PAP. & PROC. ROY. SOC. TASMANIA. 1949 (15TH SEPTEMBER, 1950)

The Intertidal Ecology of Tasmania

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WITH 2 PLATES AND 32 TEXT FIGURES

CONTENTS

It is proposed to study the detailed and general ecology of the intertidal region in Tasmania. It is hoped to obtain the general picture through the detailed study of several localities and by a study of the physical environment when such data are available for the locality under examination.

This paper is the first of a series on the intertidal ecology of the South of Tasmania. It is intended to extend the work to the North and other coasts at a later date.

PART I.—INTRODUCTION

(a) Short History of Littoral Ecology in Australia

Scientists have been attracted to the littoral region in Australia by the diversity and, in places, the extreme richness of the fauna. Hedley (1915) refers to this aspect of littoral conditions saying 'in species and individuals the local fauna is extremely rich, probably more so than in any marine area in the temperate zone of the Northern Hemisphere'. Whitelegge as early as 1889 listed 2136 species of the marine invertebrate fauna of Port Jackson (Whitelegge, 1889). Since then many species have been added to this list. This total compares very favourably with the Plymouth area, where over 2500 species, exclusive of parasites, were recorded (Marine Biological Association, 1931). This latter area has been more intensively studied than the Port Jackson area, especially as regards the smaller animals, and when knowledge of the Port Jackson area has reached a similar stage there will almost certainly be many more species than the Plymouth total.

In view of this very rich fauna a considerable amount of taxonomic study has been devoted to the littoral forms. A list of all the papers published on this topic would be irrelevant to this work, but some of the more important papers are given by Dakin, Bennett and Pope (1948). The littoral area around Sydney has been particularly rigorously searched by taxonomists and it is little wonder that Dakin, Bennett and Pope *(loc. cit.)* expressed surprise at the fact that so little interest had been taken in the communities of the littoral region. Until recently only sporadic efforts to study these communities had been made.

In Australia, with the exception of the F.I.S. 'Endeavour' and Cronulla Station, there have never been permanent stations established with marine zoology as their sole occupation. Marine zoology has been a feature at Sydney University in recent years, but most of the marine research work has been carried out by individuals using University, Museum or private facilities. This situation must be compared with that in the North-East Pacific where there have been numerous stations operating over a considerable period of time. The Californian Academy of Sciences was established in 1853 but did not undertake marine work for some years. Stanford established the John Hopkins Marine Laboratory in 1891, the Universities of California and Washington opened marine laboratories in 1901 and 1909 respectively, while the University of British Columbia has been associated with the Pacific Biological Station for a number of years. These and other institutions have all been concerned with the various aspects of marine ecology, taxonomy and hydrology. Fraser (1942) gives a summary of the history of marine zoology on the Pacific coasts of Canada and America. In view of the uniqueness of the Australian marine fauna, its geographical extent and its richness, especially on the Barrier Reef and associated islands, it is to be deplored that no permanant marine stations have been set up in this country.

In Australia one of the first papers published as an ecological study was that of Tenison-Woods (1880). This paper was largely concerned with the Mollusca and discussed the range of various species. There was little of general ecological interest contained therein. Hedley (1915) described the ecology of the Sydney beaches. This was the first attempt to discuss the ecology of any one area. Of necessity, much detail was left out of this general account but it was a stimulating introduction. However, many years elapsed before other workers turned their attention to the area. Johnston about the same time was working on the ecology of Caloundra in Queensland and this region has been ignored since his paper was published (Johnston, 1917). The Great Barrier Reef Committee Reports contain little of direct ecological interest. Several publications of the Great Barrier Reef Expedition of the British Museum in 1929-30 are of ecological interest, notably those of Manton (1935), Stephenson and others (1931), Otter (1937), Yonge (1940), Marshall and Orr (1931) and Yonge and Nicholls (1931).

It was not until 1943 that the Sydney area again received attention when Pope (1943) instituted a survey of the animal communities of Long Beach. This time the interest in littoral ecology was much more sustained and Dakin, Bennett and Pope (1948) considered the salient ecological features of the coast of New South Wales.

The only other State where active ecological work has been proceeding is South Australia. Here the littoral algal communities of Kangaroo Island have been studied by Womersley (1946*a*, 1946*b*, 1947, 1948). Edmonds (1948) has described the distribution of animal species in the same locality.

(b) The Status of Marine Zoology in Tasmania

In the past marine zoology in Tasmania has suffered from neglect to a far greater degree than in other States. General zoology in Tasmania has also been generally neglected. A review of the contributions of the members of the Royal Society of Tasmania, has been published by Somerville (1943). The present status of general zoology has been described by Plomley (1949).

