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The following species are scattered throughout the sublittoral fringe, varying considerably in abundance in different parts: *Cladophora fascicularis* (Mertens) Kützing, *Chaetomorpha billardieri* (extending down from the lower littoral), *Chaetomorpha valida* (Hooker & Harvey) Kützing, *Codium duthiae* Silva ined., *Caulerpa remotifolia* Sonder, *Caulerpa simpliciuscula* (Turner) C. Agardh var. *vesiculifera* Harvey, *Ectocarpus confervoides*, *Dictyota dichotoma* (Huds.) Lamouroux var. *intricata* (Agardh) Greville, *Stilopsis harveyana* Kylin, *Cystophora cephalornithos* (Labilladiere) J. Agardh, *Cystophyllum muricatum* (Turner) J. Agardh, *Sargassum biforme* Sonder (rare except where currents are strong), *Gelidium pusillum* (growing in coarse tufts), *Corallina* sp. (hemispherical masses to 15 cm across), *Jania natalensis* Harvey, *Gracilaria confervoides* (L.) Greville, *Centroceras clavulatum*, *Polysiphonia fuscescens* Harvey, *Polysiphonia patersonis*, *Chondria dasyphylla* (Woodward) C. Agardh, *Laurencia gracilis* Hooker & Harvey (?), *Laurencia majuscula* (Harvey) Lucas, and *Laurencia tasmanica* Hooker & Harvey.

Several animal groups are represented in the sublittoral fringe. Crustaceans occur in enormous numbers amongst the *Chaetomorpha* mats and other algae. *Brachyodontes crosus* is common, and a purple sponge (2-6 cm high) occurs just below the *Hormosira* zone in the lagoons. Other shells, polychaetes, etc. are common in the mud and under any small stones.

(ii) Lepilaena preissii *Association.*—The brackish-water angiosperm *Lepilaena preissii* (Lehm.) F. Muell. forms a pure and dense association in several isolated parts of the inlet (see Fig. 1). The reasons for its distribution are not clear, but it seems to prefer a muddy substratum between the 1·5 and 0·6 ft levels. Few algae occur with it.

(*d*) *The Sublittoral*

Associations which extend well below lowest tide level, as distinct from those limited just below this level, will be dealt with under the sublittoral zone.

(i) Zostera muelleri *Association.*—*Zostera muelleri* covers large areas of the tidal flats and forms a dense association (see Fig. 1). It occurs as an almost continuous band around the coast except for a few places on either side of Wallaby Point which are either rocky or sandy. Most luxuriant growth occurs between the 1·0 and —4 ft levels, but it may reach —8 ft and often extends into the lower littoral (though it is poorly developed here). Frequently it is mixed with the *Hypnea-Spyridia* association, and sublittoral fringe species such as *Gracilaria confervoides*, *Cystophora cephalornithos*, and *Cystophyllum muricatum* are found in the *Zostera* association in some places. In a few areas (see Fig. 1) *Zostera* occurs nearer the shore than *Hormosira*, owing to lower-lying areas between *Hormosira* and the shore.

Zostera is often free from epiphytes, but more usually has masses of *Cladophora* sp. or *Centroceras clavulatum* growing on the leaves. These masses of epiphytes float on the water surface at low tide if not growing in the deeper parts of the association. Other epiphytes on *Zostera* are *Rivularia polyotis* (Agardh) Bornet & Flahault, diatoms, and minute blue-green algae.

(ii) Posidonia australis *Association.*—*Posidonia australis* forms a dense association in all the deeper parts of the inlet, from the —0·5 ft level downwards. The

long strap-like leaves just project above the surface at low tide in higher parts of the association, giving a very characteristic appearance (Plate 6, Fig. 2; Plate 7, Fig. 1).

On the south side of the channel between Muston and Wallaby Island are extensive beds of *Zostera*, growing in a depth of water in which *Posidonia* is normally dominant. Why *Zostera* is dominant here is not clear. Along most of the channel edge *Posidonia* forms a distinct band, from 1 to 50 yd wide.

Posidonia is remarkable for the wealth of epiphytes growing on the leaves. The commonest ones are: *Polysiphonia succulenta* Harvey, *P. mollis* Hooker & Harvey, *Jania micrarthrodia* Lamouroux (north side of Pelican Lagoon and just outside the inlet especially), *Crouania vestita* Harvey, *Asperococcus bullosus* Lamouroux (best developed in winter), *Colpomenia sinuosa* (Roth) Derbes & Solier, *Laurencia gracilis*, *Rivularia polyotis*, *Centroceras clavulatum*, and *Ceramium miniatum* Suhr. Other less common species are: *Polysiphonia davyae* Reinbold, *Ceramium* spp., *Griffithsia tenuis* Agardh, *Ulva lactuca*, *Enteromorpha clathrata*, *Cladophora fascicularis*, *Ectocarpus* spp., *Sphacelaria furcigera* Kützing, *Rivularia atra* Roth, *Calothrix confervicola* (Roth) Agardh, and *Microdictyon umbilicatum* (Velley) Zanardini.

