External Copyright permission (if applicable)

In the upper gulfs *Avicennia* is often dominant in the mid littoral (see "upper littoral" above).

Few algae occur in this zone. Mats of *Enteromorpha* are occasionally found, and the blue-green algae, *Isactis plana*, *Rivularia nitida* Agardh, and others may occur though they are not conspicuous.

Lower littoral.—Where the substratum is fairly pure, deep sand, the dominant organisms are the cockles *Katelysia scalarina* (Lamarck) and *K. peronii* (Lamarck), which occur below the surface. They extend down into the sublittoral and commonly bear a plant of *Enteromorpha clathrata*.

If the substratum contains much mud, the razor shell *Pinna dolabrata* Lamarck is dominant (e.g. Outer Harbour and Streaky Bay) (Plate 10, Fig. 2), but if the mud layer is thinner *Brachyodontes erosus* (Lamarck) is common and may form extensive beds (Plate 10, Fig. 1).

Commonly growing on rock, on pebbles, or on *B. erosus* is the fucoid alga *Hormosira banksii* f. *labillardieri*, which frequently dominates and distinguishes the lower littoral zone in calm muddy bays or inlets. At the same level or slightly higher mats of *Chaetomorpha billardieri* Kützing may be common, while stunted fragments of *Corallina* also occur.

In some areas, such as at Outer Harbour and on the Cockle Bank, Eastern Cove, the burrowing anemone *Edwardsia australis* Carlgren is dominant over large areas of the sand flats at a lower littoral level. Where sand and mud are intermixed the polychaete *Arenicola assimilis affinis* Ashworth is common. Yonge (1953) states that in the northern hemisphere the presence of *A. marina* indicates the beginning of the transition from sand to mud. This is also true of *A. assimilis affinis* in South Australia. Along the mud and sand banks of channels in the lower littoral the large polychaete *Eunice tubifex* Crossland may be dominant.

On mud flats where sand is almost absent *Edwardsia* and *Arenicola* do not occur. Three terebellid polychaetes, however, become very common over large areas, *Eupolymia trigonostoma* Schmarda, *Terebella haplochaeta* Ehlers, and *Thelepus plagiostoma* (Schmarda). They occur under dead shells and rock fragments or in the mud itself.

The oyster *Ostrea sinuata* Lamarck is frequently found attached to the shells of *Pinna*. This oyster does not in South Australia form the distinct "oyster zone" of the New South Wales (Dakin, Bennett, and Pope 1948) and Queensland coasts (Endean, Kenny, and Stephenson 1956).

Animals extending from the lower littoral up into the mid littoral

MOLLUSCA: *Austrocochlea zebra* (Menke) (wide-ranging), *Cominella lineolata*, *Zeacumantis diemenensis* Quoy & Gaimard, *Anapella pinguis* (Crossland & Fischer), *Philene angasi* (Crossland), *Mactra pura* Deshayes, *Uber conicum* Lamarck (in sand), *Cardium racketti* Donovan, *Soletellina biradiata* Wood, *Fasciolaria australasia* Perry, *Vicimitra glabra* (Swainson), *Parcanassa pauperata* (Lamarck), *Niotha pyrrhus* Menke, *Ischnochiton lineolatus* (Blainville) (under stones and dead shells), and *I. cariosus* Pilsbry.

CRUSTACEA: *Helice haswellianus* ("mud crab"—mid and upper littoral), *Philyra laevis* (Bell) ("pebble crab"), *Callianassa ceramica* (Fulton & Greville), *Crangon villosus*.

POLYCHAETA (mainly lower littoral and upper sublittoral): *Eunice aphrodite*, *E. australis*, *Lepidasthenia michaelseni* (Augener) (commensal with Eunicidae), *Thormora versicolor*, *Perinereis amblyodonta*, *Glycera americana*, *Chaetopterus variopedatus* Renier, *Branchiomma cingulata* (Grube), *Clymenella insecta* Ehlers, and *Ceratocephalus edmondsi* Hartman.

HOLOTHURIAN: *Leptosynapta dolabifera* (Stimpson), and *Mensamaria thomsoni* (Hutton).

Sublittoral zone

Sublittoral fringe.—Below low tide level plant life is dominant, except in very sandy areas which harbour animals below the surface; the animals found in the lower littoral may occur here.

In muddy areas, growing on pebbles and shells, and sometimes loose-lying, are numerous algae forming a rather mixed zone, dominated by *Hypnea musciformis* (Wulfen) Lamouroux and *Spyridia biannulata* J. Agardh. Other common algae are *Centroceras clavulatum*, *Ulva lactuca*, *Enteromorpha clathrata*, *Cladophora fascicularis* (Metens) Kützing, *Acetabularia peniculus* (R. Brown) Solms-Laubach, and lithothamnia. Others are listed by Womersley (1956, pp. 80–1).

Animals usually found amongst the algae are the echinoderms *Patiriella exigua*, *P. gunnii*, and *Tosia australis*, the isopod *Eudotea peronii*, and small fish of the families Syngnathidae and Blenniidae.

Upper sublittoral.—Here the marine angiosperms *Zostera* and *Posidonia* become dominant and cover wide areas. *Zostera muelleri* extends from the lower littoral downwards. Above low tide level it is short and poorly developed, usually in moister depressions. Below low tide it forms a dense sward, up to 12 in. high, extending downwards for several feet. Owing to the smooth leaves, epiphytes on *Zostera* are few.

