

**COMMONWEALTH OF AUSTRALIA**

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region is that of sub-antarctic shores in that algae are dominant throughout the littoral all the year.

#### SOUTHERN HEMISPHERE COMPARISONS

Here the zonation on Australasian coasts will be briefly compared with that on South African, South American and sub-antarctic coasts.

The supralittoral, as in most other parts of the world, is populated largely by littorinid snails. In Australasia they belong to the genus *Melaraphe* (*Tectarius* and *Nodilittorina* on warmer coasts) but in South Africa to *Littorina*, as in the northern hemisphere generally.

The upper littoral is typically a barnacle zone on most coasts, with few if any algae except *Porphyra* (usually seasonal except under cold conditions). The mid-littoral varies from a barnacle zone to a mollusc (often mainly limpet) zone, in which serpulid worms are nearly always a prominent feature. Mussels are conspicuous in cold temperate Australasia, often forming a black band, but this is apparently not so in South Africa. Oysters are prominent in the mid-littoral on sub-tropical and sheltered warm temperate Australian coasts, and in harbours and inlets in New Zealand, but are not a feature of South African coasts. In the latter country zoanthids are important under sub-tropical conditions. The lower littoral is typically an algal zone. In Australasia coralline algae are prominent here, often associated with *Hormosira* and also larger Fucales (*Durvillea* etc.) in New Zealand. Fucales are not conspicuous in the South African lower littoral (except *Bifurcaria* on the cold temperate west coast), but other algae are dominant. *Hypnea spicifera* is noteworthy on the east (sub-tropical) coast.

There is much greater algal growth, both in bulk and in species, in the lower littoral on rough New Zealand coasts than on Australian coasts, and algal growth appears to be more prominent throughout the littoral on South African coasts (especially the west coast) than in Australia.

The upper sub-littoral shows the most distinct similarities and differences between temperate southern hemisphere countries. On cold temperate coasts this zone is dominated by large brown algae, of which the Laminariales are usually present. The differences between southern Australia and New Zealand have been previously discussed, and the account of Skottsberg (1941) shows that sub-antarctic South America is similar to New Zealand. Skottsberg classes the *Durvillea antarctica* zone as lower littoral, changing to the upper littoral domi-

nated by *Lessonia nigrescens*, with *Macrocystis pyrifera* in deeper water. *Durvillea barveyi*, however, grows below *D. antarctica* and is placed in the upper sub-littoral by Skottsberg; it is therefore comparable to *D. potatorum* in habitat. In cold temperate South Africa *Durvillea* does not occur, and Laminariales are exclusive dominants of the upper sub-littoral. *Ecklonia buccinalis* and *Laminaria pallida*, together with *Ecklonia radiata* and *Macrocystis angustifolia*, are of importance.

The distribution of the genera of Laminariales in the southern hemisphere is of interest. The South African species of *Laminaria* is the only southern hemisphere representative of this northern genus. *Ecklonia* is known from South Africa and Australasia, with one species (*E. radiata*) in common. *Lessonia* is of greatest importance in South America, but single species are known from both New Zealand and Tasmania. *Macrocystis* is a circum sub-antarctic genus (Womersley, 1954a) with *M. pyrifera* distributed in this manner, a second species *M. integrifolia* on the west coast of South America, and a third species, *M. angustifolia*, in southern Australia and South Africa.

On warm temperate coasts the large brown algae are usually replaced by smaller forms, and animals such as sessile *Pyura*s become dominant in the sub-littoral fringe or just above (e.g., South African south coast, New South Wales). In New South Wales, however, the Fucales genus *Phyllospora* (to 8 ft. long) is dominant on exposed coasts, and *Ecklonia* under less rough conditions. Red and green algae become conspicuous in the fringe zone in South Africa, and *Sargassum* is usually common on any warm temperate southern hemisphere coast.

There is no part of Australia which is comparable to southernmost New Zealand, where Knox has shown that algae are dominant throughout the littoral during the whole year (see Table V). While many cold temperate New Zealand species also occur on the south coast and Stewart Island, others are restricted to the south (e.g., *Apophloeoa lyalii*). This coast is similar to that of the sub-antarctic islands of New

5. Caution is necessary in comparing "Pyura" in different Southern Hemisphere countries. *Pyura stolonifera* in South Africa is a sessile species, characteristic of the sub-littoral fringe; the same species, according to Dakin, Bennett, and Pope (1952), is common on the New South Wales coast but is distinctly a lower littoral inhabitant. Kott (1952: 276), however, raises doubts as to whether the South African and Australian forms are identical. In New Zealand the stalked *Pyura pachydermatina* var. *gibbosa* is conspicuous in the upper sub-littoral, descending for some distance below low water (Batham, 1956).

Zealand and to sub-antarctic South America (Skottsberg, 1941: 90).

More detailed ecological comparisons between Australia and other countries will be evident by comparing Tables IV and V.

