THE MARINE ALGAE OF KANGAROO ISLAND

I. A GENERAL ACCOUNT OF THE ALGAL ECOLOGY

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Plates IX to XIII

[Read 7 August 1947]

INTRODUCTION

Kangaroo Island lies off the South Australian coast at the base of Gulf St. Vincent, being separated from Fleurieu Peninsula by Backstairs Passage (10 miles wide) and from Yorke Peninsula by Investigator Strait (about 26 miles wide). The Island is 90 miles long and up to 32 miles wide, narrowing to only ½ mile wide between the American River inlet and the south coast (see fig. 1). The long axis of the island is approximately east-west; the island lies between latitude 35° 5′ S. and 35° 34½′ S. and between longitude 136° 32′ E. and 138° 8′ E.

The situation of Kangaroo Island in relation to the mainland, and the shape of the island itself, result in great variation in conditions of roughness along the coast. The exposed and rough south and west coasts contrast markedly with the calmer areas of the north coast, while the American River tidal inlet forms a distinct type of habitat not found elsewhere around the island.

From the point of view of algal ecology Kangaroo Island offers a particularly satisfactory area for study, especially in illustrating the control exerted on the algal flora by the degree of wave action.

This paper is the first report on work carried out during the past four years. The aim has been, firstly, to give a general account of the intertidal algal ecology of a part of the Southern Australian coast, since there have been no previous ecological studies of this region; secondly, to obtain as comprehensive a list as possible of the species present; and thirdly, to carry out autecological studies of the more characteristic and dominant species.

In this paper it is proposed to describe the more important environmental factors for the island as a whole; to discuss the terminology found most satisfactory; and to give a preliminary general account of the broader aspects of the algal ecology. In subsequent papers the more detailed ecology of characteristic regions will be dealt with, and a census of the known species will be given. Floristic and ecological comparisons with other areas will also be left to later papers. By first presenting a general survey of the algal ecology of the whole island, it is hoped to give perspective to the later detailed descriptions of individual localities.

The localities around the island which have been studied are shown in fig. 4. Of these, Pennington Bay and American River have received most attention. It has been possible to pay only one or two short visits to the western end of the island, while the very rough nature of the country and lack of roads prevents visits to most of the intervening parts of the south and west coasts. This, and the restriction of field work to the University vacations, have limited examination of most localities other than American River and Pennington Bay to January. Seasonal changes in places other than American River and Pennington Bay are therefore unknown as yet, but the associations which occur in these places and are described in this paper are almost certainly present throughout the year.

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The areas studied at Western River and Middle River consist of the coast on either side of the river mouth. These rivers run only after heavy rain, at other times being blocked by a sand bar at the mouth. American River, however, is an extensive tidal inlet, consisting of a series of lagoons with wide tidal flats and a central channel, opening to the sea through a mouth some 250 yards wide. The amount of fresh water entering the lagoons from small creeks is negligible, except for possible local effects after heavy rain. The conditions at all "River" localities, therefore, are truly marine.

Previous Marine Ecological Studies in Australia

Australian phycology is based to a large extent on the work of the early European algologists, Harvey, Agardh, Sonder and others, who described collections sent to them from Australia. As a result, very little ecological information is available about the early localities from which collections were made. Harvey (1854), however, gave short notes on the Western Australian coast, and ecological information about many species in his *Phycologia Australica.*

More recently, Hedley (1915) has presented a very general survey of the New South Wales coast, and Lucas (1935) has described the algal ecology of Lord Howe Island. Pope's (1943) survey of animal and algal life on a reef near Sydney is the only work of a detailed nature, but deals primarily with the animal ecology.

The review of Chapman (1946) gives a comprehensive list of references to algal ecology studies elsewhere in the world.

Previous Records from Kangaroo Island

Previous records of marine algae from Kangaroo Island are very few. Cleland and Black (1941) listed 11 species collected from near the mouth of Sou' West River, and determined by A. H. S. Lucas. Lucas (1929), in his census, lists two species from the island, while Part I of "The Seaweeds of South Australia" records *Caulerpa hedleyi* W. v. Bosse, "dredged in some 8 fathoms off the coast." Part II of the "Seaweeds of South Australia" contains several records, all incorporated by the present author. Two short reports on the *Rivularias* and a new species of *Dasyopsis* have also been published (Womersley 1946 a and b).

The land vegetation of Kangaroo Island has received considerable attention. Tate (1883) gave the first general account of the Island, and more recently Wood (1930) has elucidated the relationships of the flora and shown a high degree of endemism, particularly in species confined to the western end. Baldwin and Crocker (1941) have described vegetation communities in the central part of the Island.

ENVIRONMENTAL CONDITIONS

1. The Coastal Geology

The present study has shown that while the individual type of rock has little effect on the flora, the rock topography, in that it may result in different types of habitats, may be of considerable importance in determining the algal associations of an area.

The only reasonably detailed geological map of Kangaroo Island is that of Wade (1915), which is followed in fig. 1. The backbone of the island consists of Pre-Cambrian schists and gneisses, overlain in the central part by siliceous sand and laterite. On the west coast, eastern part of the north coast, and to a lesser extent on the east coast, these rocks form magnificent cliff scenery. The coast west of Emu Bay is of later age (Post-Cambrian) (Madigan 1928).

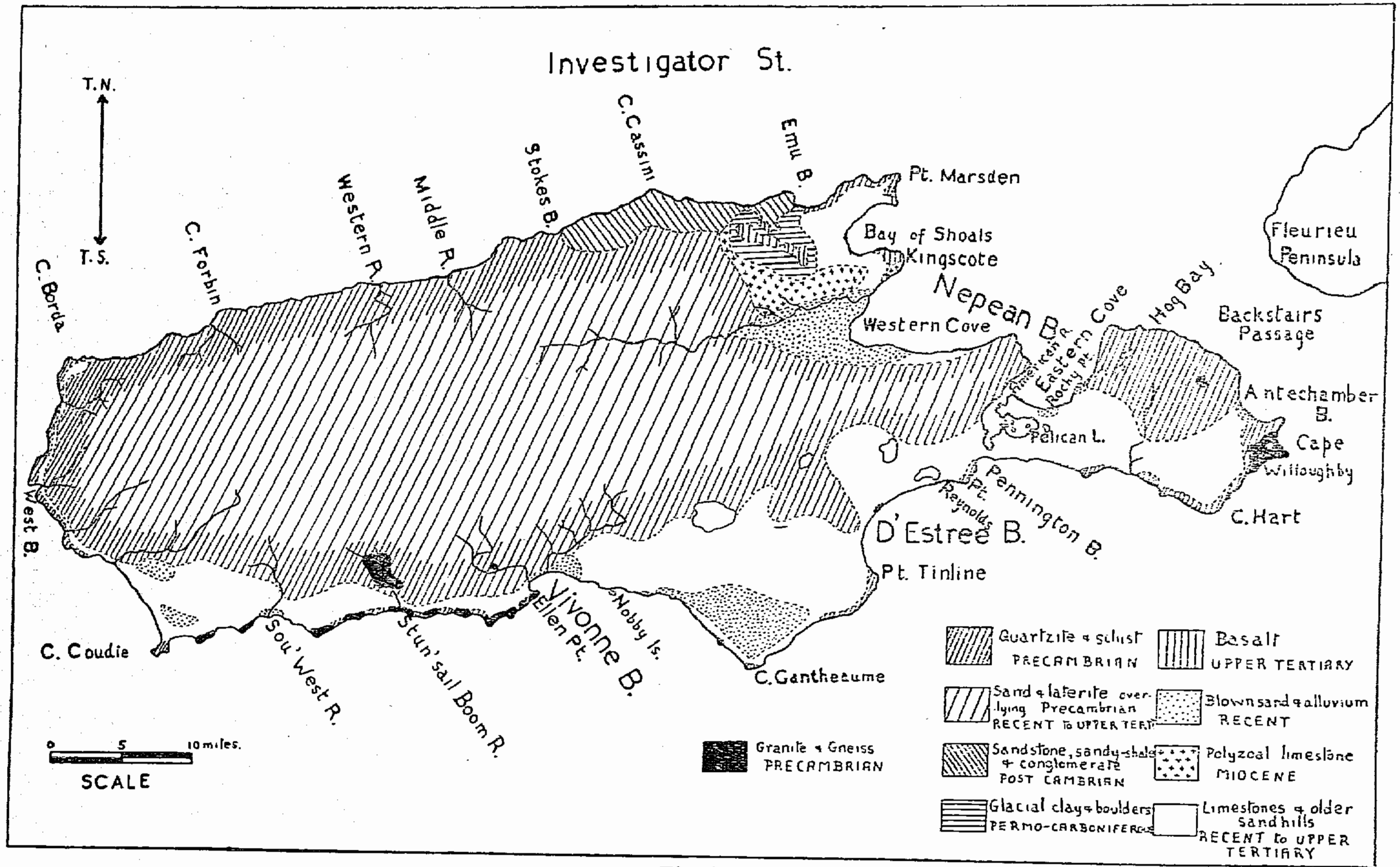

Fig. 1
Geological sketch map of Kangaroo Island. (after Wade 1915.)