Posidonia australis occurs from a foot or so below low tide into several fathoms (about 5–6) of water, forming a dense association. At very low tide the stiff leaves just project above the water, giving a characteristic appearance to the area (Plate 11, Fig. 1). *Posidonia* bears a wealth of epiphytes on its rough leaves (see Womersley 1956, p. 82).

The angiosperm *Halophila ovalis* (R. Brown) Hooker f. is also common in deeper areas (4 ft or more below low tide), particularly on the edges and sides of channels.

Large fucoid algae are virtually absent from the upper sublittoral. Occasionally *Cystophyllum muricatum* and *Cystophora cephalornithos* (Labilliardiere) J. Agardh occur in local tidal currents or under slight wave action. The absence of these fucoid algae, and dominance of *Zostera* and *Posidonia* in the upper sublittoral, are distinguishing features of this type of habitat.

The starfish *Coscinasterias calamaria*, *Uniophora multispina*, and *Petricia vernicina*, the ophiuroids *Placophiothrix spongicola* and *Ophionereis schayeri*, colonial

ascidians (*Austrobotryllus* spp.), and yellow and purple sponges are common in the upper sublittoral.

B. THE SOUTH-EASTERN COAST

The coast from Robe eastwards to the Victorian border consists of calcareous sand-rock cliffs and platforms of Pleistocene to Oligocene Age with interspersed sandy beaches. No outcrops of older rocks are indicated on the geological map of South Australia. Small islands lying a short distance offshore are common.

The topography, substratum, and conditions of wave action are similar to those described in Section IVA(i)(2). Water temperature is, however, somewhat lower, ranging from 13 to 17°C (see Figs. 2(*a*) and 2(*b*)). The coast at Robe has been examined more frequently than the coast further east.

Supralittoral zone

Melaraphe unifasciata is dominant over much of the supralittoral, though on rock exposed to continuous sun the lichens *Lichina confinis* (Plate 11, Fig. 2) and *Verrucaria* become dominant. These lichens are generally more conspicuous on the south-east coast than on the central and west coasts of South Australia. Some specimens of the banded *Melaraphe praetermissa* have been collected, and *Ligia australiensis* is always plentiful. *Calothrix* sp. may be common in some places.

Littoral zone

Upper and mid littoral.—One of the most conspicious features of the south-east coast of South Australia is the almost complete absence of barnacles in the upper and mid littoral zones. Only isolated specimens of *Chthamalus antennatus* and *Chamaesipho columna* have been observed, and no *Catophragmus* where it might have been expected. Barnacles are virtually absent from the jetty piles at Robe and Beachport, a very rare occurrence in South Australia. Bennett and Pope (1953, p. 120) also report a reduction of the barnacle zone along the western shores of Victoria.

Consequently the upper littoral is often a sparsely populated zone, though molluscs from the mid littoral extend up through it. Usually upper and mid littoral zones cannot be distinguished.

Molluscs and *Galeolaria* dominate the mid (and upper) littoral zone, though often less dense than on other coasts (Plate 12, Fig. 1). *Galeolaria caespitosa* occurs only as scattered tubes on the rock. The chief molluscs are *Cellana tramoserica, Patelloida alticostata, Siphonaria diemenensis, S. baconi, Notoacmea septiformis, Austrocochlea adelaidae, A. torri, A. concamerata* (Wood), *Melanerita melanotragus, Subninella undulata, Neothais textiliosa,* and *Bembicium melanostoma.* There is no essential difference between this mollusc population and that of the mid littoral on rock platforms of the central and west coasts of South Australia.

The extensive beds of *Brachyodontes rostratus*, typical of much of the Victorian coast (Bennett and Pope 1953) do not occur at any of the localities studied on the south-east coast of South Australia, except on the foreshore breakwater at Robe. Here *B. rostratus* forms well-developed beds in the mid littoral.

Algae are not prominent in the mid littoral. *Porphyra columbina* Montagne, with some *P. umbilicalis* (L.) J. Agardh, is plentiful in suitable habitats during winter months. *Scytosiphon lomentarius* (Lyngbye) J. Agardh is also a winter species. Patches of *Gelidium pusillum* occur in shaded areas, but blue-green algae are not so conspicuous.

Within Guichen Bay, on the foreshore breakwater, *Enteromorpha* (*compressa?*) and *Ectocarpus confervoides* occur in the upper littoral during winter.

Lower littoral.—The reef surface in the lower littoral is dominated by *Hormosira banksii* (f. *sieberi*) and is very similar to comparable reefs on central and western coasts. The chitons *Poneroplax albida* and *P. costata* are the most prominent animals, though mid littoral molluscs often move down to this zone. On the breakwater near Robe *Corallina* sp. together with tufts of *Centroceras clavulatum* and *Griffithsia* sp. dominate the lower littoral.

Upper sublittoral zone

Pools at the rear of reefs contain many of the species found on other comparable reefs, but a few of cooler-water affinities appear as well—*Myriogloia sciurus* (Harvey) Kuckuck, *Eudesme harveyana* Kylin (these two are winter forms), *Codium fragile* (Suringar) Hariot, *Grateloupia* sp., and *Pleonosporium comatum* (J. Agardh) De Toni. *Cystophora intermedia*, so characteristic of the sublittoral fringe on other coasts of South Australia, is here largely replaced by the giant fucoid *Durvillea* (*Sarcophycus*) *potatorum* Areschoug. *C. intermedia* is sometimes found but is not prominent. In deeper reef pools, with some protection, *Durvillea* disappears and species of *Cystophora* and *Sargassum* become dominant. The species of these two genera are much the same as on coasts to the west.