The reason for this wealth of epiphytes lies in the rough fibrous leaves of *Posidonia*. The other marine angiosperms (*Zostera*, *Halophila*, *Lepilaena*) have much smoother leaves and bear far fewer epiphytes.

In shallower water near the shore *Posidonia* becomes less dense, and here other species may grow amongst it. Often the *Zostera* and *Posidonia* associations merge over several yards, while *Dictyota dichotoma* var. *intricata*, *Cystophyllum muricatum*, and *Cystophora cephalornithos* occur as scattered plants in some areas.

In Pelican Lagoon there are a number of deep holes (2½-3 fm) in shallower areas. These holes bear a dense growth of masses of *Caulerpa remotifolia* on the sides and bottom, while the edges are often muddy with little growth.

(iii) Halophila ovalis *Association.*—*Halophila ovalis* (R.Br.) Hook. f. grows as a fringe in deeper water along the channel, and as small patches in deeper water in the lagoons. On a bank 4-8 ft below mean low tide level, between the flats north of American River jetty and the channel proper, it is pure and dense. More frequently, however, it is mixed up with *Zostera* and *Posidonia*, and may extend as high as the zero tide level.

Epiphytes on *Halophila* are few. Occasionally *Ectocarpus confervoides* and *Ceramium* sp. grow on the leaves.

(iv) *The Flora of the Channel.*—The channel proper supports little algal growth owing to the loose, shelly bottom which must constantly shift with the strong tidal current. Near Muston, however, there are rocky parts in the channel on which grow *Sargassum biforme* (to 1½ m tall) and *Scaberia agardhii* Greville. On some larger shells small plants of *Laurencia forsteri* (Mert.) Greville occur, while just outside the mouth of the inlet *Chiracanthia arborea* (Harvey) Falkenberg and *Polysiphonia fuscescens* are plentiful in 2-3 fm.

Along the edge of the channel near Muston, and probably on rock in the channel, numerous species occur which are rarely found elsewhere in the inlet. Most of them

are Rhodophyceae. Their presence is due to a relatively firm substratum in deeper water, together with the water movement of the tidal current. Many of the species are removed and cast up by boisterous conditions in late winter. They also grow on the deeper flats north of American River jetty, and occasionally along the channel elsewhere (rarely extending to the 0·0 ft level) but most of the drift material near American River jetty after storms seems to come from outside the inlet.

The species concerned are: *Caulerpa hypnoides* (R.Br.) Agardh, *Cutleria multifida* Greville, *Helminthora australis* J. Agardh, *Callophyllis ceratoclada* (J. Agardh) Womersley, *Botryocladia obovata* (Sonder) Kylin, *Champia obsoleta* Harvey, *C. affinis* (Hooker & Harvey) J. Agardh, *C. tasmanica* Harvey, *Lomentaria australis* (Kützing) Levring, *Griffithsia antarctica* Hooker & Harvey, *G. flabelliformis* Harvey, *G. ovalis* Harvey (rare), *Wrangelia protensa* Harvey, *Ceramium rubrum* (Huds.) C. Agardh, *Heterosiphonia gunniana* (Harvey) Falkenberg, *Halodictyon arachnoideum* Harvey, *Hypoglossum spathulatum* (Kützing) J. Agardh, *H. revolutum* (Harvey) J. Agardh, *Nitophyllum* sp., *Sarcomenia dolichocystidea* J. Agardh, *Polysiphonia cancellata* Harvey, *P. fuscescens*, *P. hookeri* Harvey, *P. roeana* Harvey, *Chiracanthia arborea*, *Brongniartella australis* (Agardh) Schmitz, *Lophocladia harveyi* (Kützing) Schmitz, *Coeloclonium opuntioides* (Harvey) J. Agardh, *Chondria dasyphylla*, *Dictymenia harveyana* Sonder, and *Jeannerettia pedicellata* (Harvey) Papenfuss.

Among the animal groups, sting-rays, eagle rays, and other smaller rays are common in the channel. Various kinds of sharks also occur, and starfish are often very plentiful on sandy patches on the edge of the channel. Large yellow sponges occur in the deeper parts of the channel.

(v) *The Flora of the Buoys.*—Two buoys near American River jetty and several outside the mouth of the inlet provide a habitat for some species which are not found elsewhere in the inlet. The rushing water movement around the buoys as the tide ebbs and flows, and the less murky water in the channel, provide conditions rather different from those on the tidal flats.