The most significant geological features of the south coast of Kangaroo Island are the outcrops of ancient rocks at the capes. These outcrops do not rise to any notable height above sea level, and mostly appear at the foot of cliffs which fringe the shore. The extent of these outcrops of Pre-Cambrian rocks is shown in fig. 1. Two types of rocks, granite and quartzite or mica schists, form alternating patches along some of the coast. Between the areas of older rocks the coast consists either of sandy beaches backed by sand dunes or of sand-rock cliffs and horizontal reefs formed from older consolidated sand dunes. This rock weathers into very sharp edges and pinnacles, and by its variable hardness makes an irregular coast.

The two different types of rock found on the south coast of Kangaroo Island, *i.e.*, the flat rock platforms of consolidated sand-rock such as at Pennington Bay, and the harder more steeply sloping rocks such as seen at Cape Willoughby, west of Vivonne Bay, and Cape Coudie, result in two very different habitats for algal and animal growth, and appear to illustrate the conditions occurring along most of the south coast (cf., pl. ix, fig. 3, and pl. xii, fig. 1).

Most of the American River inlet consists of extensive sandy or sandy-mud tidal flats, but in many areas, particularly in Pelican Lagoon, these stretch out from low cliffs of the same consolidated sand-rock as at Pennington Bay on the south coast.

The northern coast of the island is composed mainly of ancient rocks sloping off into 3 to 12 or more feet of water, giving a relatively small area of rock exposed at low tide.

2. Degree of Wave Action

The degree of roughness of any locality is of prime importance in determining the algal associations present. The south and west coasts are exposed without any protection to the Southern Ocean, and conditions are invariably rough. Heavy breakers are a constant feature of this coastline (see pl. ix, fig. 1). Passing along the north coast, from west to east, conditions become progressively calmer, owing to the shelter afforded by the mainland. Northwards from Cape Willoughby and past Hog Bay wave action is moderate, with breakers only in rough weather. American River and Pelican Lagoon, quite unlike the rest of the island, form an almost land-locked area where wave action is at a minimum.

Although wave action is of great importance as an ecological factor, its measurement in any satisfactory way seems impossible. Average values of the forces from wave action to which algae are subjected in any one locality are needed. These should be measured over short periods (when extremes may occur), as well as over monthly and yearly periods. In the absence of any such measurements it is necessary, in some cases, to use the algae themselves as an index of the conditions. This has been done in subdividing the Rocky Shore Formation into subformations, depending on the presence or absence of *Cystophora intermedia* J. Ag. This alga is dominant in the sublittoral fringe on rough rocky coasts, but is replaced by other species of *Cystophora* on calmer coasts.

3. Tides

The tides around the Australian coast, including the main characteristics and ranges of the tides in the South Australian Gulf region, have been described briefly by R. W. Chapman (1938). The tides around Kangaroo Island are of the semi-diurnal type, with two maxima, one appreciably lower than the other, and two minima during each 24½-hour period. Fig. 2 shows the form of the spring and neap ("dodge") tides at American River.

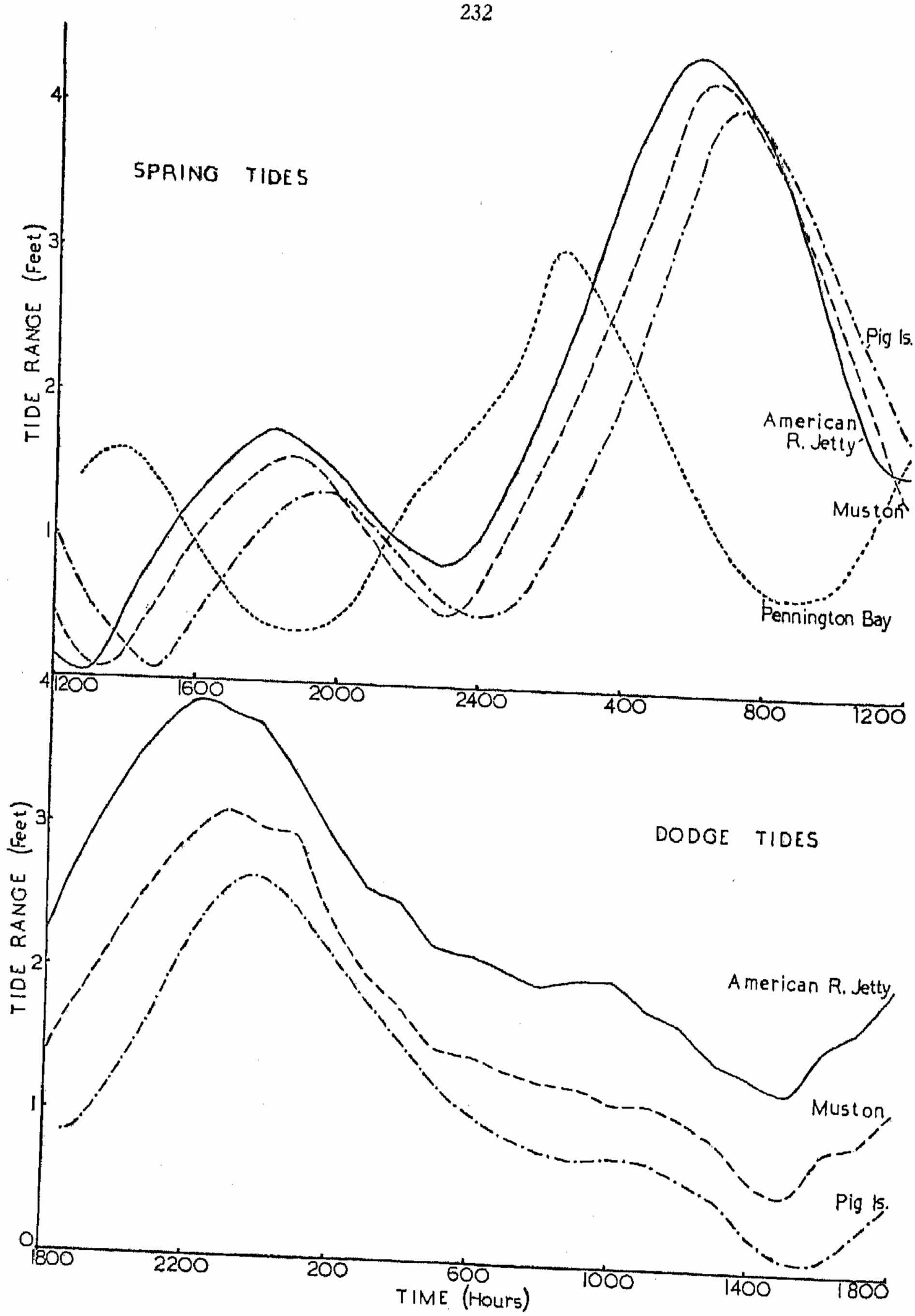

Fig. 2

Tide curves for spring and dodge tides in the American River Inlet and at Pennington Bay (spring tides only). The range of each tide curve and times of high and low water are comparable, but the heights given for each are arbitrary. The curves are derived from 24-hour surveys carried out at the American River Jetty, Muston Jetty, (3 miles south of American River Jetty), Pig Island in Pelican Lagoon, (2 miles East of Muston) and at Pennington Bay on the following dates: spring tides Jan. 10-11, 1947; dodge tides Jan. 16-17, 1947.