In deeper water, the kelp *Macrocystis angustifolia* Bory* is often dominant, rising from a few fathoms of water to the surface. It does not occur off the most exposed points, and within Guichen Bay grows just below low tide level (Plate 12, Fig. 2).

The animals of the sublittoral have not been extensively studied. *Haliotis laevigata* and *H. improbula* are amongst the commonest.

V. The Relationships of the South Australian Intertidal Flora and Fauna

(a) *Differences between the South-Eastern and Central-Western Parts of the South Australian Coast*

The south-eastern coast, consisting chiefly of rock platforms subject to strong wave action, differs from similar coasts further west in the following respects:

(1) Barnacles are virtually absent in the upper and mid littoral zones, which are populated mainly by molluscs.

(2) *Porphyra* (mainly *P. columbina*) is prominent in the mid littoral during winter, while it is of sporadic occurrence on coasts further west.

(3) The giant brown algae *Durvillea potatorum* and *Macrocystis angustifolia* are prominent below low water level.

*Incorrectly given by Bennett and Pope (1953) as *M. integrifolia*.

(4) Some algal species are limited to the slightly cooler water of the south-eastern coasts.

The reduction in numbers of barnacles has also been recorded by Bennett and Pope (1953) for western Victorian coasts. Further east in Victoria barnacles reappear. There is no satisfactory explanation as yet for this.

The most important difference is the presence of *Durvillea* and *Macrocystis*, though outlier patches of *Macrocystis* may occur further west (Womersley 1954*a*).

These differences separate the south-east coasts from the rest of South Australia, but they are relatively minor compared with the many features in common.

(*b*) *A Note on Biogeographical Provinces*

The present authors agree with Bennett and Pope and others that the organisms on open coasts are the best indicators of biogeographical provinces, since they are not exposed to the environmental (especially temperature) fluctuations of inhabitants of inlets and estuaries. This does not mean, however, that ecological studies on calmer coasts should be neglected. Comparisons between similar environments are usually justified. It is comparisons between calm inlets and exposed coasts which must be made with caution, since some species can extend their range under sheltered conditions.

This study, as were those of Bennett and Pope (1953) on the Victorian coast, Dakin, Bennett, and Pope (1948) on the New South Wales Coast, and Endean, Kenny, and Stephenson (1956) on the Queensland coast, is based on the ecology and distribution of the common intertidal organisms. In discussing biogeographical provinces it must be remembered that other aspects (such as broader floristic and faunistic relationships, including all organisms, common or rare) are also involved, and should be taken into account. In many animal groups the required data are not yet available.

(*c*) *Ecological Comparison of South Australian Coasts with Coasts Elsewhere*

(i) *Comparison with Victorian Coasts.*—Bennett and Pope (1953) give the only account of the intertidal ecology of Victorian coasts.

Supralittoral zone

This zone is essentially the same in both States, with *Melaraphe unifasciata* and *M. praetermissa* dominant and *Ligia australiensis* common. *M. unifasciata* is the commonest littorinid in South Australia. The lichens *Lichina confinis* and *Verrucaria* occur. No *Nodilittorina* or *Tectarius*, characteristic of the New South Wales and Western Australian coasts respectively, are found in South Australia.

Littoral zone

Upper littoral.—This is essentially a barnacle zone, occupying the same shore levels in both States; *Chthamalus antennatus* and *Chamaesipho columna* are found at least as far west as the head of the Great Australian Bight. An area where barnacles are virtually absent occurs in the south-east of South Australia and in western Victoria. No reason for this is apparent, as all the barnacles (except *Balanus*

nigrescens) occur in Tasmania (Guiler 1955, p. 145). *Eliminius simplex* Darwin and *E. modestus* are found in calmer parts of the South Australian and Tasmanian coasts, and *E. modestus* is recorded by Bennett and Pope from Victoria.

Mid littoral.—The mollusc–*Galeolaria*–blue-green algal zone is a feature of both States. The blue-black mussels *Brachyodontes rostratus* and *Modiolus pulex* are common in South Australia at least as far west as Point Sinclair. They never, however, cover such extensive areas as those in Victoria (Bennett and Pope 1953, Plate 4, Fig. 1), or Tasmania (Guiler 1954, Plate 1, Fig. 1). Seven of the nine bivalves listed by Bennett and Pope occur in South Australia. In rough places the surf barnacle *Catophragmus polymerus* is prominent, extending west at least as far as the head of the Great Australian Bight. In suitable habitats it completely dominates large areas. *Tetraclita purpurascens* extends through Victoria, South Australia, and the south coast of Western Australia.

Most of the gastropods of the exposed South Australian coast extend as far as Sorrento in Victoria, and of 47 species listed for the whole Victorian coast, 29 (62 per cent.) occur in South Australia. Of 11 chitons of the Victorian coast, six occur in South Australia, and *Poneroplax albida* and *P. costata* are the commonest along the exposed coasts of the two States.

