0.0011	+	
"	+	"	medium coarse sand	297	0.446	0.0015	0.00076	0.0017	0.0009	+	
<u>Hyella balani-Schizothrix sp.</u>	-	endolithic crust	"	22.1	3.400	0.019	0.012	0.0024	0.014	+	
"	-	"	"	11.6	0.16	0.016	0.014	0.032	0.017	+	
<u>Calothrix crustacea</u>	+	thin mat	binding coarse sand	34.7	0.55	0.016	0.010	0.015	0.0068		
<u>Rivularia sp.</u>	+	hemispherical colonies	on silt	93.9	1.13	0.012	0.0010				
<u>Microcoleus chthonoplastes</u>	-	film	"	36.2	0.382	0.010	0.0059	0.017	0.0085	+	
"	-	"	"	104	0.46	0.0040	0.00003				
<u>Pleurocapsa - Chroococcus</u>	-	dense suspension	edge of sheltered tidal pool	121	0.021	0.0002	0.00004			+	

BRACKISH WATER

nM C₂H₄ μg chl a⁻¹ min⁻¹



nM C₂H₄ μg chl a⁻¹ min⁻¹

SEA WATER

Figure 7.1 The relationship between C₂H₄ production in the light for several communities in sea water and brackish water

Table 7.2 Acetylene reduction by a mixed community of Hyella balani - Chromatium sp. in sea water
L = light, D = dark

date	$\mu\text{g chl } a \text{ cm}^{-2}$	$\mu\text{g Bchl } a \text{ cm}^{-2}$	$\text{nM C}_2\text{H}_4 \text{ cm}^{-2} \text{ min}^{-1}$	
			L	D
26.12.74	9.37	2.51	0.014	0.012
16.05.75	11.8	1.60	0.074	0.095
26.05.75	13.6	2.22	0.084	0.116

Table 7.3 Control experiments used with acetylene reduction assays

control	experimental details	nM C ₂ H ₄ l ⁻¹ min ⁻¹	
		L	D
sea water	filtered through a sinta 2 funnel, Passe Femme	0.00008	0.00008
sea water	filtered through a sinta 2 funnel, standing water in mangrove forest	0.00037	0.00054
sea water	filtered through a sinta 2 funnel, standing water in mangrove forest	0.00058	0.00065

Table 7.4 Acetylene reduction by mangrove silts L = light, D = dark

community	form and environment	weight of 1 cm ² core (mg)	sea water	nM C ₂ H ₄ μg ⁻¹ min ⁻¹		brackish
				L	D	
mangrove silt	brown silt, around roots of <u>Rhizophora mucronata</u> , Anse Chaux, Île Picard	170	0.0000023	0.0000034	0.0000016	0.0000017
mangrove silt	brown silt, around roots of <u>R. mucronata</u> , tidal depression Bassin Cabri, Île Picard	418	0.0000010	0.0000015	0.0000012	0.0000009

The light rate for a thin juvenile Scytonema mat, was of the order of four times higher than the rate for a mature Scytonema mat (Table 7.1). The greatest difference between light and dark rates for a Scytonema mat were from the mat in a shaded tidal depression at Bassin Cabri, Île Picard.

The highest rate of acetylene reduction obtained in all the experiments, was for a Hyella balani community; the lowest rate was found for the Pleurocapsa - Chroococcus community among bottom silt in the inland tidal pool, Bassin Lebine. The greatest difference between light and dark rates, was for the Microcoleus chthonoplastes community from the shaded tidal depression at Bassin Cabri (Table 7.1).

Positive rates of acetylene reduction are indicated from different communities dominated by three non-heterocystous species of blue-green algae.

7.12 Studies on communities of photosynthetic bacteria

The results of experiments carried out with mixed populations of Chromatium sp. and Hyella balani, are shown in Table 7.2. In only one of the experiments was the rate higher in the light than the dark. There was no significant difference between rates in the light and in the dark for any of these experiments.

It was not possible to separate populations of the two different species, as Hyella balani was endolithic in much of the sediment, and Chromatium sp. epilithic. The results have thus been presented as $\text{nM C}_2\text{H}_4 \text{ cm}^{-2} \text{ min}^{-1}$. Using either the mean value of chlorophyll a per square centimetre, or the mean

bacteriochlorophyll a value per square centimetre, the rates would fall within the range of values shown in Table 7.1. It is not possible to state with certainty, which species is reducing acetylene, or if both are.

7.13 Studies on mangrove silts

In several control experiments, higher rates of fixation were found associated with waters from mangrove forests, than from passes (Table 7.3). This suggested that mangrove silts possibly contained potential nitrogen fixing communities, and because of the significant area covered by silts within the intertidal zone (1.31), it was decided to carry out a number of experiments with mangrove muds.