South Australian tides vary so greatly from place to place along the coast, both in their nature and times of high and low water, that it is necessary to obtain actual records from each locality. The tides have been analysed at comparatively few places, especially around Kangaroo Island. An automatic tide gauge recently established at Hog Bay should give most interesting results when records become available. The data given below for Kangaroo Island tides are derived from information made available by the South Australian Harbours Board and from 24-hour surveys carried out at American River and Pennington Bay. It will be evident that until accurate and more extensive tidal data are available, general limits and heights only can be given for the main algal zones.

Tidal range around Kangaroo Island is small. Along the south and west coasts the spring range is about 2½ feet. Passing eastwards along the north coast it increases to 4½ feet at Kingscote, just over 4 feet at American River and Hog Bay, 4½ feet at Antechamber Bay, while a rise of 6 feet is recorded from Cape Willoughby from old data (but this is probably too high). The neap (or "dodge") tides probably have a range of about 1½ feet on the south coast and 2½ feet on the north. On the south and west coasts the small tidal range means that the wind and strength of the swell may exert nearly as great an effect as the tide itself, and little reliance can be placed on the tides alone.

The most notable peculiarity of South Australian tides is the "dodging" tide. This is discussed by R. W. Chapman (1924). At Port Adelaide, where the effect is most prominent, the water level may remain almost constant for 24 hours or more at the neap periods. The cause is that during the neap period the sun and the moon, together with the other tide-producing forces, exert almost equal but opposite effects, one nullifying the other. It has been suggested that the abnormally large effect of the sun is accounted for by the synchronising of the natural period of swing of the basin of water between Australia and Antarctica with the period of the tide-producing forces.

At American River (see tide curves, fig. 2) the dodge effect seems to be present, though small, at the neap period. For about 6 hours the water level remains almost stationary, before the next rise or fall commences. Along much of the north coast this period of steady water level seems to occur, but no data are available as yet apart from isolated surveys at American River.

During winter the mean sea level at Port Adelaide is from 4 inches to 6 inches higher than in summer. This applies also to Kangaroo Island, with consequently higher tides during the winter months. With heavy west to north weather during winter very high tides often occur along the north coast. This is due to Investigator Strait being about 2½ times as wide as Backstairs Passage, with consequent building up of the water mass in the area north of Kangaroo Island under the influence of westerly weather. The higher sea level during winter is of considerable importance on the south coast, where the increase is large compared with the tidal range. The level of the horizontal rock platforms of the Pennington Bay region appears to correspond approximately with an average low neap tide level in summer. While north winds and low tides occasionally leave much of the reefs exposed in summer, with consequent drying and desiccation of the algae, this rarely, if ever, occurs in winter. Apart from allowing a heavier growth in winter, this is also one of the factors controlling seasonal changes on the reefs. Similar considerations may apply to a less extent in the American River inlet.

4. Currents

The surface current flows from west to east across the Great Australian Bight, passes along both sides of Kangaroo Island and on towards Tasmania (see "Australia Pilot," 1, 24). Eastward from the Bight the coastal current is strongest in the period May to July, with an average rate of 7 miles per day off the coast between Kangaroo Island and Cape Northumberland. During February to April and August to October it is weaker, averaging 3 miles per day, while from November to January it averages less than 2 miles per day. The currents in Backstairs Passage are largely tidal, reaching a speed of 2½ knots.

5. Temperatures

Observations taken around the coast of the island give the following results for sea temperature (Table 1). No data from other sources are available, but the figures agree well with the temperature isotherms given by Sverdrup et al (1942).

Table I

Sea Temperatures around the Coast of Kangaroo Island

South coast—Summer	(Jan.) - -	inshore 19-20° C., offshore probably 18° C.
Winter	(early June) -	inshore 16° C.
	(late July) -	inshore 13·5° C.
	(Sept.) - -	inshore 14° C.
North coast—Summer	(Jan.) - -	inshore 20-21° C., offshore 19-20° C.
Winter	(June) - -	inshore 11-13° C., depending on depth and air temperature; offshore 13-14° C.

From this table it is evident that the yearly range of sea temperature on the south coast is small, being about 4° C. offshore and 5 to 6° C. on reefs. The range is greater on the north coast and depends greatly on the depth of water and degree of roughness, since the calmer water is affected much more by air temperatures. On the tidal flats at American River temperatures as high as 32° C. have been recorded during summer in 6″ - 12″ of water, and as low as 10° C. in winter. Algae on the flats must be able to withstand a far greater range in temperature than south coast forms. In isolated rock pools at Vivonne Bay and along the north coast temperatures of up to 30 - 34° C. are frequent in summer.

Air Temperatures

The climate of Kangaroo Island is fairly uniform. Some data for Kingscote are given in Table II. The humidity figures probably give little indication of the humidity near algae exposed at low tide. Air temperatures are of greatest importance when a hot day (sometimes 35 - 38° C. in summer) coincides with a low tide. Under such conditions algae on the Pennington Bay reefs may be almost or quite exposed for several hours and considerable damage may result.

Table II

Air Temperature and Humidity Data for Kingscote

(From data made available by the South Australian Weather Bureau)

All readings were taken at 50 feet above sea level, over a period of 17 years.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Av.
Mean Max. Temp.°C.	22·3	22·7	21·4	19·3	17·7	14·9	14·2	14·5	15·8	17·8	19·8	21·4	18·4
Mean Min. Temp.°C.	14·5	15·6	14·2	12·5	11·0	9·6	8·7	8·5	9·3	10·5	12·1	13·8	11·7
Mean Rel. Humidity	70	74	75	76	80	83	82	80	79	75	72	72	76

6. Salinity

Chlorinity of sea water on the south and north coasts is within the range 19·6 - 19·9‰ (salinity 35·4 - 35·9‰). North coast values are usually slightly higher than those from the south coast. At Pelican Lagoon chlorinity in summer reaches 20·5‰ (salinity 37·0‰), while in isolated rock pools (some with a heavy growth of *Enteromorpha*) summer chlorinity figures of 24·0‰ have been obtained. After three days of heavy rain (January 1946) chlorinity on the tidal flats at American River decreased to 17‰; such conditions, however, are very exceptional.

Normal sea salinity around Kangaroo Island is high compared with other regions (*e.g.*, 34·9‰ salinity near Sydney (Pope 1943)).

7. Phosphate and Nitrate

Estimations of these two major nutrients are as yet too few in number for any general conclusions to be reached. It appears, however, that nitrate is often extremely low (less than 1 part per 10^9), while phosphate is rather variable. Phosphate figures of 14 and 23 p.p. 10^9 have been obtained from the south coast, and values between 2 and 60 pp. 10^9 from the American River inlet. Isolated high figures obtained at American River are probably due to the large bird population.

8. Alkalinity

The pH of water (by colorimetric methods) at Pennington Bay is about 8·2 - 8·3, while at Pelican Lagoon figures of 8·1 have been obtained.

9. Dissolved Oxygen

The constantly boisterous seas on the south and west coasts result in water supersaturated with oxygen. The water on reefs at Pennington Bay is usually about 110% saturated with oxygen. Oxygen figures in shallow water at the American River inlet in summer show high supersaturation during the day (120 - 150%, rarely as high as 250%), dropping to 50 - 70% saturation at night (an extreme of 10% saturation has been recorded). Such large ranges are due to the heavy growth of algae in the calm shallow water. For the most part it is unlikely that oxygen content of the water is of importance in the algal ecology. The Winkler method was used in all estimations.

10. Light

No attempt has been made to measure light intensities at different depths, but correlation of shaded littoral areas with communities of sub-littoral algae has been observed at Pennington Bay and Vivonne Bay. On the south coast, with constantly broken water, light penetration will be less than in calmer waters off the north coast. At American River the large amount of silt carried in the tidal current reduces light penetration and may influence algal distribution.

TERMINOLOGY

At the present stage there is little uniformity in nomenclature used in marine algal ecology. Chapman (1946) reviews opinions expressed about terminology, and advocates adoption of the terms used in land ecology. However, land ecologists are far from agreement on their terminology, and until many more marine ecological studies in different parts of the world have been carried out, uniform and satisfactory meanings of the terms cannot be expected. This applies particularly to the Australian coasts. As in the past, each worker must use the terminology which best suits his locality and his own concepts.

The definitions adopted here have been found satisfactory in describing the algal vegetation of the Kangaroo Island coasts. Only further studies in other regions of the Southern Australian coast will show to what extent the concepts need to be modified, and their usage at present makes no pretension to be final.