Galeoaria caespitosa is prominent as far west as Eucla, but is best developed in sheltered localities. The brown alga *Splachnidium rugosum* is common in suitable habitats in both States, while *Porphyra* in winter is more conspicuous from Robe eastwards.

Lower littoral.—This zone is essentially similar in both States, being occupied by a "coralline mat" or "algal turf" (Bennett and Pope 1953), with *Poneroplax* chitons prominent on bare rock at or just below this level. On very rough areas *Balanus nigrescens* is prominent. On rock platforms at a low littoral level *Hormosira banksii* forms a distinct association, with *Notheia anomala* as its chief epiphyte in exposed localities. The "bare" zone described by Bennett and Pope (1953, p. 121) for Victoria, where chitons are common, is usually covered in South Australia with thin encrusting lithothamnia or other small algae. *Pyura stolonifera* (Heller) is absent in South Australia except on the piles of a few jetties.

Upper sublittoral or sublittoral fringe zone

Here the major difference between the Victorian coast and the central–western parts of the South Australian coast is found. In the latter areas, this zone is dominated by species of *Cystophora*, particularly *C. intermedia* under rough conditions. From Robe eastwards (to Bermagui in New South Wales) and also in Tasmania the giant fucoid *Durvillea* (*Sarcophycus*) *potatorum* is dominant from above low water level down for some feet, in conditions of strong wave action. Under slightly calmer conditions *Cystophora* spp. or *Phyllospora comosa* (Labilliardiere) Agardh become dominant, and *C. intermedia* has been recorded from some parts of the Victorian coast (e.g. Wilson's Promontory). In deeper water the kelp *Macrocystis angustifolia* occurs, the tops of the fronds floating on the surface. *Ecklonia radiata* is of scattered occurrence but fairly common on exposed coasts in both States. Only on sheltered rocky coasts, however, does it become dominant.

Associated algae of this zone are similar in both States. There is, however, a small element of Victorian species which are not found in South Australia (e.g. *Cystophora torulosa* (R. Brown) J. Agardh).

Of the other animal groups listed by Bennett and Pope (1953, pp. 127–34) for Victorian coasts, 13 of 17 echinoderms, 20 of 25 arthropods, 2 of 4 ascidians, and 5 (at least) of 8 polychaetes are known from South Australia. South Australian sponges and Bryozoa are not sufficiently well known to make comparisons.

Bennett and Pope (1953, p. 147) list 16 species of animals which they claim "characterize" the cool temperate region (i.e. the Victorian and Tasmanian coasts). Of these, 10 are well known in South Australia, viz. *Melaraphe praetermissa*, *Lepsiella vinosa*, *Cominella lineolata*, *Siphonaria diemenensis*, *Tosia australis*, *Nectria ocellata*, *Patiriella brevispina*, *Mensamaria thomsoni*, *Brachynotus octodentatus* (Milne Edwards), and *Lomis hirta* (Milne Edwards), and an eleventh, *Austropromia polypora* (Clark), which they state is "rarer", is recorded by Clark (1946, p. 114) as extending from Tasmania to Rottnest I.

Of some 93 algae listed by Bennett and Pope for the Victorian intertidal zone, 15 are unidentified and nine are from the "wrack". It is likely that further collecting would show many algal species to be present where not recorded by Bennett and Pope. Of the 78 named algae, 10 are cosmopolitan, 53 are widely distributed along southern Australia and Tasmania, and 15 are limited to Victorian and Tasmanian coasts or the eastern part of South Australia. Thus 63 of 78 species are common to both States. This does not support the view that Victorian coasts should be separated as a distinct province from South Australian coasts.

(ii) *Comparison with Tasmanian Coasts.*—Bennett and Pope (1953) considered that most of the Tasmanian coastline is allied to the Victorian, with the probability of a "truly cool-temperate region" in southern Tasmania. The south-eastern Tasmanian chitons were considered by Iredale and May (1916) sufficiently distinct from those of the north coast to designate the east coast of Tasmania as the Maugean Region (Province). The north coast chiton fauna was considered to be "practically pure Adelaidean, but with a slight Tasmanian element". Bennett and Pope (p. 153), however, believe that these differences were a "mere accentuation of the differences . . . already evident on the Victorian coast", and they extend the Maugean Province to include the whole coast of Tasmania and that of Victoria. Guiler (1952*b*, 1954) supports this view of the close affinities between Tasmanian and Victorian coasts. He points out, however, that *Balanus nigrescens* is absent in Tasmania (Guiler 1955).

Ashby (1926) recognized a "Tasmanian region" on the basis of chiton distribution, since there are a "sufficient number of species that are peculiar to Tasmania".

The accounts of Guiler and of Cribb (1954), and algal collections of Miss I. Bennett from a number of exposed localities around northern Tasmania (determined by H. B. S. Womersley) show that apart from *Lessonia corrugata* Lucas, *Xiphophora gladiata* (Labilliardiere) Montagne (=*billardieri*) and *Adenocystis utricularis* (Bory) Skottsberg the prominent algae of the intertidal zone are very similar to those of Victoria, and the majority of them are also found on South Australian coasts.

Guiler (1954) lists common intertidal animal species of the Tasmanian coast. Of 65 listed for the north coast, 43 are well known in South Australia; for the west coast, 39 of 55; for the south coast, 90 of 147; and for the east coast, 73 of 122.