Ecological comparisons of the intertidal zone are made on the life form of a relatively limited number of organisms. When species of the same genus are being compared, the conclusions are more significant than when different genera of a group are compared. Ecological comparisons tend to be broad and may often be rather superficial if more fundamental floristic and faunistic differences are not also considered. Thus statements such as Guiler's (1952, p. 59) that "ecologically the Tasmanian coasts have a greater affinity with New Zealand or Chile than with the shores of South Australia" are incorrect. The similarity between Tasmania and New Zealand and Chile is based largely on the presence of *Durvillea* and *Macrocystis* in the upper sub-littoral, but different species of *Durvillea* and in part of *Macrocystis* are involved, and *D. potatorum* in Tasmania is an upper sub-littoral alga while *D. antarctica* in New Zealand and the Sub-Antarctic is lower littoral. Otherwise, as Guiler himself states (p. 52), the animal zonation on Tasmanian coasts is basically similar to that on both Victorian and South Australian coasts. Floristically Tasmania is closely related to South Australia but much less to New Zealand and scarcely at all to Chile.

#### SOUTHERN HEMISPHERE MARINE FLORAS

Stephenson (1947) discussed Ekman's (1935; English edition, 1953) account of southern hemisphere faunas and clearly showed the existence of cold temperate (west coast), warm temperate (south coast) and sub-tropical (east coast) regions on the South African coast. Stephenson's conclusions are based on the water temperature and the fauna and flora of the intertidal zone. Stephenson (pl. 15) gives a map of southern countries surrounding Antarctica and classes the coasts as Antarctic and Sub-antarctic, cold temperate, warm temperate, and tropical and sub-tropical. Hedgpeth (1957b) also reviews the "littoral provinces" of the world, basing his map (Pl. 1) largely on the work of Ekman. It is now possible to consider the position of southern Australia in this scheme and comment on the position of other countries (Fig. 2).

Stephenson followed Ekman in classing southern Australia and New Zealand as warm temperate, but recognised that future work may prove part of these regions to be cold-temperate. Bennett and Pope (1953)

and Guiler (1952) have shown that Victorian and Tasmanian coasts should be regarded as a cold temperate region, characterised by the giant brown algae *Durvillea potatorum*<sup>6</sup> and *Macrocystis*, and by other zonation features such as the virtual absence of *Pyrua*. These coasts contrast with the whole New South Wales coast, that Dakin, Bennett and Pope (1948) have shown to be warm temperate.

The position of the southern Australian coast west of Robe in South Australia has been discussed by Womersley and Edmonds (1958) and previously in this paper. Ecologically it differs from Victoria and Tasmania only in the absence of *Durvillea* and *Macrocystis* and some minor species; the upper sub-littoral is instead characterised by other genera of Fucales, notably *Cystophora*, which are only of moderate size. South Australia differs from the warm temperate New South Wales coast significantly in certain zones, especially in the absence of *Pyrua stolonifera* which may be regarded as a warm temperate indicator species. Floristically and faunistically the differences between the South Australian and New South Wales coasts are considerable, while the whole southern Australian region is a floristic and faunistic unit (Ekman, 1953). It thus seems best to class southern Australia from Robe to the south-west corner of Australia as a region intermediate between warm-temperate and cold temperate in its affinities but closely related to the cold temperate Victorian and Tasmanian shores.

There can be little doubt that most of New Zealand should also be classed as cold temperate, with the northern extreme becoming warm-temperate and the southern-most coast sub-antarctic. What little is known of the west coast of South America indicates that cold temperate conditions extend far northwards under the influence of the cold Humbolt current. Howe (1914) records giant kelps such as *Macrocystis pyrifera*, *M. integrifolia*, *Lessonia* and *Eisenia* extending to the northern part of Peru.

Sub-antarctic and Antarctic coasts have usually been grouped together by marine ecologists. Skottsborg (1941), however, showed that there are considerable differences between the flora of the Antarctic continent and that of the sub-antarctic islands and southernmost South America. It is probably justified to regard these regions as distinct, comparable to the distinction between cold and warm temperate regions. Southern-

6. It is surprising that *D. antarctica* does not occur on the Tasmanian coast, since it occurs in New Zealand under water temperatures higher than those in Tasmania.

most New Zealand should probably be included in the Sub-antarctic region which is characterised by algal dominance throughout the littoral zone, by *Durvillea antarctica* and kelps in the lower littoral and upper sub-littoral respectively, and by species such as *Hildenbrandtia lecanellieri*. The true Antarctic flora is quite different from that of sub-antarctic islands, as large brown algae are largely absent from the upper sub-littoral. *Desmarestia* and *Leptosarca* are the most prominent sub-littoral genera (Skottsberg, 1941). The littoral region is poorly populated due to ice action, but *Hildenbrandtia lecanellieri*, *Monostroma*, *Iridaea* and lithothamnia do occur.