Association and Community

The concept of an association is fundamental to all ecological work, yet many different meanings have been applied to the term. The association is used here in the sense of a grouping of organisms distinct in species composition and facies from another grouping. It is composed of a dominant or dominants usually accompanied by other species whose presence is determined by responses to factors similar to those influencing the dominants (see Rees 1935). This concept is to some extent subjective, but experience shows that most associations are objective entities. Studies over a long stretch of coast are usually necessary before the associations present can be determined. Intensive work on small areas often results in variations of one basic association being considered as separate associations. On the other hand, an association may be scattered in its occurrence and cover areas of only a few square feet of rock, yet may be typical of that particular habitat, and pure and well defined in its occurrence. This is especially true of irregular and dissected coastlines.

When associations occur during certain periods of the year only, they are classed as "seasonal associations."

The term "community" is commonly used with the same meaning as association, but often in a more general sense. It is applied in this and following papers when the status of the algal grouping has not been satisfactorily established.

Formations

Apart from classifying the associations in their zones (see later), the only other grouping used is the formation. This is applied to the principal types of marine vegetation, much as it was used by Cotton (1912) for Clare Island and Rees (1935) for Lough Ine. Cotton's formations were based on the substrate and environment for algal growth, and comprised the following:

1. Rocky shore Formation.
2. Sand and Sandy-mud Formation.
3. Salt-marsh Formation.

He also distinguished:

4. Vegetation of river mouths.
5. Vegetation of brackish bays.

Of these, the Rocky Coast ("Shore" of Cotton) and Sand and Sandy-mud Formations are found around Kangaroo Island, and they are real and natural entities. Rees' formations are based to a larger extent than Cotton's on the degree of wave action, but this is nearly always closely associated with the nature of the coast, and there is little difference between the formations of Rees and Cotton. The distribution of algae around Kangaroo Island shows that the degree of wave action is the most important environmental factor, as was emphasised by Rees.

Use of the substrate and environment as criteria for "formation" is criticised by Chapman (1946, p. 658), who advocates following the practice of naming land plant formations on the dominant species. However, Tansley (1940), to whom Chapman refers, describes Salt-marsh and Sand-dune Formations, and the naming of formations on the type of plant, while conveying at the same time something of the nature of the environment, is common in land ecology (*e.g.*, mallee, savannah woodland, forest formations). Naming of the formation on the dominant plant or animal species is quite impracticable in many cases, such as with the Sand and Sandy-mud Formation.

In any case the formation is an abstraction. Of the four chief characteristics of an association, *viz.*, floristic composition, life-form, structure and habitat, Tansley uses two only (life-form and structure) as a basis for uniting associations into formations. It is just as logical to use either habitat or floristic composition as a criterion for such higher grouping (Crocker and Wood 1947).

Some algal formations in Tansley's sense can be readily determined by life form, *e.g.*, a blue-green formation and coralline-mat formation. On Kangaroo Island these formations are formed essentially of a single association, each delimited by definite environmental conditions, with the former occurring above the latter. It is evident that when the distinctive zones of algae around a coast-line have very different life-forms, one zone must be chosen on which to base any classification; around Kangaroo Island this is the upper sub-littoral zone. To regard each zone as a distinct formation is clearly not justified.

It is well not to lose sight of the fundamental principle underlying the existence of communities, namely, that certain species live together in a particular situation because they have been selected by that environment, *i.e.*, all of the species have the same habitat requirements for growth. This gives the basis for defining associations.

Within any one tidal zone, different associations may occur depending upon local variations. These associations often have similar life forms, and possess unity in the fact that they have certain habitat requirements in common. Such "habitat zones" are realities and are the natural units of higher grade than the association.

In practice tide level, degree of exposure to wave action and nature of the substratum are the chief habitat factors. Using he latter two criteria a large unit (formation) is obtained; depending on the degree of wave action, the formation may be divided into sub-formations; and by using tide levels zonation is obtained.

Using habitat factors as criteria does present us with realities common in all parts of the world, and in this lies a real hope of achieving some degree of uniformity in marine ecological nomenclature. The formations of Cotton and Rees, or a combination of them, would be of world-wide occurrence, and subdivisions could well express the characteristic algal groups of the geographical regions.

Zonation

The occurrence of marine algae in distinct zones between and often below tide levels is a distinctive feature of rocky coasts, though more prominent where the tidal range is large. The tidal range around Kangaroo Island is small (between 2 and 4½ feet), but zonation is always present and often marked.

In delimiting the zones around Kangaroo Island absence of accurate tidal data is a limiting factor. Until such data become available, the position of the zones of algae in relation to tide levels can be given only approximately, and what appear to be critical levels only from subjective observations. Thus the two main littoral associations of rocky coasts are referred to as being in the "upper littoral" and "lower littoral," but the relation of these to tide levels cannot be given. The upper littoral zone of blue-green algae probably does not extend to high water mark of spring tides, except when influenced by splash effects.

As long as the occurrence of algae and animals on the shore is referred to as "zonation"—a word which is far too well established to be dropped—there seems no justification for replacing the term "zone" by "belt," as is advocated by Chapman.

It has been possible to relate the algal zones to measurements of tide levels only in the American River inlet. Here the stationary low water level of dodge tides appears to be of most importance, marking the separation of the *Hormosira* zone from a zone of red algae (*Hypnea - Centroceras - Spyridia*) which is nearly always covered. This level is very little higher than the low water level of neap tides (see graphs, fig. 2). On the south coast the low water mark of neap or dodge tides in summer appears to correspond closely with the surface level of the flat rock-platforms, and this marks a distinctive change in the algal flora. The higher mean sea level in winter may cause an elevation of the littoral flora, but the lower summer level will be the limiting factor at least for the more permanent algae.

The littoral zone is therefore considered as ranging from the stationary low of dodge tides, or the low water mark of neap tides to the upper limit of the algal vegetation. Accurate fixation of this level will have to await detailed tidal information.

The term "supralittoral" is often applied to the zone above high water level of spring tides. Alternative names are the "splash" or "spray" zones. Cotton (1912) has given good reasons for rejecting this term, and investigations around Kangaroo Island support the view that algal vegetation above actual high water level is simply an upward extension of the upper littoral algae under the influence of shade and wave-splash. One exception to this lies in the occurrence of *Prasiola* during winter at Pennington Bay and on Shag Rock in Pelican Lagoon, well above the area splashed by waves. This alga is subject to fine blown spray, but is as much terrestrial as marine. In both localities it occurs only where penguin and shag excrement is present. The lichen *Lichina* may occur in small patches in and above the splash area, and the mollusc *Melaraphe unifasciata* extends many feet above high water mark. Apart from these associations the term supralittoral is of little use in describing the algal ecology of Kangaroo Island.

Below the littoral is the sublittoral, which extends down to the limit of algal vegetation. The upper limit of the sublittoral, particularly on exposed rocky coasts, bears a distinctive algal flora, and this area, between low water mark of neap tides and extreme low water of spring tides, has been termed the "sublittoral fringe" by Stephenson (1939). The sublittoral fringe on rough coasts is exposed during the suck back between waves at low tide, and the short but frequent periods of exposure to air are probably of importance in determining the algal flora present.. On the south and west coasts of the island this zone is dominated by *Cystophora intermedia,* which is strictly confined to the region exposed between waves at low tide. On calmer rocky coasts other species of *Cystophora* are dominant, but these extend to 6 or more feet below low water. At American River also the flora just below low water is not so distinctive, and is better referred to as "upper sublittoral." The sublittoral fringe must be regarded simply as a useful division of the sublittoral in certain areas, such as the rough coasts of Kangaroo Island.

A GENERAL ACCOUNT OF THE ALGAL ECOLOGY

This account is of a general nature only. While it is derived from the study of localities illustrating most of the coast and appears at the present stage well founded, it makes no pretensions to be final, and modification may be necessary as other coastal areas are visited. Descriptions of the typical localities will be given in later papers.