Common species on the buoys are: *Ulva lactuca*, *Enteromorpha clathrata*, *E. compressa* (L.) Greville, *Cladophora fascicularis*, *Bryopsis minor* Womersley, *Ectocarpus confervoides* (winter), *E. fasciculatus* (Griff.) Harvey, *Colpomenia sinuosa*, *Scytosiphon lomentarius* (Lyngbye) J. Agardh, *Bangia fuscopurpurea* (Dillwyn) Lyngbye (winter), *Acrochaetium* sp., *Gloiosaccion brownii* Harvey, *Champia obsoleta*, *Corynospora australis* Harvey, *Wrangelia plumosa* Harvey, *Dasya naccarioides* Harvey, *Polysiphonia abscissa* Hooker & Harvey, *P. succulenta*, *P. mollis*, *Chondria dasyphylla*, and *Laurencia forsteri*. Less common species are *Callymenia cribrosa* Harvey, *Gloioderma halymenioides* (Harvey) De Toni, and *G. fruticulosum*.

The buoys are cleaned each year, so fast-growing species are more prominent. In winter *Bangia fuscopurpurea* forms a band 1-2 in. high just above the water level, and *Enteromorpha* just at or below water level, while *Scytosiphon* and *Ectocarpus confervoides* are prominent below this. Most of the other species occur on the lower sides or underneath the buoys. During winter a fringe of *Ulothrix pseudoflacca* Wille grows at the water-line on boats which have not been cleaned, with *Enteromorpha* below it.

V. American River Inlet as a Distinct Marine Formation

In the introductory account of the algal ecology of Kangaroo Island (Womersley 1947), reasons were advanced for regarding American River inlet as an algal formation distinct from the rest of the coast of the island. It is perhaps better referred to as a "marine" formation, as angiosperms and animals as well as algae are involved. Following the terminology of Cotton (1912) it was called the "sand and sandy-mud flat formation". The following are regarded as the distinctive features:

(1) The very calm environmental conditions, with wave action at a minimum. This has allowed the development of wide tidal flats of mud or sand, with occasional exposed rock in the littoral zone.

(2) The characteristic flora, of which the main features are the virtual absence of large brown algae in the sublittoral fringe, and the presence of very extensive beds of the marine angiosperms, *Zostera* and *Posidonia*.

The detailed survey of the inlet that has now been made has substantiated the opinions previously expressed, but has shown that there are a few exceptions within the inlet.

The absence of large brown algae (*Cystophora*, *Sargassum*, etc.) in the sublittoral fringe within the inlet is not complete. For instance, *Cystophora polycystidea* dominates the sublittoral fringe over some 300 yd of the north coast of Pelican Lagoon. This alga is a characteristic component of the upper sublittoral on parts of the north coast of Kangaroo Island. The reasons for its occurrence in the inlet are the sharp drop of the cliffs to 3 or 4 ft below low tide level, and a greater degree of wave action due to the prevailing south-west winds passing over some 2 miles of open water, coupled with deeper water close inshore.

This small area of coast is a fragment of the sheltered rocky coast subformation within the inlet, owing to the unusual conditions.

Three other species of larger brown algae occur within the inlet, viz. *Cystophora cephalornithos*, *Cystophyllum muricatum*, and *Sargassum biforme*. These species, however, are never found dominant in the sublittoral fringe, and in general are not common. *Sargassum biforme* is restricted to the channel where water movement is greater, while the *Cystophora* and *Cystophyllum* occur in some areas as scattered plants in the sublittoral fringe and just below. The latter are two of the few species of fucoids which grow well under very calm conditions and where the temperature range is considerable. *Cystophyllum muricatum* also occurs on the much rougher south coast reefs (though as a stunted form), but *Cystophora cephalornithos* is rare outside the inlet.

The development of beds of *Zostera* is restricted to American River inlet (or similar very calm bays) and this seems to be a useful distinguishing characteristic. *Posidonia* beds, however, occur elsewhere around Kangaroo Island, but always in deeper water. The *Posidonia* at the inlet is a broad-leaved form, whereas elsewhere it is mostly a narrow-leaved form (probably a distinct species).

Many other differences between American River inlet and the rest of Kangaroo Island coast are found. Species characteristic of the south coast are rarely found in the inlet, and vice versa, although some species with wide environmental tolerance

occur in both calm and rough localities. In species such as *Hormosira banksii*, distinct ecological forms are largely restricted to the different formations.

Animals also provide points of difference. Barnacles (*Elminius*) are virtually absent from the inlet (except where wave splash is greater, or on jetty piles), whereas they form a conspicuous feature of the upper littoral on the rest of the north coast. Characteristic molluscs of the north coast such as *Melaraphe unifasciata* Gray, *Melanerita melanotragus* Smith, *Cellana tramoserica* Sowerby, and *Siphonaria diemensis* Sowerby are also absent from the inlet but for a very few restricted places.