Table 7.4 shows the results of studies on acetylene reduction by mangrove muds from Rhizophora mucronata forest at [^]Ile Picard. There was no significant difference between the rates in the light and the dark, but the rates were significantly higher than either the brackish water or sea water control rates (Table 7.3).

It was difficult to obtain a uniform 1 cm² area replicate from the silt, and weights are probably an overestimation of 1 cm². Nevertheless, if the rates for 1 cm² for the silts are compared with those for the communities of blue-green algae, they are seen to be of the same order of magnitude. The rates for the silts are higher than the lowest rate obtained for a blue-green algal population, which was 0.021 nM C₂H₄ cm⁻² min⁻¹ for the mixed Pleurocapsa - Chroococcus community. The highest rate for a blue-green algal community

($2.09 \text{ nM C}_2\text{H}_4 \text{ cm}^{-2} \text{ min}^{-1}$), was approximately six times that for silts ($0.34 \text{ nM C}_2\text{H}_4 \text{ cm}^{-2} \text{ min}^{-1}$).

7.2 Acetylene reduction assays in the laboratory

Whenever acetylene reduction assays were carried out in situ, samples of the algal communities were collected and dried for return to Durham (2.19). This section presents the results of acetylene reduction assays carried out on these re-wetted samples.

13 experiments were carried out under laboratory controlled conditions, and the results are shown in Table 7.5. A light intensity of 10000 lx was selected as this was the average value found in open mangrove areas on Aldabra (4.21). A lower intensity of 2000 lx was also used, to simulate the intensities found in more shaded areas on the atoll (4.21). The ambient air temperature at Aldabra was found to be approximately 32°C (1.21), and this was used in all the laboratory experiments. Microaerophilic conditions are known to promote nitrogenase activity in certain species of non-heterocystous blue-green algae (Stewart & Lex, 1970), and hydrogen sulphide has been shown to stimulate growth in Anabaena flos-aquae (Stewart & Pearson, 1970); a number of experiments were therefore designed to study the effects of low oxygen concentrations, and hydrogen sulphide supplemented media, on fixation rates of re-wetted material.

Table 7.5 shows the results of laboratory experiments with three communities of Scytonema sp., two of Hyella balani and one of Rivularia sp. A. No rates of fixation were detected

Table 7.5 Experimental conditions used in laboratory acetylene reduction assays (the acetylene reduction rate given in the last column is nM C₂H₄ µg chl a⁻¹ min⁻¹)

species	n	pre-treatment	media	gas phase	°C	lx	rate
<u>Scytonema</u> sp.	6	24 h wetting	ASP-2	air	32	10000	-
"	6	"	"	Ar (79.08%)/CO ₂ (0.02%)/O ₂ (20.0%)	32	10000	-
"	6	"	dist. water	Ar (98.08%)/CO ₂ (0.02%)/O ₂ (1.0%)	32	10000	-
"	6	"	natural sea water	air	32	10000	-
"	6	6 h wetting	"	"	32	10000	-
"	6	24 h wetting	natural sea water	"	32	10000	-
"	6	3 h wetting	ASP-2	"	32	10000	-
"	6	24 h wetting	samples moist	"	32	10000	-
"	6	6 h wetting	"	"	32	10000	-
"	6	3 h wetting	"	"	32	10000	-
"	6	24 h wetting	"	Ar (79.08%)/CO ₂ (0.02%)/O ₂ (20.0%)	32	10000	-
"	6	3 h wetting	"	"	32	10000	-
"	6	6 h wetting	"	"	32	10000	-
"	6	3 h wetting	"	"	32	10000	-
"	6	24 h wetting	ASP-2 natural sea water	air	36	10000	-
"	6	"	dist. water	"	36	10000	-
"	6	"	natural sea water	"	36	10000	-
<u>Hyella balani</u>	6	"	"	"	32	2000	-
"	6	"	water	Ar (98.08%)/CO ₂ (0.02%)/O ₂ (1.0%)	32	2000	-
"	6	"	"	air	32	10000	-

Table 7.5 con.

species	n	pre-treatment	media	gas phase	°C	lx	rate
<u>Hyella balani</u>	6	24 h wetting	natural sea water samples	Ar (98.08%)/CO ₂ (0.02%)/O ₂ (1.0%)	32	10000	-
"	6	"	air moist dist. water	"	32	10000	-
"	8	6 h wetting	natural sea water + 4 mM S=	"	32	10000	-
"	8	3 h wetting	"	Ar (98.08%)/CO ₂ (0.02%)/O ₂ (1.0%)	32	10000	-
"	8	6 h wetting	"	"	36	15000	-
"	6	24 h wetting	"	"	36	15000	-
<u>Rivularia</u> sp.	6	"	ASP-2	air	32	10000	-
"	8	"	"	Ar (98.08%)/CO ₂ (0.02%)/O ₂ (1.0%)	32	10000	-
"	6	"	"	Ar (79.08%)/CO ₂ (0.02%)/O ₂ (20.0%)	32	10000	-