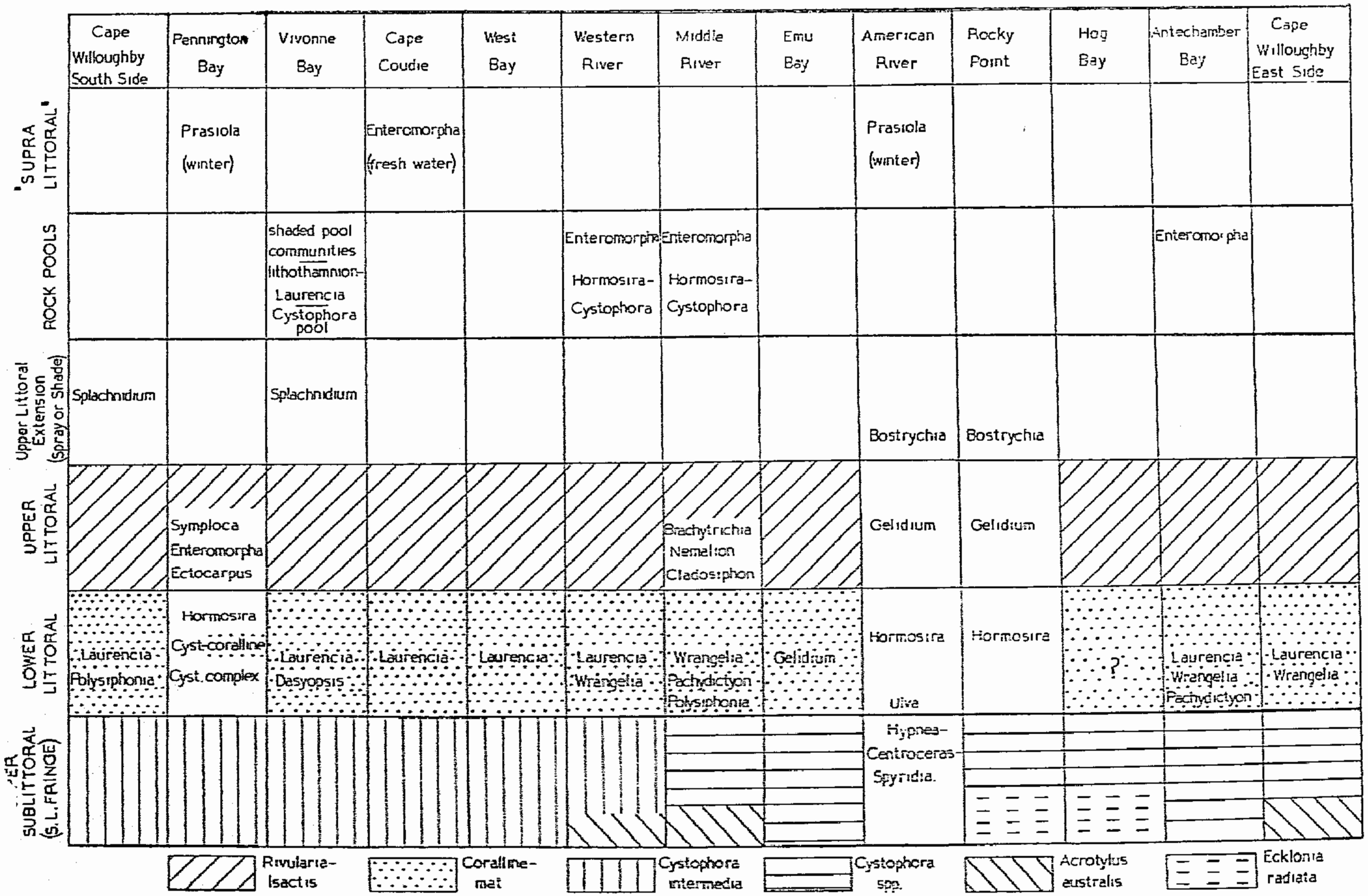

Fig. 3

The basic algal zonation at the localities studied around the coast of Kangaroo Island. Shading or dotting symbolises the main associations, but in the lower littoral zone the most prominent accompanying species are shown superimposed on the coralline-mat association. The *Prasiola* association at Pennington Bay and American River is found only where penguins or shags inhabit the coast.

Fig. 3 shows the basic zonation at the localities studied. Two main regions are clearly defined:

(1) The American River tidal inlet where species of *Cystophora* (or other large brown algae) are almost completely absent from the upper sub-littoral zone. *Hormosira banksii* Dcne., *Gelidium pusillum* (Stackh.) Le Jol and *Bostrychia simpliciuscula* Harv. dominate the basic littoral zones from lower to upper littoral.

(2) The rest of the coast of the island where species of *Cystophora* (or *Ecklonia radiata* (Turn.) J. Ag.) are dominant in the upper sub-littoral zone. Coralline-mat and blue-green algae here form the two characteristic zones of the littoral.

Hence, depending on the presence or absence of species of *Cystophora*, the coast may be divided into two formations named from their characteristic habitat, the "Sand or Sandy-mud (Flat) Formation" (American River inlet) and the "Rocky Coast Formation" (see fig. 4). The naming of these formations on the habitat has been discussed under "Terminology."

The chief differences between the two formations are:

(1) *The difference in species composition.* Species common to both formations are rare, and if common they usually differ greatly in relative abundance. The *Gelidium pusillum* association, well developed and prominent in Pelican Lagoon, is present, but poorly developed at Pennington Bay, and fragments may be found elsewhere along the coast. *Hormosira banksii* forms well-developed associations in both formations, but the ecological forms in each are very distinct (see pl. B, fig. 4, and pl. E, fig. 4). In number of species the Rocky Coast Formation is much richer than the Sand and Sandy-mud Flat Formation, while the size of the algae is usually greater in the former.

(2) *Methods of attachment.* A wide, expanded, holdfast disc is characteristic of all the larger algae in the Rocky Coast Formation. In rough places this disc is extremely strong. Other methods of attachment are found in the littoral zone; *viz.*, ramifying and densely matted attaching filaments of the coralline mat association, and the gelatinous adhesive thalli of the blue-green association of the upper littoral.

In the American River inlet the expanded holdfast disc is rarely found, and the adhesive thalli of blue-green algae are almost completely absent from the upper littoral. The chief mode of attachment is by rhizoidal filaments (a notable exception being *Hormosira*). Attachment of filaments by means of a basal cell or cells occurs in both formations.

(3) *The growth substratum.* On rocky coasts the vast majority of algae grow on rock, while a few occur as epiphytes where the growth is dense. Many epiphytes can grow equally well on rock or on other algae, but a few are limited to particular hosts (*e.g.*, *Notheia* on *Hormosira*).

At American River most of the tidal flats are colonised by the marine Angiosperms *Posidonia australis* Hook. and *Zostera muelleri* Irmisch, and these bear a profusion of epiphytic algae. Apart from *Bostrychia*, *Gelidium* and *Porphyra*, which occur on rock in the upper littoral, and to some extent *Hormosira*, all others are either epiphytes or grow on shells and small stones in the sand and mud. No macroscopic algae are able to grow directly in or on the sand or mud, although they may often be partly buried in mud; growth in sand or mud is, however, characteristic of the marine Angiosperms.

In discussing the Rocky Coast Formation, no account is taken of stretches of sandy beach between rocky sections of the coast. Rees considered such areas as a separate subformation, but devoid of algae. No macroscopic forms are found on such beaches, and wherever rocks occur the typical algae of the Rocky Coast Formation are found.

Within the Rocky Coast Formation conditions of roughness vary from very rough to moderately calm, and the coast may be divided on the presence or absence of *Cystophora intermedia*. This brown alga is found only in conditions of fairly strong to very strong wave action, and never occurs on calm coasts. It grows best under the constant action of heavy breakers, and has by far the strongest thallus for its thickness of any Kangaroo Island alga. *Cystophora intermedia* is dominant in the sublittoral fringe zone from Cape Willoughby along the south and west coasts, and along the north coast to between Western River and Middle River, where it is replaced by other species of *Cystophora*.