(iii) *Comparison with the South Coast of Western Australia.*—Little information is available on the intertidal region of the Western Australian coast. The following brief notes are based largely on a survey of the south coast made by Miss E. Wollaston, Department of Botany, University of Adelaide, during January–February 1957. Macpherson (1954) gives a list of the molluscs of the Recherche Archipelago, and certain mollusc records have been made available by Mr. B. C. Cotton of the South Australian Museum. Mrs. L. Marsh, Department of Zoology, University of Western Australia, has also confirmed distribution records along this coast.

The present authors are in no way attempting here to give an account of the intertidal organisms of the south coast of Western Australia. A few important differences only from South Australian coasts will be mentioned.

Little information is available on the coast between Eucla and Israelite Bay, a distance of over 300 miles. The Admiralty Chart and Vol. 1 of the "Australia Pilot" indicate that this coast probably consists of long stretches of sandy beach, with only isolated rocky outcrops except, perhaps, between Eyre and Point Culver.

From near Israelite Bay westwards, granitic points and outcrops occur, with interspersed areas of Tertiary limestone giving intertidal platforms similar to the calcareous sand-rock platforms in South Australia.

Supralittoral zone

Melaraphe unifasciata and *M. praetermissa* are well known on the south and south-west coasts, and blue-green algae (*Calothrix*) are a feature of the high supralittoral on granite points. *Tectarius rugosus* (Menke) occurs at Cape Leeuwin and at Albany, but was not collected at Esperance. The supralittoral thus differs from that in South Australia in the presence of *Tectarius* in the far west.

Littoral zone

A striking difference from South Australian coasts appears to be the absence of barnacles in the upper and mid littoral zones. No *Chthamalus*, *Chamaesipho*, or *Catophragmus* were seen by Miss Wollaston anywhere on the south coast, though in the lower littoral *Balanus nigrescens* is often prominent and *Tetraclita purpurascens* occurs in its normal habitat. The mussel *Brachyodontes rostratus* is also apparently absent. Macpherson (1954) remarks on the absence of this bivalve from the Recherche Archipelago.

Many of the South Australian mid-littoral molluscs occur in the west. The following were collected at Esperance: *Siphonaria baconi*, *Notoacmea septiformis*, *Patelloida alticostata*, *Bembicium melanostoma*, *Melanerita melanotragus*, *Austrocochlea concamerata*, *A. adelaidae*, *A. zebra*, *A. torri*, *A. rudis*, and *Subninella torquata*. Notable absentees were *Cellana tramoserica*, *Neothais textiliosa*, and *Siphonaria diemenensis*, while species found only in Western Australia include *Dicathais aegrota* (Reeve) and *Siphonaria luzonica*.

Of some 159 species listed by Macpherson (1954) for the Recherche Archipelago, 113 occur in South Australia.

Galeolaria caespitosa occurs along the south coast of Western Australia, but apparently disappears somewhere north of Dunsborough (near Cape Naturaliste) on the west coast.

The lower littoral is similar to the corresponding zone in South Australia, the most noteworthy change being the disappearance of *Hormosira banksii* west of Albany. *Poneroplax albida* and the Western Australian *Clavarizona hirtosa* (Blainville) were the main chitons collected at Esperance.

Upper sublittoral zone

This zone is little known on the south coast of Western Australia. Unfortunately unfavourable conditions in many places prevented its examination by Miss Wollaston. The general aspect—dominance by *Cystophora* species, *Ecklonia radiata*, and *Scytothalia dorycarpa*—appears to be very similar to South Australian coasts, though *C. intermedia* was not observed. Species of *Sargassum* become more prominent on the west coast.

An account by Smith (1952) describes the algal ecology of the Cockburn Sound–Rottnest I. area on the west coast of Western Australia. The reefs in this area show many similarities to the calcareous sand-rock reefs of exposed South Australian coasts, and their algal ecology is also similar. Higher sea temperatures are evident from the slight subtropical element—the greater importance of lithothamnia and of *Sargassum*, and the presence of species such as *Caulerpa racemosa* (Forskål) J. Agardh (f. *cylindracea* (Sonder) Weber van Bosse), *Halimeda cuneata* (=*macroloba* Harvey), and *Penicillus nodulosus* (Lamouroux) Blainville. *Cystophora* is much less important and is largely replaced by species of *Sargassum*. The great similarity in the algal flora, however, is shown in that of some 196 species listed by Smith, about 155 are also found in South Australia.

It is clear that although the south and south-west coasts of Western Australia show many similarities with those in South Australia, distinct changes appear passing west from Esperance. These changes involve the fauna to a greater extent than the flora. Particularly noteworthy are the presence of *Tectarius* in the supralittoral, the absence of barnacles in the mid and upper littoral, and the absence of *Brachyodontes rostratus* and the replacement of several prominent gastropods in the mid littoral. The disappearance of *Hormosira* west of Albany and the gradual decrease in dominance of *Cystophora* spp. up the west coast are the most noteworthy floristic features.

(*d*) *Floristic Comparisons along Southern Australia*

An analysis* of the marine algal flora of southern Australia shows that of some 1010 species of green, brown, and red algae considered, 8 per cent. are cosmopolitan, 32 per cent. range along southern Australia (including Tasmania), 42 per cent. are of eastern affinity (South Australia eastwards), and 16 per cent. are of western affinity, not reaching Victoria. A very few species are known only from the central parts of the southern Australian coast. The eastern group (42 per cent.) may be subdivided into those extending through most of South Australia (about 25 per cent.) and those confined to Victoria and Tasmania (about 17 per cent.).