Table 7.6 Acetylene reduction by Scytonema sp. under laboratory conditions

n	pre-treatment	media	°C	lx	nM C ₂ H ₄ µg chl a _g ⁻¹ min ⁻¹
8	24 h wetting	ASP-2	32	2000	0.00020
7	"	"	32	10000	0.00090
8	"	"	32	2000	0.00025
8	"	"	32	10000	0.00042
5	"	"	32	dark	0.00015

in any of these experiments using a wide range of culture conditions and experimental variables. No enhanced fixation was detected using sea water media supplemented with 4 mM S²⁻. Table 7.6 shows the only positive rates of fixation obtained from one community of Scytonema sp. The rate of acetylene reduction at 10000 lx in air is the only rate significantly higher than that in the dark. This rate is of the same order as the dark rate for this community in situ. The rate at 2000 lx in the argon mixture, is higher than that in air, at 10000 lx the rate is lower than that in the argon mixture.

8 DISCUSSION

8.1 Lagoon sediments

Various interactions of blue-green algae with sediments were discussed in Section 1.11, and it is evident from the present studies, that Aldabra Lagoon provides examples of several of these. For instance algal mats and recent stromatolites are accumulating sediment in certain areas, and endolithic species are widespread in carbonate substrata (4.19). Because of the intimate association of sediments with communities of blue-green algae, and the important role of these algae in several geological processes occurring within the lagoon, a discussion is first given of lagoon sediments.

Coarsest sediments were found in the vicinity of passes where they formed beaches and sandflats, often covering a wide area (4.172). Samples collected from these areas usually had visually distinguishable remains of calcareous algae such as Halimeda spp., which together with the larger size particles, constituted the greatest percentage of the dry weight (Table 4.14). When moving away from the passes, sediments became finer and along the north and south coasts fine and very fine silts covered many square kilometres (4.169, 4.170, 4.171). In many places the sediment cover was thin, although a fine silt of c 50 cm depth was recorded at Bras Anse du Bois (4.169), this being the deepest recorded within the lagoon away from passes. Farrow (1971), found no sediments deeper than one metre, in a detailed study of lagoon sediment facies

at Aldabra.

The nature and distribution of sediments, is a reflection of prevailing tidal conditions and local mangrove vegetation. Finest sediments are thus found along the sheltered south coasts and coarsest sediments near passes. Brown gelatinous silts are found at Entre Deux, Cinq Cases and much of the north coast where dense forests of Rhizophora mucronata, Bruguiera gymnorhiza and Avicennia marina are present (4.164, 4.165, 4.167).

Generally all sediments were darker in colour below the surface, to the extent that white silts often appeared black or grey at a depth of only a few centimetres (4.167, Fig.4.12c). Sheltered sediments found in open tidal depressions at Cinq Cases were grey at the surface, and black below three centimetres depth (4.167). When exposed to the air for a number of hours, these blackened sediments became grey. Kanwisher (1962) found similar results with sediments in shallow marine habitats at Woods Hole, Massachusetts. He found that freshly dug clams covered in black mud, soon became grey on exposure to air, and this was shown to be due to the oxidation of black ferrous sulphide within the mud. It seems likely therefore, that dark sediments in Aldabra Lagoon contain high concentrations of sulphides. The fact that many of these sediments when disturbed, gave off a pronounced smell of hydrogen sulphide (4.162, 4.163, 4.167), gives support to this view.

The pH and Eh ranges for all lagoon sediments to a depth

of 40 mm, is shown in Fig.4.25. Except for the lower pH limit of 4.1, these values all fall within the ranges given by Zobell (1946) for marine sediments (6.4 to 9.5, -500 to +350 mV). Although the lower pH value of 4.1 is outside these limits, Whitfield (1969) has shown that under low redox conditions, sulphide activity may be high enough for concentrations of HS^- to lower the pH. Both the lower limits of pH and Eh are outside the limits of the estuarine environment as given by Baas Becking and Wood (1955a, 1955b). However the average values these authors give for surface sediments (7.8, -100 mV), are consistent with the present findings.

The low values of pH and Eh, widespread occurrence of blackened sediments and high associated concentrations of hydrogen sulphide, all suggest that many of the intertidal sediments within the lagoon are reducing and anaerobic. Due to the sheltered nature of some parts of the lagoon, many of these sediments are rarely disturbed except for the activities of the local fauna. The giant tortoise is a major agent in the disturbance of sediments found in tidal depressions of the upper intertidal zone at Cinq Cases (Fig. 4.12c), and in the open mudflats of the south and north coasts, burrowing activities of crabs and other animals may lead to the oxygenation of some lower sediments (4.169).