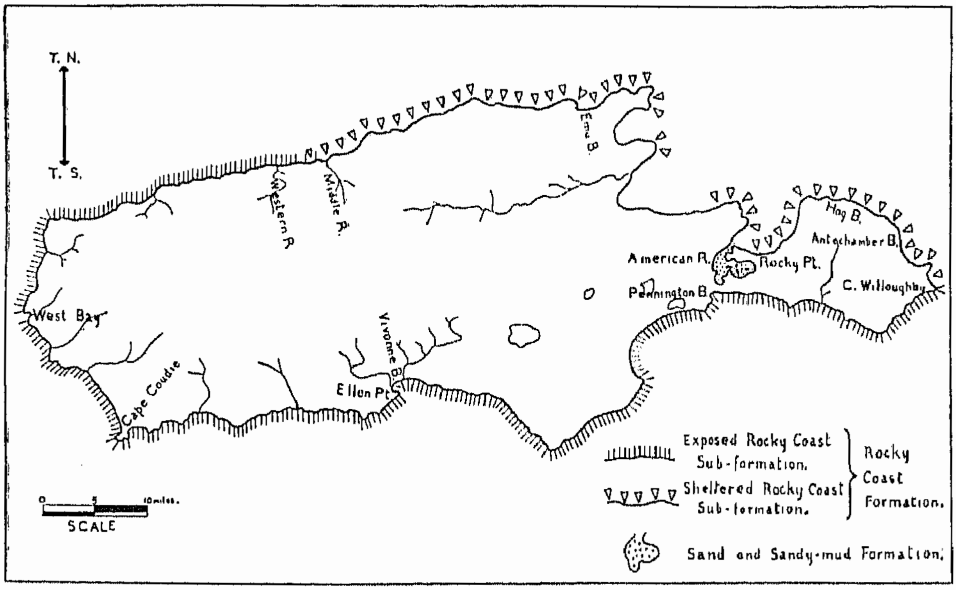

Fig. 4

The Algal Formations and Subformations around the Kangaroo Island coast. Areas in the Bay of Shoals and Western Cove not yet studied are left unclassified. Only the localities actually examined are shown on the map.

On the north coast between Cape Willoughby and Middle River (excepting the American River inlet) other species of *Cystophora* (*C. subfarcinata* (Mert.) J. Ag., *C. siliquosa* J. Ag., and others) or *Ecklonia radiata*, and in some places the red alga *Acrotylus australis* J. Ag., are dominant in the upper sublittoral zone. These species require constant water movement, but sudden rough weather will remove many plants from the rock. The outer edge of the Pennington Bay rock platforms is very rough, with calmer conditions nearer in and at the rear of the reefs, where *Cystophora subfarcinata* and *C. siliquosa* are very common. Along the whole south coast, however, *C. intermedia* is dominant in the sublittoral fringe, and although fairly common, the species characteristic of more sheltered coasts occur only where conditions are locally less rough.

The Rocky Coast Formation is therefore divided as follows (see fig. 4):

(1) THE EXPOSED ROCKY COAST SUBFORMATION: from Cape Willoughby along the south, west and north coasts to between Western River and Middle River. The area is characterised by the presence of *Cystophora intermedia* in the sublittoral fringe.

(2) THE SHELTERED ROCKY COAST SUBFORMATION: found along the north coast between Cape Willoughby and Middle River, excluding the American River inlet. Characterised by other species of *Cystophora, Ecklonia radiata,* and in some areas *Acrotylus australis,* in the upper sublittoral. *Sargassum* spp. may also occur in some areas.

Cotton found it necessary to divide his Rocky Shore Formation into Exposed and Sheltered Series. This appears to correspond closely as far as environment and status go with the two subformations of the Rocky Coast Formation on Kangaroo Island.

Although referred to as "sheltered," the degree of shelter in this subformation is very much less than in the Sand and Sandy-mud Formation. The latter is developed mainly in almost land-locked areas, whereas the Rocky Coast Formation is always found on open coasts.

Within the exposed Rocky Coast Formation two distinctive types of habitat occur, dependent on the geology of the coast (see "Coastal Geology," under "Environment"). These are the horizontal sand rock reefs, actually wave cut platforms, occurring along much of the south coast (pl. ix, fig. 3), and the steeply sloping rocky areas occupying the rest of the coast (pl. xii, fig. 1). A brief description of the main associations in these two areas is given below, but detailed reports will be left till later papers.

A. THE ROCKY COAST FORMATION

I. THE EXPOSED ROCKY COAST SUBFORMATION

(a) The Pennington Bay Rock Platforms

The type of horizontal wave-cut platform (pl. ix, fig. 3) found at Pennington Bay occurs along much of the south coast of Kangaroo Island (see fig. 1). The reefs which have been studied in detail at Pennington Bay are probably representative of this type of algal habitat, and a detailed account will be given in another paper. The following are the main associations found in the Pennington Bay area:

(1) THE LITTORAL ZONE.

REAR LITTORAL ASSOCIATIONS—These occur on the vertical or sloping rock backing the reefs, usually at a higher elevation that the reef itself. The associations are exposed at low tide, but washed or splashed continuously at medium and high tides.

1. *Rivularia firma* association (pl. x, fig. 2). This alga favours areas where wave splash is moderate or else there is constantly running water. For further notes see Womersley (1946 a).
2. *Symploca hydnoides* association: forming scattered patches in shaded hollows of vertical or sloping rocks.
3. *Gelidium pusillum* association: common, but usually poorly developed.
4. *Enteromorpha* association: forming bright green, usually pure areas on sloping well-washed rock.
5. *Ectocarpus confervoides* and *Pylaiella* seasonal associations. These form brown mats and tufts on well-washed sloping rock, *Ectocarpus* occurring during winter and *Pylaiella* mainly in summer.

LITTORAL ASSOCIATIONS (on the flat reef surface).

6. The *Cystophora* complex. Four species of *Cystophora, C. subfarcinata, C. siliquosa, C. uvifera* (Ag.) J. Ag. and *C. brownii* (Turn.) J. Ag., together with *Sargassum muriculatum* J. Ag., form a complex of associations on the flat reef surface, always where they are submerged. Each species may form a pure association or occur mixed with one or more of the others, depending on the depth of water at low tide (pl. x, fig. 1). This complex covers the larger part of the reef surface.
7. *Hormosira banksii* association. This is a well-marked association on slightly higher and therefore more exposed parts of the flat reef surface. On higher areas it is pure and dense (pl. ix, fig. 4, and pl. x, fig. 4); in other places it may become mixed with species of *Cystophora. Notheia anomala* Bail. et Harv. is always found growing from the conceptacles.
8. *Cystophyllum muricatum* association. A pure area of this alga occurs in well-washed, relatively calm, and rather sandy parts of the main reef.
9. *Laurencia heteroclada* association. This occurs in fairly rough places, where it forms a dense mat of stunted plants.
10. *Cystophora* – coralline association. A distinctive association found on the rougher parts of the reefs, consisting of *Corallina cuvieri* Lamour. on rock and *Jania fastigiata* Harv. on species of *Cystophora;* a dense and rich association.

(2) THE SUBLITTORAL FRINGE

11. *Cystophora intermedia* association. This brown alga dominates the outer edges of the reefs in the roughest conditions. It is an extremely rich association of small, often stunted species (over 50 have been recorded from an area of a few square yards), completely covering the rock (pl. ix, fig. 2).

The sublittoral assemblage will not be dealt with here, but it is very similar to that listed for Vivonne Bay (see p. 244). The coast at Pennington Bay is very rich in number of species; over an area of ½ mile more than 220 species have been recorded, and many more, no doubt, remain to be found.

(b) Steeply Sloping Coasts

Three main zones, each comprising one association and in certain localities others, occur in the intertidal areas of the more steeply sloping parts of the south and west coasts. Heavy wave splash or regular passage of breakers up sloping rocks results in considerable upward extension of these zones.

1. RIVULARIA - ISACTIS ASSOCIATION of the upper littoral.

This association is composed of *Rivularia firma* Womersley, *R. atra* Roth. and *Isactis plana* (Harv.) Thuret, all forming scattered, dark blue-green gelatinous thalli on otherwise bare rock. In some areas they are very well developed (especially *R. firma*), in other places they are almost absent. Degree of wave action is the determining factor, but the association is often poorly developed where least expected.

2. CORALLINE-MAT ASSOCIATION.

The lower littoral, between the blue-green algae and the sub-littoral fringe, usually consists of a dense mat of stunted *Jania fastigiata* and/or *Corallina* (probably *C. cuvieri*) (pl. xi, fig. 4). This mat is 1-3 cm. in thickness, pinkish-white in colour, and forms a continuous covering on much of the rock. Where breakers run well up sloping rocks it may reach a height of 5 or 6 feet. At Vivonne Bay (on the south side of Ellen Point), *Dasyopsis clavigera* Womersley, and a small stout *Laurencia* are prominent amongst the corallines. This *Jania-Dasyopsis-Laurencia* variant is probably general in many areas of the south and west coasts, but rather than being a distinct association it consists of the addition of the latter two algae to the basic coralline-mat association.