While parts of the South African, Australian, New Zealand and South American coasts can be all grouped as cold-temperate, floristically and faunistically they are quite distinct from each other, though Australia and New Zealand have a considerable number of species in common (some 20% of the algae).

This segregation of coasts into cold and warm temperate is based on the organisms present, the zonal dominants and water temperatures. Bennett and Pope (1953) are probably correct in saying that on Australian coasts the temperature limit of the true cold temperature region seems to be higher (12°C.) than on South African coasts (10°C. in winter), (Stephenson, 1948, p. 125). Knox also states that the limit on New Zealand coasts is higher than 10°C.

In the northern hemisphere the ratio  $\frac{\text{Rhodophyta}}{\text{Chlorophyta}}$  has been used (see Chapman, 1957) to distinguish broad regions; this ratio is close to unity in the arctic and increases to about 4 in the tropics. Chapman pointed out, however, that this is not applicable in New Zealand, and the ratio for southern Australia would be about 7, which reflects the peculiarly strong endemism and development of Rhodophyta in this region.

### ECONOMIC ASPECTS

The first record of utilization of Australian marine algae is that of Labillardiere (1800) who found the Tasmanian aborigines using dried fronds of *Durvillea potatorum* as water-carrying and drinking vessels. Large pieces of the frond were cut into a circular or oval shape and molded into a pouch; the ends were often bunched up and tied with thin parts of the frond or with a stick. Labillardiere also refers to the natives eating broiled pieces of the frond. Apart from this early record

there appear to be no others of the use of marine algae by Australian aborigines, though coastal tribes in South Australia did use *Posidonia* leaves for making baskets.

During the last century, and to some extent this century, *Eucheuma speciosum* and *Pterocladia lucida* were employed for making jellies by Western Australian women, and *Gracilaria* was similarly used in Tasmania (Lucas, 1936; Wood, 1946). Such use is probably very small if it exists at all at the present time.

Modern use, or possible use, of Australian marine algae is concerned with the algal extracts, agar and alginates.

*Agar.* Pre-war Australia obtained all her supplies of agar from Japan, using some 70 tons per annum, principally in meat canning and the manufacture of confectionery, spices and condiments (Wood, 1946). Supplies were seriously reduced in 1939 and ceased, owing to economic sanctions, in 1941. By 1942 one Australian firm was producing its own requirements for meat canning from *Gracilaria confervoides*, and others were undertaking production. In the later years of the war and after, Australia produced her own needs, but this production ceased some years later when the Japanese product came back on the market. At present virtually no agar is manufactured in Australia.

The development of an agar industry in Australia became possible when it was shown that sufficient beds of *Gracilaria confervoides* existed in estuarine bays on the New South Wales coast, and that a good quality agar could be produced from it (Wood and Peddie, 1941; Wood, 1942, 1945, 1946). A possible production of 100 tons or more of agar per annum was estimated. There are two main forms of *Gracilaria*, one estuarine with a high agar content (50-60%) and good gel strength, the other occurring in lagoons and brackish water with a lower agar content and poor gel strength (Wood, 1953). The first form was used. It grows on solid objects on a sandy bottom and was harvested by trawls or grapnels. Drift weed was also collected. The plant reaches a length of eight feet in beds two feet thick and of considerable extent, in depths of 15 to 20 feet of water.

Compared with Japanese agar, the Australian product has greater viscosity, its gel strength is greater at higher concentrations and less at lower concentrations, it is more transparent and the setting point is higher. Attempts to lower the setting point were not successful. The Australian agar was considered very satisfactory for most uses.

In western Australia *Eucheuma speciosum* was used for agar, being harvested from drift weed only.

During the last year or two, dried *Gracilaria* has been exported to Japan for agar manufacture.

*Alginate*. There is no production of alginate in Australia at present, but the extensive beds of *Macrocystis pyrifera* on the south-east coast of Tasmania have been surveyed (Cribb, 1954a) to obtain an estimate of resources. Cribb estimated that a minimum of 35,000-44,000 tons of air dried weed could be obtained in three harvests per year from nearly 30,000 acres of *Macrocystis* beds. The samples gave an average alginic acid content of 21% and average mannitol content of 8.3% on a dry weight basis.

*Durvillea potatorum* is the only other Australian brown alga that could be used to any extent for alginate production if an industry based on *Macrocystis* were already established. Moss and Naylor (1954) have found a high alginic acid content (about 40% dry weight) in the New Zealand *Durvillea antarctica* and *D. willana*, and *D. potatorum* would probably give similar results. Harvesting of living *D. potatorum* is not possible, since it grows under surf conditions, but deposits of several tons are often cast up on beaches in Victoria and Tasmania. Areas of *Ecklonia* and *Fucales* shown by Woodward (1955, Fig. 1) on South Australian and New South Wales coasts could not be utilised, since the plants are relatively small and scattered, and they could not be readily harvested.

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