8.2 Lagoon waters

The physical and chemical nature of lagoon waters are in part determined by the underlying sediments, although waters

moving from one region to another due to tidal influences, often have characteristics quite different to those of local sediments. It was usually possible to estimate the characteristics of some waters simply by their colour, due to the sediment in suspension. Samples of water collected from the south coast were often milky white in appearance and had the highest concentrations of cations (Table 4.15), and in areas where mangrove silts were abundant, the brown coloured waters had the lowest concentrations of cations (Table 4.15). Waters from the central part of the lagoon, over sands, and in the vicinity of passes, closely resembled sea water in their chemistry (Table 4.18). In the central parts of the lagoon this was no doubt due to the small deposits of sediment (1.33).

The lowest values of pH and Eh were all recorded from waters over carbonate silts, and the highest values from waters associated with sands (Table 4.18, Fig. 4.29). This was more or less the same as that found for sediments, and emphasizes the influence of sediments on the chemistry of lagoon waters. The important influence of sediments is further realised when one considers that the upper limit of pH of sea water is controlled by calcium carbonate precipitation, and the lower limit by sulphide precipitation (Ben-Yaakov, 1973). At Aldabra, Trudgill (1972) considered the release of organic complexes from sediments to have important effects on the pH of waters in the lagoon, and it is known that the release of organic matter from marine

sediments, can lead to the formation of fulvic acid in surface waters (Nissenbaum et al., 1971). Effects such as these will probably be most marked in areas where brown mangrove silts are abundant.

Apart from the role of sediments in affecting the chemistry of lagoon waters, there is also the influence of land drainage. As can be seen in Table 4.18, waters over both carbonate silts and brown mangrove silts had levels of $\text{NH}_4\text{-N}$, of the same order as found in several freshwater pools. Diamond (1971) has mentioned the role of guano as a nutrient input into lagoon waters at Aldabra, particularly in the east and southeast parts of the lagoon where large bird populations are present. The honeycomb nature of the land rim, and its connection with the lagoon (1.31), suggest that during heavy rains, decomposing plant remains and animal faeces may be carried into the lagoon. The activities of fishes within the lagoon will also make a contribution to the nutrient input. It is likely therefore, that ammonia, urea and other nitrogen compounds are available to algal populations within the lagoon. Remsen (1971) has shown that urea is an available source of nitrogen for phytoplankton, in the continental shelf between Panama and Peru.

Although measurements of dissolved oxygen from lagoon waters are few (Table 4.17), they do indicate lower values than for incoming sea water through passes. Waters along the lagoon beach of La Gigi had levels of dissolved oxygen, which were almost half of the values for tidal waters in

Passe Femme (Table 4.17). It is almost certain that these low values were due to the reducing nature of the sediments, and bacterial activity in the mangrove silts. Due to bacterial respiration, and the large amounts of organic matter in suspension, it is suggested that in some waters, low values of dissolved oxygen may persist even during daylight hours. Trudgill (1972) has shown that the long residence time of some waters among mangrove forests at Aldabra, can lead to high concentrations of carbon dioxide. The decomposition of organic matter will continue in standing water during neap tides, leading to low values of dissolved oxygen. At the onset of spring tides, tidal sea water will 'flush' out most of this standing water and give rise to higher values. Skirrow (1965) has noted the extent to which circulation can effect the pH and dissolved oxygen concentration of poorly ventilated waters.

Isolation of waters during low tides also leads to high salinities, and this varies within different areas of the lagoon. Along the south coast, waters have the longest isolation times, and with the lack of shade here, high salinities occur. Algal communities in these area must withstand large variations in salinity, from c 20‰ after rain storms, to in excess of 55‰ during the hottest parts of the day.

The mean values of pH, Mg, Ca and salinity, obtained by Trudgill (1972) for lagoon waters at Aldabra, all agree closely with those found in the present study.

8.3 Communities of photosynthetic prokaryotes

8.31 Blue-green algae

The distribution of marine blue-green algae in the intertidal zone of limestone shores was discussed in Section 1.11. At Aldabra, blue-green algae are widespread in marine and brackish habitats of both the lagoon and the seaward coasts (3.1), although the greater number were recorded from inside the lagoon (Table 3.3). Of the total number of species recorded from marine and brackish habitats (116), only 18 of these were heterocystous (Table 3.3). This result is remarkably similar to that of Donaldson and Whitton (1976), who recorded 124 species of blue-green algae from freshwater and terrestrial habitats at Aldabra, 19 of which were heterocystous (Table 3.4). On comparing the results of Donaldson and Whitton (1976) with those of the present study; only one heterocystous species, Tolypothrix byssoidea is recorded from both freshwater and marine habitats at Aldabra, yet there is considerable overlap in non-heterocystous species (Table 3.4). This is perhaps some justification for the view given in Section 1.11, that the validity of a distinction between marine and freshwater species within the orders Chroococcales and Chamaesiphonales is questionable.