American River inlet, if considered as a whole, presents many features of its marine ecology which justify its being considered as a distinct marine area. Following Cotton (1912) and others, it can well be termed a "sand and sandy-mud flat formation". The merits of this use of "formation", as against the application by Feldmann (1951) and others of this term to a grouping of associations of similar life form, will not be discussed further here.

Few similar areas of the Australian coastline have been studied from the ecological viewpoint. Guiler (1951) describes Pipe Clay Lagoon, near Hobart in Tasmania. This lagoon shows similarities to American River inlet in the *Arthrocnemum-Salicornia*, *Bembicium melanostoma*, and *Zostera* associations, but differs in the absence of *Posidonia* and apparent lack of many algal species.

Several areas of the South Australian coastline are similar to American River inlet, viz.: on the west coast of Eyre Peninsula, parts of Denial and Smoky Bays, Beard's Bay, Venus Bay, and parts of Coffin Bay; in the gulf region, Proper Bay near Port Lincoln, Franklin Harbour, and many small bays or sheltered areas within Spencer's Gulf and St. Vincent's Gulf. Wherever very calm, sheltered conditions occur, with sandy or muddy tidal flats, the American River inlet ecosystem probably occurs. Apart from the South Australian coasts, such sheltered bays or inlets are less frequent, but parts of King George's Sound in Western Australia, Port Phillip in Victoria, and areas such as Pipe Clay Lagoon in Tasmania may show similarities. Although good accounts are available of exposed parts of the New South Wales coastline (Dakin, Bennett, and Pope 1948), ecological studies on calm areas are lacking.

VI. Acknowledgments

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EXPLANATION OF PLATES 1-7

PLATE 1

Fig. 1.—View over American River inlet at high tide from the south, looking slightly east of north. Pelican Lagoon is on the far right, American River settlement on the upper left, and the head of the inlet in the right foreground.

Fig. 2.—Tidal flats backed by samphires, below which appear: (1) a light-coloured zone of *Bembicium*; (2) a darker grey zone of *Hormosira*; (3) the sublittoral fringe just covered by water, with the edge of a *Posidonia* bed just exposed on the right.

PLATE 2

Fig. 1.—The samphire association of the supralittoral. The larger bushes are *Arthrocnemum arbuscula*, the lower ones *Salicornia australis*.

Fig. 2.—The coast near Salt Lake Point, showing the low cliffs (8-12 ft high) with small shaded caverns and hollows at the base, backing the gently sloping mud flat.

PLATE 3

Fig. 1.—*Bostrychia simpliciuscula* on rocks withdrawn from a shaded hollow of the upper littoral.

Fig. 2.—*Gelidium pusillum* as a dark mat on rock in a part relatively exposed to waves—hence the lower zone of serpulid worm tubes, various limpets (*Siphonaria*), and *Melanerita* which are not characteristic of most of American River inlet.

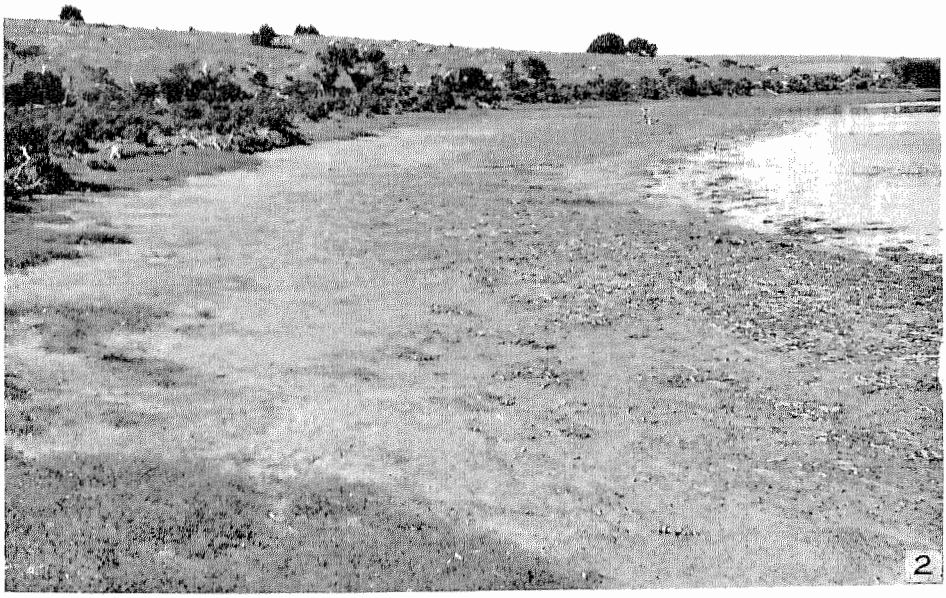
PLATE 4

Fig. 1.—*Bembicium melanostoma* on firm mud in the mid littoral.