*Full data to be published elsewhere by H. B. S. Womersley.

A preliminary analysis of the Kangaroo I. algal flora shows that of 482 named species 78 per cent. occur on Victorian coasts, 54 per cent. in Tasmania, and 56 per cent. in Western Australia. Only 22 per cent. of the Kangaroo I. algae occur in New South Wales (compared with 24 per cent. in New Zealand).

Two genera which have been studied recently show similar distributions. In *Sargassum*, subgenus *Phyllotrichia* (Womersley 1954*b*), all five southern species range along southern Australia and Tasmania. Of 14 southern Australian species of *Codium* (Silva and Womersley 1956), 11 range through South Australia and Victoria, 7 of these extending also to Tasmania. Four species occur all along southern Australia and in Tasmania, and 7 along southern Australia but not in Tasmania.

These data indicate that a large proportion of algal species range along southern Australia, with a very considerable eastern element and smaller western element. Of the eastern element, a high proportion is common to South Australia, Victoria, and Tasmania, while a smaller proportion is limited to Victoria or Tasmania, or both.

VI. Discussion and Conclusions

Endean, Kenny and Stephenson (1956) have shown the distinct change from the north Queensland tropical Solanderian Province to the south Queensland and New South Wales warm temperate Peronian Province at about lat. 25° S. Bennett and Pope (1953) have given convincing evidence of a distinct change from the Peronian to a cool temperate province on the extreme east coast of Victoria. They have also shown the similarities of the Victorian and Tasmanian intertidal zonation and organisms. The Victorian and Tasmanian coasts they class as a cool temperate Maugean Province. They further compare this province with the Flindersian to the west, including the South Australian and southern Western Australian coasts. The latter comparisons were made when little information was available about South Australian coasts. In the light of evidence now at hand some of Bennett and Pope's conclusions need modification.

In describing the marine provinces of the Australian coastline it is desirable that they should be of much the same importance, i.e. the differences between them should be of similar magnitude. Endean, Kenny, and Stephenson (1956, Fig. 13) have shown clearly the great changes on the Queensland coast between lats. 25° and 26° S. Here the percentage of southern species changes from nearly 60 per cent. to 20 per cent. and of northern species from just over 10 per cent. to nearly 60 per cent. This, with major changes in the dominant intertidal organisms, shows that the tropical Solanderian and warm temperature Peronian differ markedly.

The differences between the Peronian and Victorian shores are clearly of similar magnitude. It will be evident from the present account, however, that the differences between the Victorian (and Tasmanian) coasts—the Maugean Province of Bennett and Pope—and the South Australian coast (Flindersian as restricted by Bennett and Pope) are of much smaller magnitude. The evidence for this will be further discussed below.

Certain organisms have come to be regarded, often from a world viewpoint, as "warm temperate" and others as "cool temperate". While it may be comparatively

easy to separate tropical, temperate, and arctic or antarctic species, the separation of warm and cool temperate species is not always easy. The kelps—Laminariales—are regarded (e.g. Stephenson 1947, p. 227) as indicators of the cool temperate regions, and are largely absent in warm temperate regions. In the Antarctic Ocean, extending to New Zealand, southernmost Australia, and South America, *Macrocystis* is the most prominent kelp, and in addition a "kelp-like" alga, the giant Fucales genus *Durvillea* (including *Sarcophycus*) has become dominant in the upper sublittoral or lower littoral regions.* *Macrocystis* and *Durvillea* were accepted by Bennett and Pope as indicators of cool temperate conditions, and this is fully justified.

The position along southern Australia is complicated by the high degree of endemism in the algal flora. Many genera, large and small, or groups of species have evolved here and are found nowhere else. The Fucales are a noteworthy case, with genera such as *Cystophora* (about 25 species), *Hormosira*, subgenus *Arthrophycus* of *Sargassum*, and several other small genera. Species of *Cystophora* reach 6 ft in length. It is difficult to say whether such genera should be classed as warm or cool temperate, but with *Durvillea* accepted as a cool temperate alga caution is needed in excluding other Fucales from "cool temperate" when their range coincides in part with that of *Durvillea*. *Phyllospora comosa* is characteristic of the New South Wales coast and (though less prominent) of the Victorian and Tasmanian coasts, but not of the central–west coasts of South Australia. In this case, factors other than temperature must control its distribution.

Of the three Australian kelps (Laminariales), *Macrocystis* is limited to the Tasmanian, Victorian, and eastern South Australian coasts (with a different species in southern and eastern Tasmania from that on the mainland). *Ecklonia radiata* is widely distributed along southern Australia and Tasmania but is more prominent on the New South Wales coast. It is not, however, "a dominant infra-littoral alga . . . in the Flindersian province" (Bennett and Pope 1953, p. 146), but at least on exposed coasts is of minor importance as in Victoria. *Lessonia corrugata* is limited to Tasmanian coasts.