It is possible to make a number of generalizations, regarding the distribution of the ten most frequently recorded species from marine and brackish water habitats, shown in Table 4.8. Entophysalis granulosa, Hormathonema violaceo-nigrum and Hyella balani are recorded by various

authors, as frequent in the upper intertidal zone of limestone shores (1.11, 3.13). At Aldabra, all three species were common in the upper zone, the latter two being endolithic. Hyella balani was shown to be responsible for the green colour of beach sand at La Gigi (4.163), and the blue colour of beachrock in front of Settlement (Fig. 3.2a). The latter has been discussed by a number of authors (1.4). The other common endolithic species, Mastigocoleus testarum, was found both inside the lagoon and on the sea ward coasts in the low intertidal (Table 3.1). A simplified vertical zonation pattern in species growing within the intertidal zone of the lagoon was given in Table 4.10. Non-filamentous forms such as Entophysalis granulosa, Hormathonema violaceo-nigrum and Pleurocapsa fuliginosa were abundant in the upper zone of the intertidal, Hyella balani was most abundant in the mid zone, and Mastigocoleus testarum in the low zone. Of the four mat forming species, Scytonema sp., Schizothrix calcicola, Microcoleus chthonoplastes and Rivularia sp.; Scytonema sp. had the most restricted distribution within the lagoon. This species formed visually conspicuous mats, only in a narrow zone parallel to the shore in the upper intertidal. In many areas, the mats covered the surface of exposed limestone hummocks which were at a higher elevation than the intertidal flat. Fragments of mats were also found covering the knee and prop roots of mangroves (Fig. 3.1b), again above the level of any standing water. Scytonema sp. appears to be unable to tolerate long

submergence in sea water. For the mat in transect L1, this grew in a narrow zone which was under tidal water for only 90 hours of the lunar cycle. The growth of this species also appears to be favoured by sheltered conditions. On sea ward coasts, exposed to the effects of wind and wave action, its distribution is restricted to small pits in champignon rock (Fig. 3.2b). Along the north coasts of the lagoon which are more exposed to the influence of the southeast trade winds, and which have a relatively high tidal amplitude, Scytonema sp. grows in a narrower zone than along the south coasts, which are sheltered. Studies on regeneration of mats of Scytonema sp. also indicate that it has a slow growth rate (4.19). Whitton (pers. comm.) confirmed that the 'crescent' shaped mat at La Gigi (L1), see Fig. 4.4a, had undergone negligible change in area since a study in 1967.

Blue-green algae reached their greatest abundance within the lagoon, in areas where they trapped sediment and formed mats and recent stromatolites (4.172). The dominant species in these communities (Microcoleus chthonoplastes, Scytonema sp. and Schizothrix calcicola) were the same as found by other authors in recent stromatolites elsewhere (1.11). However the depth and area of algal stromatolites in Aldabra Lagoon, were less than recorded by other authors (1.11), and this is no doubt a reflection of the shallow nature of the lagoon sediments. Nevertheless, the stratiform stromatolites of Microcoleus chthonoplastes - Schizothrix calcicola at Îles

Moustique were very similar to those recorded by Walter et al. (1973) in the Coorong Lagoon, South Australia, and the extensive areas of stromatolite in parts of the Persian Gulf (1.11) are formed by the same species of Scytonema as found at Aldabra (Dr. S. Golubić, pers. comm.).

For seven of the eight communities studied which were associated with sediments, the highest percentage of the dry weight of sediment associated with each community was the same (Figures 4.21, 4.22, 4.23). These results are very similar to those found by Neumann et al. (1970) for sediments associated with subtidal mats of Lyngbya sp. and Schizothrix calcicola at Abaco, Bahamas. Along the south and north coasts of the lagoon, the sediment trapping activities of communities dominated by Scytonema sp., Rivularia sp. A, Schizothrix calcicola and Microcoleus chthonoplastes may be a major factor influencing accumulation of sediments in these areas.

The ranges in pH and Eh associated with these communities were narrower than those found for lagoon sediments, and these are shown in Fig. 4.26. However the range of pH for these communities is in close agreement with those given by other authors (Baas Becking et al., 1955a, 1960; Fenchel & Riedl, 1970; Conover, 1962), although the ranges in Eh are lower. In the latter case this is probably a reflection of the reduced nature of the sediments associated with some of these communities. Blue-green algae studied within the lagoon were associated with negative as well as positive Eh values; only

Hyella balani was associated exclusively with negative values (Fig. 4.26). The more positive values tended to be found in communities dominated by branched filamentous species, and the lower values with non-heterocystous communities. These results are consistent with the findings of Baas Becking et al. (1955a, 1955b, 1960). It is interesting to note that those algae associated with the higher positive values of Eh, were found in the upper part of the intertidal zone, and those in the low zone with negative values. This may reflect the drainage characteristics of the reduced interstitial waters, draining quickly from the upper part of the zone, but remaining as standing water for much longer periods lower down the zone.