Fig. 2.—General view of the *Hormosira* association of the lower littoral, exposed during low tide.

MARINE ALGAE OF KANGAROO ISLAND. IV

1



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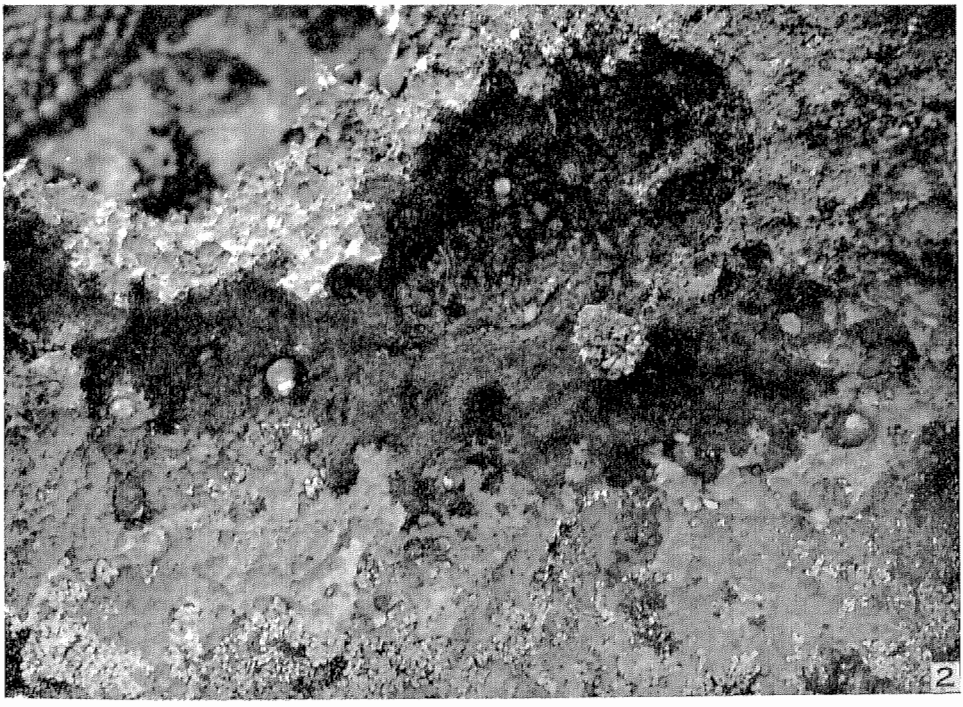
MARINE ALGAE OF KANGAROO ISLAND. IV



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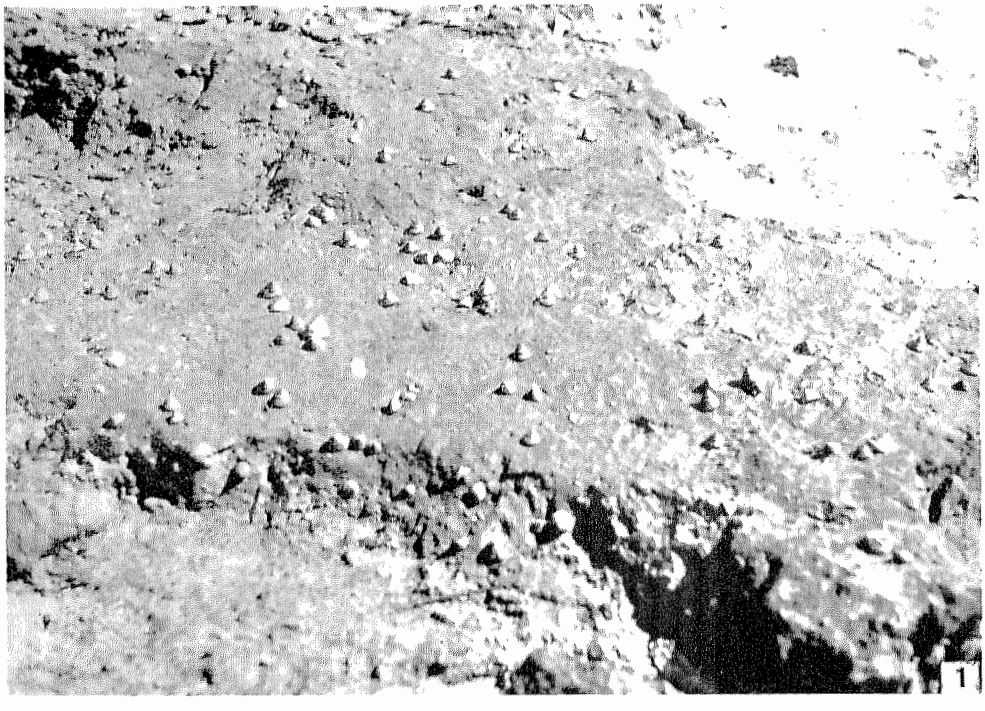