It is now clear that the South Australian, Victorian, and Tasmanian coasts show many similarities; they differ mainly in the presence of *Durvillea* and *Macrocystis* in the slightly colder waters of eastern South Australia, Victoria, and Tasmania. Other cooler-water algae appear in the east, especially in Tasmania, where the mussel *Mytilus planulatus* also becomes more important in sheltered habitats. Our contention is that the coastline of the three States should be grouped as a single province, with the coast east of Robe in South Australia classed as a subprovince. Bennett and Pope (1953, p. 152–3) suggest that Victorian and Tasmanian coasts are very similar, and Guiler (1954, p. 110) supports this. These authors consider that this extended "Maugean" province (first applied to the south and east coasts of Tasmania) is a cool temperate region.

We would suggest then: (i) that the Flindersian Province, which was originally based on the fauna in the vicinity of Adelaide (Hedley 1904; Cotton 1930), extends throughout South Australia, Victoria, and Tasmania; (ii) that eastern South

*In Australia, *Durvillea potatorum* is essentially a sublittoral alga, but in New Zealand (and other subantarctic countries) *D. antarctica* (and *D. willana*) are lower littoral species.

Australia, Victoria, and Tasmania comprise the Maugean subprovince within the Flindersian. The Flindersian Province is of cool temperate affinities, distinctly so in southern Tasmania, grading to an area on the central and west coasts of South Australia which is perhaps best considered as having affinities intermediate between cold temperate and warm temperate regions.

The Flindersian Province has usually been considered to extend around south-west Western Australia as far as Geraldton, intergrading with the tropical Dampierian Province on the west coast (cf. Bennett and Pope 1953, Fig. 5).

Ashby (1924) on the basis of chiton distribution modified the provinces first described by Hedley (1904) by suppressing the Solanderian within the Dampierian, extending the Peronian northwards to Great Sandy I., and introducing an "Indo-Australian region extending from the Abrolhos Islands around south-west Australia into the Great Australian Bight". This overlapped with the Adelaidean (=Flindersian), which extended from Bass Strait as far as Cape Naturaliste. These last two regions represented in Ashby's view two distinct currents, the warm Indian Ocean surface current and the cold western current below, both flowing eastwards along southern Australia (Halligan 1921).

The Indo-Australian region includes the coast where a grading from the typical Adelaidean (Flindersian) to the tropical Dampierian occurs, including the Baudinian region of Kott (1952). The surface warm current and deeper cold current along southern Australia (Halligan 1921) are not stressed by later authors, but the slight spread of warmer-water species around south-west Western Australia may be associated with this warm surface current. Similarly, the reported deeper cold water current passing northward up the Western Australian coast may be the cause of the extension of many typical Flindersian species as far north as the Abrolhos (Hedley 1904; Verco 1912).

Kott (1952) proposed a new zoogeographical province, the Baudinian, to describe the ascidian fauna of the south-west corner of Western Australia (from Perth to Albany). It is very doubtful if the algal distribution would support the recognition of a distinct province here, comparable in status with the other recognized provinces of the Australian coast.

Passing west from South Australia, differences are evident at Esperance in Western Australia (and probably from the first rocky coast some distance east of Israelite Bay). Here *Tectarius rugosus* appears in the supralittoral, barnacles are absent from the mid and upper littoral zones, and *Brachyodontes rostratus* is apparently absent from the mid littoral. Other species disappear gradually around the south-west corner of Western Australia. *Hormosira* is not found west of Albany, *Galeolaria* disappears somewhere north of Cape Naturaliste, and some molluscs are gradually replaced. Near Rottnest I. a tropical influence is appearing, shown by the presence of the algae *Halimeda* and *Penicillus*, and zoanthids, corals, and alcyonarians. The genus *Cystophora* is much less important at Rottnest I. but *C. uvifera* extends as far north as the Abrolhos Is.

Bennett and Pope (1953, pp. 144–6) consider that the New South Wales warm temperate Peronian and their restricted Flindersian (South Australia and south coast of Western Australia) show many similarities. On South Australian coasts,

however, the differences are greater than the similarities. Bennett and Pope (1953, p.144) list six characteristic warm temperate (Peronian) echinoderms, of which two (*Heliocidaris erythrogramma* and *Patiriella gunnii*) are found in South Australia. The first of these is widespread in temperate Australian waters, being an upper sublittoral species in South Australia. Their "typical" Peronian barnacles *Tetraclita rosea* and *Balanus imperator* are not found in South Australia, *Pyura stolonifera* is absent on rocky coasts, and the molluscs show considerable differences. *Tectarius rugosus* and *Clavarizona hirtosa* are not found on South Australian coasts, but appear on the south coast of Western Australia.

The algal differences between New South Wales and South Australian coasts are very considerable, partly because New South Wales is largely outside the southern Australian region of strong algal endemism. The few prominent species in common are widely ranging forms (e.g. *Ecklonia radiata*, *Hormosira banksii*) or ones such as *Phyllospora comosa*, the distribution of which is governed by factors other than temperature. A preliminary analysis of the Kangaroo I. algal flora showed that ony 22 per cent. of the 483 species considered occurred in New South Wales, compared with 78 per cent. in Victoria, 54 per cent. in Tasmania, and 24 per cent. in New Zealand. Any "resemblance between the algal floras of New South Wales and the southern coast of the continent in South Australia" (Bennett and Pope 1953, p. 140, based on Newton and Cribb 1951) does not stand up to detailed analysis.