3. CYSTOPHORA INTERMEDIA ASSOCIATION of the sublittoral fringe.

This brown alga forms a striking sublittoral fringe zone on sloping rocks of the south, west and north-western coasts of Kangaroo Island. The upper edge of the association is often very sharply limited, as shown in pl. xi, fig. 2, the zone appearing as a dark band stretching along vertical rock at Cape Willoughby. In situations where waves pass along the rock, rather than breaking against it, the coralline-mat and blue-green zones may be poorly developed, but the sharpness of the upper limit to *Cystophora intermedia* can be seen from pl. x, fig. 3. Where waves break heavily on rocks the upper edge is less well defined, and the coralline-mat often merges with *Cystophora intermedia* (pl. xi, fig. 4).

The dark-brown pinnate fronds of *Cystophora intermedia* reach a length of 40 to 45 cm. The stems are extremely strong, and only very rarely are fronds found cast up. A common epiphyte is *Corynophloea cystophorae* J. Ag.

THE SUBLITTORAL.

Study of the sublittoral flora is restricted to the algae cast up but not known to occur in the intertidal area. The following list includes the commonest forms of the sublittoral assemblage of the south coast, but comprises only a small fraction of the total.

CHLOROPHYCEAE—*Caulerpa harveyi* F. v. M.; *C. obscura* Sonder; *C. vesiculifera* Harvey; *Codium galeatum* J. Ag.; *C. mamillosum* Harvey; *C. pomoides* J. Ag.

PHAEOPHYCEAE—*Phloeocaulon spectabile* Reinke; *Dictyota latifolia J. Ag.; Zonaria turneriana* J. Ag.; *Sporochnus scoparius* Harvey; *S. comosus* C. Ag.; *Bellotia eriophorum* Harv.; *Encyothalia cliftoni* Harvey; *Perithalia inermis* (R. Br.) J. Ag.; *Ecklonia radiata* (Turn.) J. Ag.; *Scytothalia dorycarpa* (Turn.) Grev.; *Sierococcus axillaris* Greville; *Scaberia agardii* Grev.; *Myriodesma quercifolium* (Bory) J. Ag.; *Carpoglossum confluens* (R. Br.) Kütz.; *Cystophora monilifera* J. Ag.; *C. dumosa* J. Ag.; *C. retorta* (Mert.) J. Ag.; *C. racemosa* Harv.; *C. platylobium* (Mert.) J. Ag.; *C. spartioides* (Turn.) J. Ag.; *C. siliquosa* J. Ag.; *C. paniculata* (Turn.) J. Ag.; *Sargassum varians* Sonder; *S. sonderi* J. Ag.; *S. trichophyllum* J. Ag.; *S. cristatum* J. Ag.

RHODOPHYCEAE—*Asparagopsis armata* Harvey; *Mychodea compressa* Harvey; *Hypnea episcopalis* H. & H.; *Delisea elegans* C. Ag.; *Phacelocarpus labillardieri* J. Ag.; *Plocamium nidificum* (Harv.) J. Ag.; *P. preissianum* Sonder; *P. costatum* (J. Ag.) H. & H.; *Hymenocladia polymorpha* (Harv.) J. Ag.; *Antithamnion mucronatum* (J. Ag.) De Toni; *Monospora elongata* (Harv.) De Toni; *Ceramium puberulum* Sonder; *Lasiothalia formosa* (Harv.) De Toni; *Spongoclonium* sp.; *Spyridia opposita* Harv.; *Sarcomenia dasyoides* Harv.; *Nitophyllum curdieanum* Harv.; *Amansia pinnatifida* Harvey; *Lenormandia spectabilis* Sonder; *Osmundaria prolifera* Lamour.; *Thuretia quercifolia* Dcne.

OTHER COMMUNITIES OF STEEPLY SLOPING COASTS

An *Enteromorpha* association occurs on rock well above normal wave-splash at Cape Coudie. It is dependent on the presence of fresh water percolating through the upper limestone stratum and running down over the harder ancient rocks forming the base of the cliffs. The species has not been determined, but it occurs in dense, pure masses on otherwise bare rock. *Enteromorpha* associations dependent on the presence of fresh water have been recorded by numerous other authors (see Cotton 1912).

A *Splachnidium rugosum* association is found in the upper littoral at Cape Willoughby, usually at a higher level than the blue-green zone. The Cape is composed of granite boulders, and where waves break heavily, leaving the rock exposed between waves, *Splachnidium* forms a pure association of short, tufted plants (see pl. xi, fig. 3).

At Vivonne Bay, on gneissic rock, *Splachnidium rugosum* (L.) Grev. is often common on wave-splashed rock, but may merge with *Rivularia firma*. *Helminthora tumens* J. Ag. and *Polysiphonia dasyoides* Zan. are also characteristic of this region during January.

On other types of rock *Splachnidium* is very rare. If further studies show that it is restricted to granite or gneissic rock, this will be one of the very few cases known from Kangaroo Island of the type of rock influencing algal distribution.

A marked feature of the south side of Ellen Point, Vivonne Bay, is the occurrence of at least five species of lithothamnia. Elsewhere on the island they are rare. Two distinct species (generic determination has not yet been possible) form pure but localised communities in the littoral zone in what are apparently rather specialised habitats. They grow as crustose thalli forming small irregular branches.

The coast at Ellen Point consists of fossiliferous calcareous limestone overlying the hard gneissic base. Wearing back of the softer limestone has resulted in many rock pools, from very small to over 20 yards across, being left in the harder base (pl. xi, fig. 1). Most of these pools are subject to wave influx only at high tide, and during summer their water temperature is considerably higher than that of the sea (up to 28° C. when sea temperature is 18° C.).

Some of these pools bear distinctive algal communities; others, where conditions are apparently too severe, are devoid of growth.

One pool, shown in the foreground in pl. xi, fig. 1, contains a *Laurencia*—lithothamnion community. The lithothamnion forms scattered, irregular pinkish masses (to 10 cm. across and 3 cm. thick), while *Laurencia heteroclada* Harv. grows on the rock or the lithothamnion and is heavily epiphytised by *Ceramium miniatum* Suhr. and *Polysiphonia abscissa* Harv.

In the rear pool of the two shown in pl. xi, fig. 1, the end shaded by the cliff bears a community of red algae which are normally sublittoral forms. *Dictymenia tridens* Grev. and *Bornetia* sp. are the commonest, while in another shaded area of the same pool *Lyngbya majuscula* (Dillw.) Harv. forms a pure community in January. The effect of continual shade is evident in both cases.

In another pool, at a lower level and subject to wave influx except at low tide, species of *Cystophora* are dominant. One corner, however, is shaded by overhanging rock, and here *Ecklonia radiata, Scytothalia dorycarpa, Myriodesma latifolia* Harv. var. *duriuscula* J. Ag. (with epiphytic *Sphacelaria tribuloides* Menegh.), and *Gelidium australe* J. Ag. are prominent. All these are normally upper sublittoral forms.

In some of the pools minor communities of *Bryopsis plumosa* (Huds.) C. Ag., *Bryopsis baculifera* J. Ag.; *Derbesia* sp., two lithothamnia, and two species of coral occur. This assemblage shows more relationship to the flora of tropical waters, and is almost certainly due to the higher temperatures maintained in these pools during summer.

To deal adequately with the complex nature of the littoral zone at Ellen Point requires detailed mapping of the greatly dissected coastline. The variation in minor habitats is almost without limit, and similar complex areas probably occur along other parts of the south coast. However, the basic zonation of blue-green, coralline-mat and *Cystophora intermedia* zones is found on all rocks directly exposed to the sea.

II. THE SHELTERED ROCKY COAST SUBFORMATION

Wave action on the coast included under this subformation is from moderate to slight (see pl. xii, fig. 2 and 4). In fine weather waves gently lap the shore, while breakers a few feet high occur in rough weather. Some degree of water movement is always present, whereas in the American River inlet conditions are more often than not a dead calm on the tidal flats.

Littoral zonation is basically similar to that on exposed coasts, comprising blue-green and coralline-mat associations.

1. The Upper Littoral Zone of Blue-green Algae.

On the eastern end of the island, and at Middle River, *Rivularia firma* is dominant, accompanied by *Rivularia atra, Isactis plana* and sometimes *Symploca hydnoides* Kutz. In calmer areas *R. firma* disappears and *R. atra* and *Isactis* become dominant. From Middle River to Stokes Bay (and probably further east) *Brachytrichia quoyi* (Ag.) B. & F. is prominent in January.