8.32 Photosynthetic bacteria

In contrast to the widespread distribution of obvious blue-green algal growths within the lagoon, visually conspicuous communities of photosynthetic bacteria were noted at only two localities within the intertidal zone (4.163, 4.167). Baas Becking et al. (1960) noted photosynthetic bacteria as regular inhabitants of the black mud surface of reduced marine sediments. The ranges in Eh and pH these authors give for photosynthetic bacteria are 4.92 to 9.58 and -230 to +320 mV. In the present study Chromatium sp. and Thiocystis sp. were never found associated with positive Eh values, and considering the widespread distribution of black reduced sediments (e.g. 4.167), it is somewhat surprising that they were not found to be abundant in many more areas.

As was discussed in Section 5.21 the zonation of Chromatium sp. in the small intertidal residual pools of La Gigi was marked, the characteristics of the sediments in the Chromatium and diatom zones being quite different from one another, as well as from the overlying water. It at first seemed strange that at certain times of the tidal cycle bacteria showed this zonation in pools, whereas at other stages, particularly after springs, the pink surface growth would be visible over a wide area of the beach (4.183). Ott and Machan (1971), when studying sand beaches of the North Carolina coasts, found interstitial dynamics to be the key to many of the observed phenomena of Eh. When the tide went out, hydrostatic head built up in the upper part of the beach (more permeable at low tide) causing water to flow to the sea. In a flat beach this results in a net transport of interstitial waters from the deepest layers to the surface. By considering these known facts on beach dynamics, and the features observed at La Gigi beach, it appears that the zonation observed in pools could be explained in terms of the flow of reduced waters from the underlying sediments towards the lagoon. The zonation in pools was always orientated in such a way, that the bacteria were closest to mangrove forest in the upper part of the intertidal zone (4.183). Water draining from the mangroves would appear in pools at the side closest to the mangroves, and would account for the polarity of the bacteria. This was indicated by many observations at La Gigi, pink surface growths of Chromatium only being found in creeks

at that side closest to the mangrove forest. During spring tides more waters would drain from the mangroves and be brought to the surface, which would account for the much greater cover of the surface sediment by Chromatium at this time. As mentioned in Section 8.31 drainage may account for the distribution of some communities, and would certainly explain the periodic smell of hydrogen sulphide noted on the sea ward facing beach in front of the research station, at certain times of the tidal cycle. Within the lagoon, mangroves fringe all of the lagoon coasts, and much of the intertidal mud and sandflat areas have negligible slope. It is possible therefore that there is a periodic, if not continual transport of low redox waters to the surface in many areas.

8.4 Standing crop of communities of blue-green algae

Communities of blue-green algae were abundant in a number of areas (Table 4.11), and the importance of several of these communities in trapping sediment was discussed in 8.31.

Large percentages of samples of these mats were indicated by microscopic examination, to be dead when collected. These communities are subject to a wet - dry regime due to the lunar tidal cycle, and it is assumed that the high levels of phaeophytin a found in many samples (Table 6.3), is a consequence of their growth habit. In comparison with terrestrial communities which come into contact with water spasmodically over approximately six months of the year; intertidal communities are influenced by tides all year round,

as well as by rainwater during the monsoon season. The ensuing stress in salinities in the latter case may be more detrimental to the algae, coupled with the fact that many are in exposed areas with no shade. It is perhaps worth noting here that the percentages of phaeophytin a were less in communities growing in shaded tidal depressions, than in those from exposed intertidal sandflats (Table 6.3). The differences in incident light intensity may vary from ≤ 800 lx in a shaded tidal depression to in excess of 30000 lx on an exposed mudflat (4.12). For terrestrial communities of Nostoc spp., these remain damp over several months (A. Donaldson, pers. comm.), either in freshwater pools or simply due to high humidities under shaded conditions. It is suggested that a cycle of c six months wet then six months dry observed for freshwater and terrestrial communities, is more advantageous to growth than the situation in the intertidal environment, where there is a constant cycle of wetting and drying, with sometimes rapid and abrupt changes in salinity and temperature.

In the case of mats, it was difficult to relate the concentration of chlorophyll a to dry weight of samples, because of the variable percentages of associated sediment, often with its own chlorophyll a component. For example, Hyella balani was endolithic in much of the sand sediments at La Gigi (4.163), and other species such as Microcystis reinboldii were often epilithic on grains.