Sea temperatures support the recognition of one biogeographical province along southern Australia, including Victoria and Tasmania. Figures 2(*a*) and 2(*b*) show mean sea temperatures around Australia during February and August. The whole southern coast of Australia is subject to similar temperatures, 17–20°C in February (summer) and 12–15°C in winter. The waters around Victoria are only about 2°C lower than those in the Great Australian Bight, and those in Tasmania 1–2°C lower again. Such a difference is not usually sufficient to cause a marked change in the flora and fauna (a 5°C difference is usually associated with major changes). Bennett and Pope seem to have unduly emphasized the temperature difference between the waters in Bass Strait and off Kangaroo I. This difference does, however, fit in well with the observed "subprovincial" changes in the intertidal fauna and flora.

Passing from southern Australia up the west and east coast, marked increases of temperature occur. In summer, sea temperatures north of Cape Naturaliste and off the Victorian–New South Wales border are higher than sea temperatures on open coast along southern Australia (except within Spencer and St. Vincent Gulfs). In winter, the sea from about Albany around the south-west corner of Western Australia and from about a quarter of the way up the New South Wales coast is subject to higher temperatures than southern Australian waters.

In conclusion, then, the distribution of algae and animals, the intertidal ecology, and the sea temperatures support the recognition of one geographical province, the Flindersian, along southern Australia. This province grades from the Dampierian of north-west Australia around the south-west corner of Western Australia and includes South Australia, Victoria, and Tasmania. The coast from Robe in South Australia around Victoria and Tasmania forms a subprovince, the Maugean, within the Flindersian. This changes to the warm temperate Peronian on the easternmost

shores of Victoria and in New South Wales, while in the west a gradual transition commences on the rocky coast near Esperance. The large stretches of sandy beach between Eucla and Israelite Bay may provide sufficient barrier between South Australian and Western Australian rocky coasts to account for this change, which would not be expected on sea temperature alone.

VII. Acknowledgments

For identifications of animals the authors are indebted to the following: Mr. B. C. Cotton (South Australian Museum) and Miss Hope Macpherson (National Museum of Victoria)—Mollusca; Miss Elizabeth Pope (Australian Museum, Sydney)—Cirripedia; Mr. H. M. Hale (South Australian Museum)—Crustacea; Dr. Olga Hartman (University of Southern California)— Polychaeta; and the late Prof. O. Carlgren (Lund)—Actiniaria. They are also indebted to Mrs. P. M. Thomas (University of Adelaide) for suggestions and information, and to Mrs. L. M. Marsh (University of Western Australia) for information about the fauna of Western Australia.

Thanks are due to Professor J. G. Wood for critically reading the manuscript.

VIII. References

Ashby, E. (1924).—The regional distribution of Australian chitons (Polyplacophora). *Rep. Aust. Ass. Adv. Sci.* **17**: 366–93.

Australia, Bureau of Meteorology (1950).—"Climatic Averages of Australia." (Bur. Met. Aust.: Melbourne.)

Bennett, Isobel, and Pope, Elizabeth C., (1953).—Intertidal zonation of the exposed rocky shores of Victoria, together with a rearrangement of the biogeographical provinces of temperate Australian shores. *Aust. J. Mar. Freshw. Res.* **4**: 105–59.

Chapman, R. W. (1924).—The tides of the South Australian coast. Handb. 17th Mtg. Aust. Ass. Adv. Sci., Adelaide, pp. 18–19.

Chapman, V. J., and Trevarthen, C. B. (1953).—General schemes of classification in relation to marine coastal zonation. *J. Ecol.* **41**: 198–204.

Chapman, V. J. (1950).—The marine algae of New Zealand. Part I. Myxophyceae and Chlorophyceae. *J. Linn. Soc. (Bot.)* **55**: 333–501.

Cotton, A. D. (1912).—Clare Island survey. Marine algae. *Proc. R. Irish Acad.* **31**: 1–178.

Cotton, B. C. (1930).—Fissurellidae from the "Flindersian" region, southern Australia. *Rec. S. Aust. Mus.* **4**: 219–22.

Council for Scientific and Industrial Research (1944).—18th Ann. Rep. Chap. 9, p. 46.

Cribb, A. B. (1954).—The algal vegetation of Port Arthur, Tasmania. *Pap. Roy. Soc. Tasm.* **88**: 1–44.

Dahl, E. (1953).—Some aspects of the ecology and fauna on sandy beaches. *Oikos* **4**: 1–27.

Dakin, W. J., Bennett, Isobel, and Pope, Elizabeth C. (1948).—A study of certain aspects of the ecology of the intertidal zone of the New South Wales coast. *Aust. J. Sci. Res.* B **1**: 176–230.

Edmonds, S. J. (1948).—The commoner species of animals and their distribution on an intertidal platform at Pennington Bay, Kangaroo Island, South Australia. *Trans. Roy. Soc. S. Aust.* **72**: 167–77.

Endean, R., Kenny, R., and Stephenson, W. (1956).—The ecology and distribution of intertidal organisms on the rocky shores of the Queensland mainland. *Aust. J. Mar. Freshw. Res.* **7**: 88-146.

Fairbridge, R. W. (1950).—The geology and geomorphology of Point Peron, Western Australia. *J. Roy. Soc. W. Aust.* **34**: 35–72.

Feldmann, J. (1951).—"Manual of Phycology." (Ed. G. M. Smith.) Chap. 16. (Chronica Botanica: Waltham, Mass.)