In some places where wave-splash is absent this blue-green zone may be very inconspicuous. The gelatinous thalli occur scattered singly or in patches on otherwise bare rock. No other algae normally occur in this area of the upper littoral. Blue-green algae are absent at Rocky Point, where the substrate is consolidated sand rock and the littoral zonation is closely allied to that found in Pelican Lagoon.

A community of *Nemalion helminthoides* (Velley) Batt. occurs on rocks on the east side of the beach at Middle River, in the mid-littoral, while on the west side of the beach *Cladosiphon filum* (Harv.) Kylin is common below the blue-green zone.

2. Coralline-mat association.

This is usually well developed in the lower littoral, often forming a closed community with a well-defined upper edge (see pl. xii, fig. 4, at Emu Bay). *Jania fastigiata* and fragments of *Corallina* are the main constituents, but *Dasyopsis clavigera* and the *Laurencia* of the south coast association are absent. *Gelidium pusillum* is often, in calmer localities, an integral part of the mat, while other species commonly present are: *Wrangelia plumosa* Harv., *Pachydictyon paniculatum* J. Ag., *Zonaria turneriana* J. Ag., *Amphiroa charoides* Lamour, *Laurencia heteroclada* Harv., *Ceramium miniatum* and *Polysiphonia spp.*

At Rocky Point *Gelidium pusillum* has become completely dominant, with only fragments of coralline left amongst the *Hormosira* association at a lower level. Above this is a zone of *Bostrychia,* similar but often better defined than in Pelican Lagoon.

3. The Upper Sublittoral Zone.

This region, on sheltered rocky coasts, is characterised by the dominance of fairly large brown algae, forming several associations in different localities.

Cystophora association.

Three species, *C. subfarcinata, C. polycystidia* Aresch., *C. siliquosa,* and to a lesser extent *C. spartioides,* extend from low water mark to a depth of 6 or 8 feet. They may reach a length of 1½ metres, and at low tide in some localities the fronds float at or below water surface, giving the zone a distinctive appearance.

C. subfarcinata is found throughout the subformation, but in calmer areas (*e.g.*, Rocky Point) forms numerous vesicles and is more branched. *C. siliquosa* and *C. spartioides* are restricted to slightly rougher parts, while *C. polycystidia* becomes dominant in calmer regions. In shallow water and locally calm places *Cystophyllum muricatum* forms a distinct community.

Although *C. polycystidia* is characteristic of the north coast of Kangaroo Island, it does occur in locally sheltered places on the south coast.

On the east side of Ballast Head (north of American River) *Sargassum* sp. dominates the upper sublittoral.

Ecklonia radiata association.

At Hog Bay and Rocky Point, where wave action is slight, *Ecklonia radiata* forms a distinct sublittoral fringe, accompanied by some *C. subfarcinata*. Under locally suitable conditions elsewhere around the island it may be found; at Cape Coudie a protected channel bears a dense fringe of *Ecklonia*.

Acrotylus australis association.

At Middle River and the east side of Cape Willoughby dense and pure patches of the red alga *Acrotylus australis* occur in the upper sublittoral. The dark brown dichotomous fronds, from 10 to 20 cm. high, completely cover the rock, forming a distinct association. At both localities conditions of wave action are very similar, and the general algal ecology is almost identical. *Caulerpa brownii* Endl. often forms dense bright green mats within a few feet of low water mark.

The following species are commonly cast up within the Sheltered Rocky Coast Subformation: *Codium spongiosum* Harv., *C. pomoides*, *Cladostephus verticillatus* (Lightf.) Ag., *Halopteris pseudospicata* Sauv., *Sargassum* sp. (small stunted plants), *Cystophora botryocystis* Sonder, *C. grevillei* (Ag.) J. Ag., *C. monilifera* J. Ag., *Amphiroa charoides*, *Dictymenia harveyana* Sonder, *Laurencia* sp.

In Eastern Cove, and probably in Western Cove, at least four distinct associations occur in deep water.

(1) *Posidonia australis*, known as the "sea grass" or "tape weed," forms extensive meadows on a sandy bottom in from 1 to 6 or 7 fathoms of water.

(2) *Scaberia agardhii* Grev. occurs on a rocky bottom in from $\frac{1}{2}$ to 3 or even 5 fathoms below low water.

(3) *Cystophora monilifera* occurs in from 1 to 7 fathoms.

(4) *Chiracanthia arborea* (Harv.) Falk. forms dense masses, especially in winter, in 1 to $2\frac{1}{2}$ fathoms.

The shore in the Bay of Shoals and Western Cove is sandy and muddy, with few rocky areas. Tidal flats, however, are not formed to any extent. This type of habitat is intermediate between the Sheltered Rocky Coast Subformation and the Sand or Sandy-mud Formation, with closer affinities to the latter. Until the area has been more thoroughly investigated, no classification will be attempted.

Along the shore of the Bay of Shoals *Zostera muelleri* is common, and amongst it, on old shells, occurs the green alga *Acetabularia peniculus* R. Br. (probably a winter form). In deeper water *Posidonia australis* is dominant.

Rock Pool Associations.

At Western River and Middle River rock pools are a feature of the coast. They are mostly small, from 1 to 10 feet across and to 2 or 3 feet deep. During summer the temperature in smaller pools (containing *Enteromorpha*) reaches

35° C. The conditions in any pool depend on its size, height above sea level, and general situation; the environment of smaller pools during summer is extreme in both temperature and salinity conditions. Two types of pools occur:

(1) ENTEROMORPHA POOL ASSOCIATION.
This association occurs in the smaller and higher pools where conditions are extreme and very variable. *E. lingulata* J. Ag. and *E. intestinalis* (L.) Link. form a dense fringe around the edge. In summer exposure on the water surface often kills and bleaches the upper plants. The toleration these algae have for high temperatures is shown by their active oxygen liberation under temperatures of 30 - 35° C.

(2) HORMOSIRA - CYSTOPHORA POOL ASSOCIATION.
In larger and lower pools, where waves enter more frequently and temperatures are therefore lower, *Hormosira banksii* forms a dense fringe around the edge, at or just below water level (see pl. xii, fig. 3), while *Cystophora subfarcinata*, *C. polycystidia*, *C. siliquosa*, *C. brownii*, and often *Cystophyllum muricatum* and *Sargassum* sp. grow on the lower sides and bottom.

In many pools along the north coast, particularly those with a sandy bottom, the only algal growth consists of small mats of *Gelidium pusillum* and fragments of *Corallina* and *Jania*.

B. THE SAND AND SANDY-MUD FORMATION

The American River tidal inlet comprises several large lagoons with wide tidal flats and a central channel, opening into Eastern Cove through a narrow neck. Conditions are very calm, particularly on the tidal flats where large beds of *Posidonia* and other weed tend to minimise wave action.

Tidal range is just over 4 feet, decreasing only 2″ or 3″ from American River to Pelican Lagoon (see fig. 2). The fast scouring currents during spring tides, together with the sandy bottom, prevent algal growth in the channel proper. The temperature range on the flats is large, for at low tide less than a foot, and often only 1″ or 2″ of water covers the algae. Winter temperatures reach as low as 10° C., summer up to 32° C. on the flats.

In Pelican Lagoon the tidal flats usually extend out from low cliffs of calcareous sand-rock (similar to the coast at Pennington Bay) (pl. xiii, fig. 2), but sandy beaches are frequent, especially between Muston and American River jetty. South of Muston samphire swamps cover several miles of the shore.

An important characteristic of this formation is the large quantity of moveable sand and mud. The fast tidal currents carry suspended mud, which algae on the flats must be able to tolerate. The characteristic colour of Rhodophyceae at American River is a dirty brown, very different from the red of clean water forms at Pennington Bay.

The basic zonation in Pelican Lagoon is shown in fig. 5. Where a sandy beach occurs, *Hormosira* or *Zostera* comprise the upper zone. Over most of the flats the area colonised by *Hormosira*, *Zostera* and *Posidonia* is much greater than shown in the figure, but the sequence of zones and their positions in relation to tide levels applies generally. Microscopic algae, particularly diatoms, are usually present as epiphytes on the larger algae, but identification has not been attempted.

On Shag Rock (a small island at the entrance of Pelican Lagoon), and probably elsewhere where shag colonies occur, a filamentous form of *Prasiola* covers rocks affected by the bird droppings. This appears to be a winter association only, occurring several feet above high tide level.