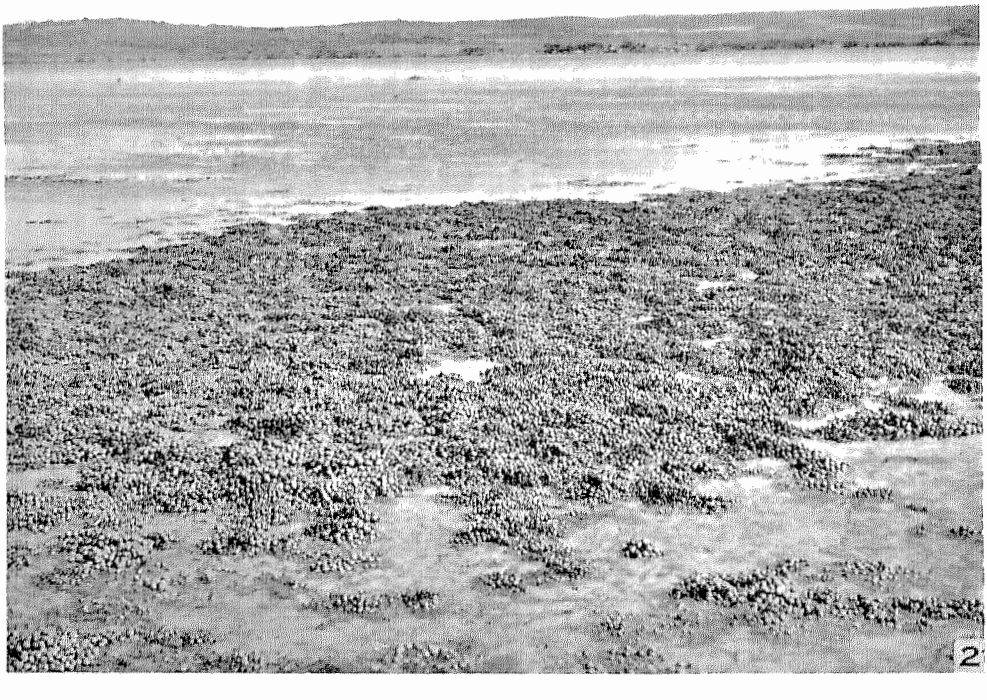

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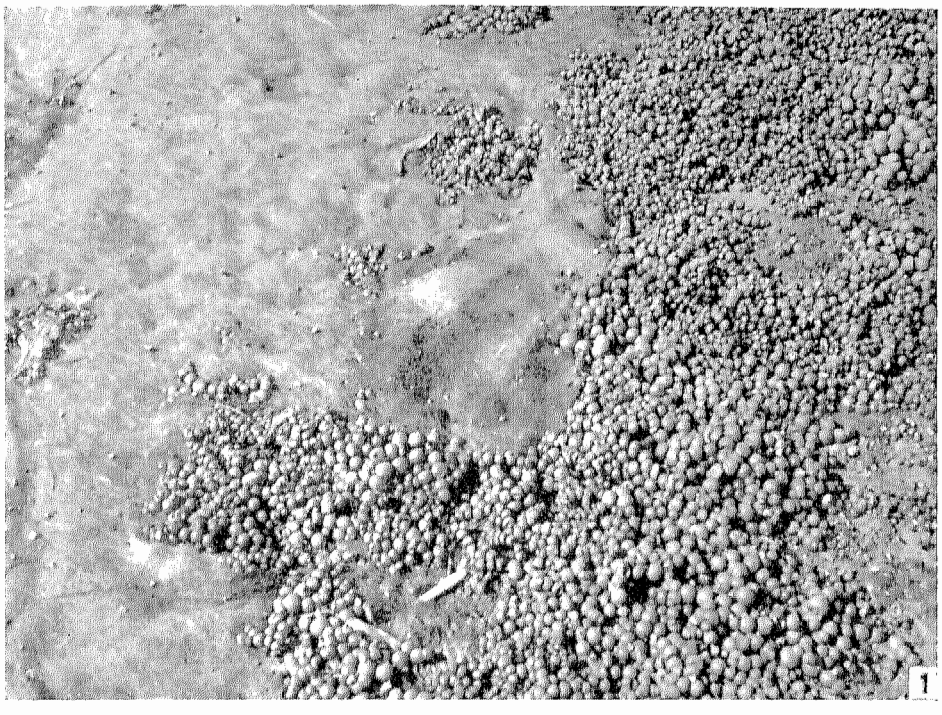