In Tasmania marine studies may be considered under two main heads (1) Taxonomic and (2) Ecological. The former of these may be further divided into the sub-littoral or dredged and the littoral studies.

The dredging has been conducted by both expeditions and individuals. The most important of these expeditions are the 'Challenger' (Bass Straits); 'Alert' (Bass Straits); Australian Antarctic Expedition, 1911-14 (off Maria Island); 'Endeavour' (in Bass Straits and off the East Coast). Individuals have conducted numerous dredging expeditions and the results of these trips are scattered in various journals. A great many of the earlier expeditions were not properly recorded and species described from these are simply mentioned as being found in Tasmania. The work of Haswell (1882) contains many Tasmanian references and the works of Dendy on sponges contain several Tasmanian records, as does that of Lendenfeld (1889). More recent additions to the marine fauna are to be found in Briggs (1914), Tweedie (1941), Flynn (1918), Shaw (1927), Clarke (1946), Guiler (1948), and others. The fishes are fully described in various works and are listed in Lord and Scott (1924).

Taxonomic work on the littoral fauna has been virtually neglected in Tasmania. Hickman (1948) describes the biology of littoral spiders, while May (1921, 1923) describes the Mollusca of Tasmania with scant notes as to habitat of each species. Very few other phyla have been mentioned and one is forced to attempt identification from literature referring to mainland forms or to describe the species before any work of ecological value can be undertaken. Apart from the two references mentioned in this context there has never been any attempt to systematically collect representatives of one phylum and to produce a detailed descriptive work on those species.

This lack of interest in the littoral fauna is probably due to the poverty of that fauna compared with the richness to be found at Sydney. The lower tidal zones of the shores are richer in forms that the upper zones, but there is difficulty in collecting in these zones due to the behaviour of the tides.

With such little attention having been paid to the littoral region in Tasmania it is therefore not surprising that no work has been attempted on the ecology of the intertidal region.

(c) Scope of the Present Work

The present work has been undertaken with a view to establishing some of the basic ecological features of the Tasmanian littoral region. In the initial stages it is intended to concentrate on the shores of the South of the island. The salient features of the other parts of the island will be examined for comparison with those noted in the South. It is to be observed that the South furnishes examples of exposed rocky coasts, various degrees of sheltered rocky coasts, sandy beach, mud, surf beaches, storm beaches and several lagoons. There are also two large rivers, the Derwent and the Huon, with numerous small streams. In the more detailed work it is intended to concentrate on the Derwent estuary, D'Entrecasteaux Channel and Frederick Henry Bay areas.

PART II.—LITERATURE

In this review it is proposed to consider Australian works referring to marine ecology, and the relevant overseas literature on littoral ecology will be included in discussions of the various topics in this work.

The literature shows the evolution of littoral ecology in Australia. Ecological work has been of a very sporadic nature, but there is certain evidence that the present interest in this phase of marine biology will be maintained. The dates of publication of the various papers on littoral ecology, 1880, 1915, 1917, 1931, 1943, 1946, 1947 and 1948, illustrate the fluctations of interest. The many Scientific Reports of the Great Barrier Reef Expedition contain much of ecological interest, those of Manton and Stephenson (1935) and Stephenson, Stephenson, Tandy and Spender (1931) being primarily concerned with ecology.

The first paper on littoral ecology in Australia by Tenison-Woods (1880) was of a very general nature and could have stimulated other workers to turn their attention to the study of the littoral region. The Mollusca dominated the paper and the author was concerned mainly with their distribution over a large area. The paper represents the tentative suggestions of a taxonomist, in this case a conchologist, who has become interested in the biotic relationships of the animals with which he has worked. Due to the then prevalent lack of knowledge of the physical environment, Tenison-Woods was only able to indicate the geographical range, habits and food of a number of species.

The study of littoral ecology was carried a stage further when Hedley (1915) applied the widening knowledge of the physical environment to the littoral area. The application was uncertain in nature and little consideration was given to the effect of the physical factors forming the environment. The bulk of the paper is devoted to the habitats and the habits of the forms found there.

Johnston (1917) described the habitats encountered at Caloundra and the forms inhabiting them, but gave no consideration to the physical environment.

In the studies of Pope (1943) the evolution of littoral ecology proceeded a step further in the form of a detailed study of the plant and animal communities of one limited area in the Sydney region. This paper represents the same stage, as do the Barrier Reef Expedition Reports mentioned above.

Dakin, Bennett and Pope (1948) extended this work to cover the features of a large area of coast and analysed the physical and biological features encountered. With a large team of workers this and the preceding stage can be carried out simultaneously.