For its area, the beach facing the lagoon at La Gigi

(4.163) had the highest standing crop of the communities studied (Table 6.2). Very high horizontal variability in chlorophyll a was found in mature mats of Scytonema and Calothrix (Table 6.2), whereas the variability for Hyella communities was small. This perhaps reflects the extent to which sediment grains of the latter community are moved around with tides and constantly mixed. In the case of Scytonema and Calothrix mats, extreme horizontal variability was also found with phaeophytin a concentrations (Table 6.3). These mats appear to be very heterogenous communities, as even microscopic examination indicates. Growing portions with relatively high chlorophyll a contents may be in close proximity to dead material. In laminated mats, the lower layers have the greatest concentrations of phaeophytin a.

8.5 Nitrogen fixation

For those communities where blue-green algae were the dominant photosynthetic organisms, all showed rates of nitrogen fixation which were significantly higher than the background levels estimated in control experiments (Tables 7.1, 7.3). In many experiments, the light rates were significantly higher than dark rates, and two processes could account for the higher rates in the light; fixation of nitrogen by blue-green algae, or enhanced fixation by heterotrophic bacteria, using extracellular compounds released by the algae. As the algae formed by far the highest percentage of the biomass, it is assumed that the fixation was attributable to these communities. It would require many

laboratory experiments with axenic cultures to prove this conclusively.

For 20 experiments, the rate in the light was significantly higher than the rate in the dark, and for 11 it was not. It is possible that the short incubation time (2.112), prior to the start of the experiments, led to dark nitrogen fixation by the algae, using intracellular photosynthate. In two experiments with the greatest difference between light and dark rates, these came from Scytonema mats in shaded mangrove forest, and this tends to support the above supposition (Table 7.1). Rates for juvenile communities of Scytonema were of the order of four times higher than for mature mats, which in the case of the latter, also had the highest concentrations of phaeophytin a and dead material. It is possible therefore that young mats will fix nitrogen at much higher rates than mature mats, the rates probably decreasing with age and growth of the mat.

The greatest difference between a light and dark rate was that found for a community dominated by the non-heterocystous species Microcoleus chthonoplastes; the dark rate being only 1% of the light rate (Table 7.1). The highest fixation rate on a chlorophyll a basis was found for a community of Hyella balani, another non-heterocystous species. For the other non-heterocystous community studied (Pleurocapsa - Chroococcus), there was no significant difference between the light and dark rates. The high fixation rates shown by non-heterocystous communities within the lagoon, are probably a

reflection of the environments in which these algae are growing. All were associated with low redox conditions (Fig. 4.26), and sediments which contained relatively high levels of sulphides (8.1). Stewart and Lex (1970) have shown microaerophilic conditions to favour nitrogen fixation in the non-heterocystous species Plectonema boryanum, and several recent papers indicate that sulphides may act as a reductant in photosynthesis (Cohen et al., 1975; Utkilen, 1976; Castenholz, 1976).

If one assumes a conversion factor of 3.2 when converting rates of acetylene reduction to nitrogen fixation (Stewart et al., 1968), it is possible to compare several of the rates found for Aldabra communities with those found by other authors (1.11). The highest rate for a Scytonema sp. community was $2.09 \text{ nM C}_2\text{H}_4 \text{ cm}^{-2} \text{ min}^{-1}$ i.e. $93 \text{ nM N}_2 \text{ m}^{-2} \text{ sec}^{-1}$, and for Rivularia sp. A $1.24 \text{ nM C}_2\text{H}_4 \text{ cm}^{-2} \text{ min}^{-1}$ i.e. $55 \text{ nM N}_2 \text{ m}^{-2} \text{ sec}^{-1}$. These are within the range of 0 to $390 \text{ nM N}_2 \text{ m}^{-2} \text{ sec}^{-1}$ given by Wiebe et al. (1975) for different communities of Rivularia sp. and Hormothamnion sp., growing in intertidal habitats of Eniwetok Atoll, Pacific. However the difference in light and dark rates for Aldabra communities was not as marked as found by these authors (1.11), and as was mentioned earlier, this was probably due to the short pre-incubation time used before the start of each experiment.

For all experiments the rates in sea water versus brackish water showed no statistical difference (Fig. 7.1). This implies that intertidal communities may fix nitrogen at

comparable rates during rain storms, as well as high tides. In effect they are able to fix nitrogen all year round under suitable conditions of light and temperature. This is in contrast to the situation for terrestrial communities of blue-green algae at Aldabra, where potential nitrogen fixation will occur only when the communities are in contact with rainwater i.e. during the monsoon season (c six months).

It was difficult to ascertain whether Chromatium sp. was responsible for the observed rates of fixation at La Gigi (Table 7.2), or Hyella balani which was endolithic in the sand grains over which Chromatium sp. was growing (4.163). Areas where Chromatium was absent and Hyella present, showed rates of the same order to where both were present, and it is probable that the observed rates were due to Hyella.