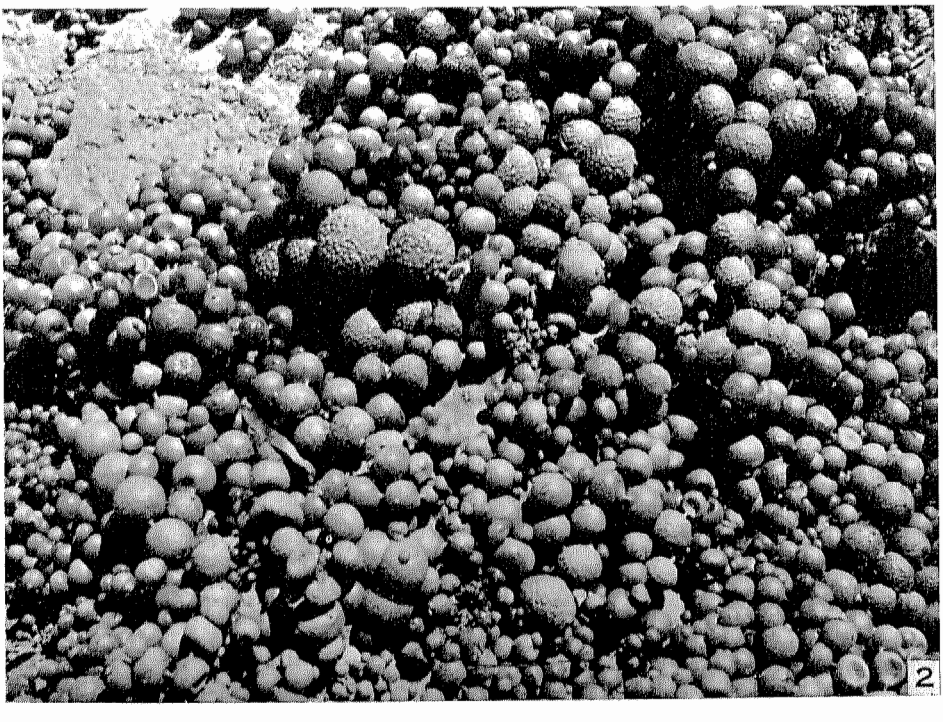

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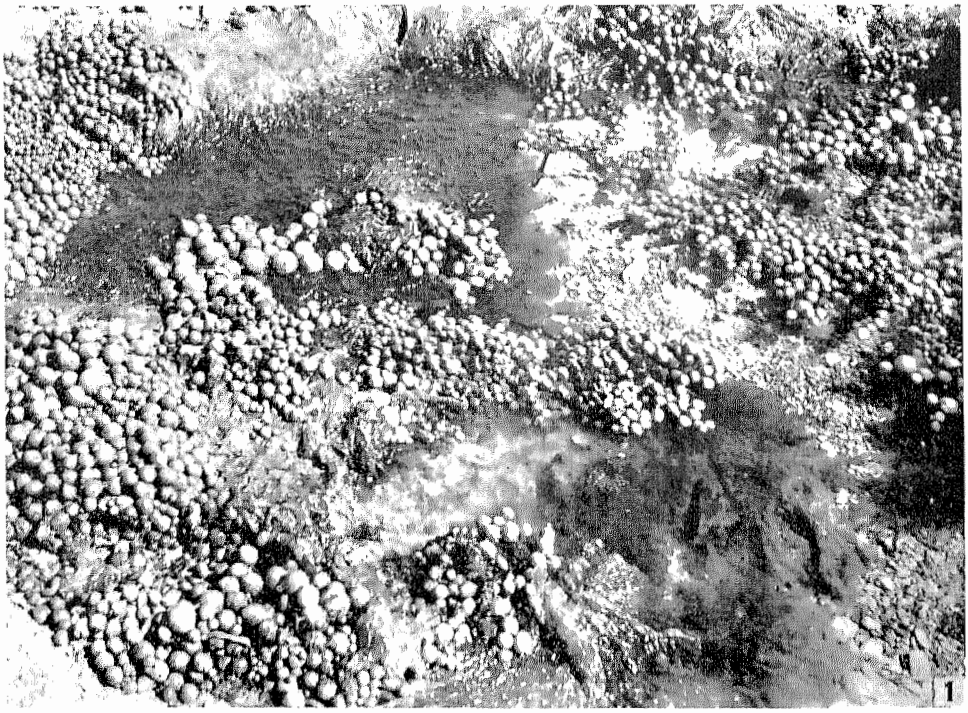