Mangrove muds showed significant rates of fixation (Table 7.4). However microscopic examination showed insignificant numbers of photosynthetic prokaryotes, and it is assumed the rates observed were due to nitrogen fixing bacteria, which are known to be common in many marine habitats (Kawai & Sugahara, 1971; Brooks et al., 1971; Head & Carpenter, 1975). This was further indicated by the insignificant difference between light and dark rates (Table 7.4). The rates on a 1 cm^2 basis were only one sixth of those for several of the blue-green algal communities (Table 7.1). However, mangrove muds covered an area of c 32 km^2 , far in excess of that covered by blue-green algal communities, and in places the mud was 50 cm deep, much deeper than the

thickest algal mat. It is unlikely that mangrove muds have equivalent rates of fixation at different depths, or that all of the muds will fix nitrogen at the same rate, but nevertheless it is possible that mangrove muds are quantitatively more significant in terms of input of nitrogen into the lagoon, than communities of blue-green algae.

Of the 14 experiments on acetylene reduction by re-wetted samples under laboratory conditions, only one gave positive results (Table 7.5), and this must be looked upon with suspicion, in view of the subsequent experiments in which no nitrogen fixation could be detected. Hydrogen sulphide, which is known to stimulate growth in some species of blue-green algae (Stewart & Pearson, 1970), and which was found in high concentrations in parts of the intertidal zone at Aldabra (4.163, 4.167); had no stimulatory affect on nitrogen fixation in Hyella balani (Table 7.5). The use of low oxygen levels also proved to have no affect on fixation rates, eventhough Stewart and Lex (1970) showed microaerophilic conditions to promote nitrogenase activity in Plectonema boryanum.

The failure of these re-wetted samples to fix nitrogen, at rates comparable to those of field populations from which they were collected, was in marked contrast to that found for terrestrial communities of Nostoc spp., which fixed nitrogen under laboratory conditions even after three years storage in a dried condition (Myers, 1974; Potts, unpublished data). It seems probable that storage of samples of intertidal

communities has reduced the viability considerably. It is also probable that these algae have well defined growth conditions, which are difficult to reproduce in the laboratory.

SUMMARY

Descriptions are given of species of photosynthetic prokaryotes, recorded from brackish and marine intertidal habitats of both the lagoon, and the seaward coast of Aldabra Atoll. Studies have been made of communities of photosynthetic prokaryotes growing within the intertidal zone of the lagoon.

A total of 116 species of blue-green algae were recorded from brackish and marine intertidal habitats. Of these, 88 were recorded only from inside the lagoon, 6 were recorded only from the seaward coast and 22 were recorded from the intertidal zones of both the lagoon and seaward coast. 98 of the total species were non-heterocystous and 18 heterocystous. Microcoleus chthonoplastes, Schizothrix calcicola, Scytonema sp. and Rivularia sp., were the dominant species in communities forming lagoon algal mats and recent stromatolites. Scytonema sp. formed sediment-binding mats in the upper intertidal of the lagoon, in a narrow zone parallel to the shore. This species is the same as that found by another worker from intertidal habitats of the Bahamas and the Persian Gulf, and by conventional taxonomic criteria may be considered a distinct new species.

Three species of photosynthetic bacteria were recorded from studies of the intertidal zone of the lagoon. Two of these, Chromatium sp. and Thiocystis sp., formed visually conspicuous communities at two localities. The ranges in pH and Eh of the sediments associated with photosynthetic bacteria,

were the lowest found among the communities studied. For Chromatium sp. the ranges in pH and Eh of the associated sediment were, pH 5.75 to 8.3, and Eh -330 to -80 mV.

At La Gigi beach, the highest average values of chlorophyll a cm^{-2} , were obtained from communities of photosynthetic prokaryotes. Values of 159 $\mu\text{g chl a cm}^{-2}$ were found in mats of Scytonema sp., and average values of 27.6 $\mu\text{g chl a cm}^{-2}$ were recorded from sediments in which Hyella balani was endolithic.

The highest rate of acetylene reduction, was found for a community of Hyella balani, the rate in the light being 0.034 $\text{nM C}_2\text{H}_4 \mu\text{g chl a min}^{-1}$. Several of the light rates obtained for other communities were: 0.03 $\text{nM C}_2\text{H}_4 \mu\text{g chl a}^{-1} \text{min}^{-1}$ for a Calothrix mat, 0.012 $\text{nM C}_2\text{H}_4 \mu\text{g chl a}^{-1} \text{min}^{-1}$ for Rivularia colonies and 0.01 $\text{nM C}_2\text{H}_4 \mu\text{g chl a}^{-1} \text{min}^{-1}$ for a Microcoleus chthonoplastes community. Acetylene reduction was found to be associated with heterocystous as well as non-heterocystous species of blue-green algae.

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