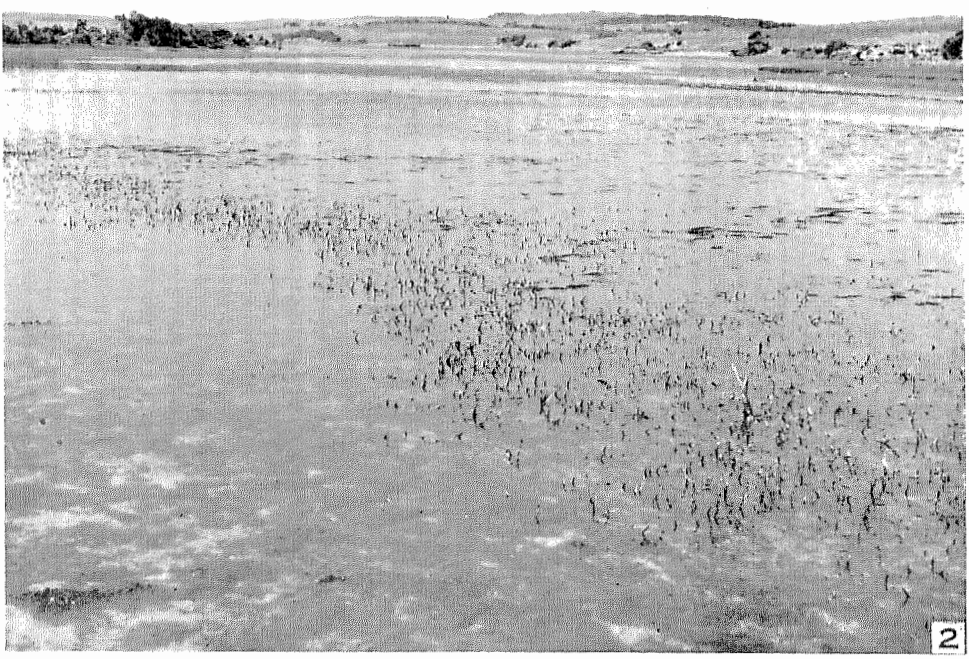

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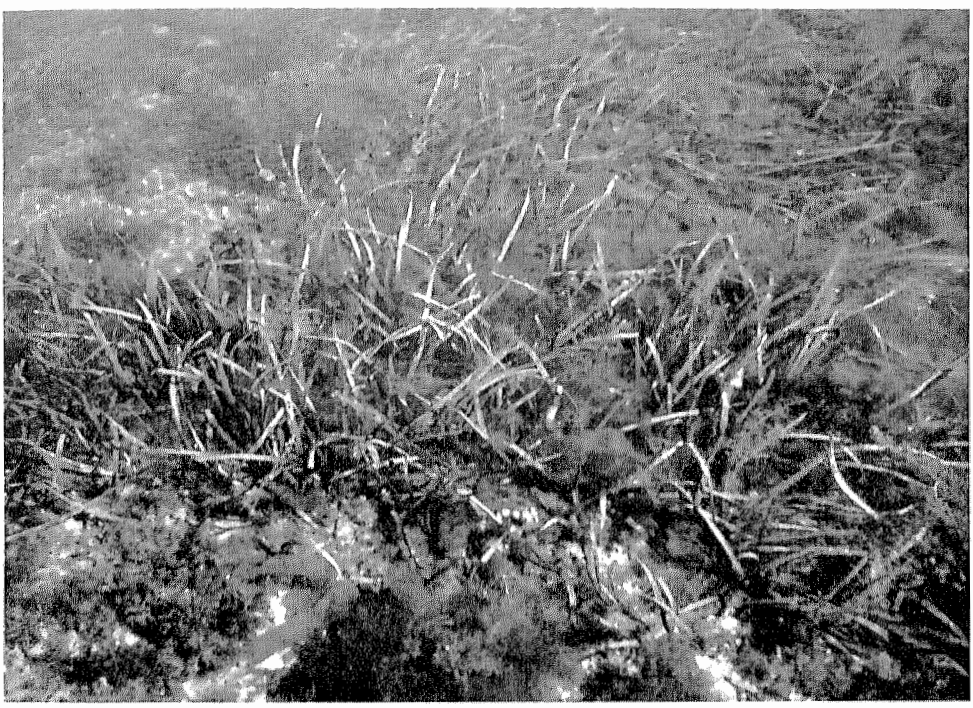

PLATE 5

Fig. 1.—*Hormosira banksii*, with part of an extensive mat of *Chaetomorpha billardieri* on the left.

Fig. 2.—A dense and pure area of *Hormosira banksii* in the lower littoral. The largest bladder is about 2½ cm across, with prominent conceptacles.

PLATE 6

Fig. 1.—Lower parts of the *Hormosira* association, with *Ulva lactuca* in shallow water-retaining depressions or just exposed.

Fig. 2.—A *Posidonia* bed at low tide, with the leaves just projecting above the water surface, and patches of epiphytes floating on the surface.

PLATE 7

Fig. 1.—The edge of a *Posidonia* bed, with various algae of the sublittoral fringe (*Hypnea*, *Laurencia*, *Asperococcus*) in the foreground.