Womersley (1946*a* and 1946*b*) considered the ecology of individual species of algae in a restricted area. His general accounts of the algal ecology of the area appeared in 1947 and 1948. Edmonds (1948) correlated the animals of the same area with the plant communities.

It must be stressed that, although one or more of these stages may be omitted, it is essential before attacking a specific problem to have a general knowledge of the major ecological features of the region in which the problem is being considered.

In the future, work of this nature lies in furthering our knowledge of general littoral conditions in Australia and in the study of the ecology of species and how they are built up into communities.

Detailed Review of the Literature

(a) On Some of the Littoral Marine Fauna of N.E. Australia

Tenison-Woods, J. E. Proc. Linn. Soc., N.S.W., Vol. 1, 1880, pp. 106-131

The author is primarily concerned with the mollusca and the survey covers the area between Trinity Bay and the Endeavour River. The author does not give any details of the physical environment. In this respect the paper may be severely criticised, but allowance must be made for the very undeveloped state of ecology at that time. Since the publication of this paper, Sumner and others (1914) have stated 'any investigation not based on a knowledge of physical data may be dismissed as futile'. The paper, however, contains a wealth of observations on the habitats of various molluscan species and notes as to the geographic range of certain species. The author recognises three faunal types of coast, namely, coral reef, mangrove swamp and exposed rocky coast. His account contains little more than a list of the shells to be found on the coral reef areas while the mangrove swamps are also dealt with very briefly. The rocky coast has been studied more closely and the paper contains several references to the range and variations of some Tasmanian littoral species. In all three descriptions of faunal types of shore these are the notes of the keen observer on habits, food and enemies of various species.

(b) *An Ecological Sketch of the Sydney Beaches*

Hedley, C. Proc. Roy. Soc., N.S.W., 49, 1915, pp. 15-77

The author notes the physical environment as being composed of the following factors . . . nature of floor, temperature of air and sea, salinity and purity of the sea, tides and currents. The monthly averages of sea temperatures from 1881-90 are given. The author considered them too restricted to be of any great value. He further points out that, compared with overseas, the temperatures are fairly constant, varying from 75·5° F. on 15th and 20th January, 1887, to a minimum of 50·1° F. in July of the same year, a variation of 25·4° F. This comparison is difficult to substantiate, as the figures for Plymouth as quoted by Hedley only show a variation of 14·8° F. The temperatures for the English Channel are given by Lumby (1935), who analysed records extending over 25 years. The mean monthly temperature for March, 1908, is 9·18° C. and that for August is 15·75° C. These temperatures were taken in region 5. These figures, picked at random, show a much smaller range of variation than those given by Hedley. It is worth noting here that more valid figures for water temperatures are given by Dakin and Colefax (1940). The station in this latter work was three to four miles off Sydney and the temperature range was found to be approximately 7° C. This is very similar to the figures given by Lumby (*op. cit.*).

Hedley points out that the Notonectian current swings off-shore in winter and on-shore in summer. This results in the appearance in summer of animals used to warmer seas. He further considers that the critical time for littoral organisms is low water spring tides (L.W.S.T.) on a winter night.

The tidal data given were very meagre and very little was done to correlate the data with the effects on the flora and fauna. This objection may be held for all the physical data given in the work.

The flora and fauna of Sydney were compared in a numerical sense with other places. The Mollusca replace the Crustacea as the dominant group, and the algae are poor and monotonous in comparison with the colder Northern Hemisphere seas. The migrations of the family Littorinidae from sea to shore are discussed and the zoning of this family in ascending order is given as *Bembicium melanostoma; Melaraphe acutispira; M. infans; M. mauritiana; Tectarius pyramidalis; M. scabra.*

The shingle beach is recorded as having no flora or fauna, while the ocean sand beach has a small fauna. The latter is mostly of burrowing carnivores. The muddy estuary is discussed and notes on the flora and fauna are given with some references to the forms growing on the species of mangrove. Some little attention is also devoted to the zosteretum and the fauna inhabiting it. Lagoons which have been formed by the damming of streams by heavy storms are described.

The ocean reefs are most fully covered in the paper. The surf is stated to be more heavy than in Europe and a zonation is given. In descending order this is as follows:—Upper Zone with *Tectarius* and *Melaraphe* and *Chthamalus* and *Tetraclita*. A Median zone with *Galeolaria* followed by a Lower *Cynthia* zone. *Hormosira* is present and forms a *Hormosiretum*. The various animals inhabiting the reefs are described and *Galeolaria* is noted as being intolerant of sand or mud. The *Galeolaria* habitat for other animals is mentioned.

Mussel beds are noted as not forming an important part of the shore fauna. Below tidal levels are the kelp beds. These are described in a very general fashion and a few of the forms living there are recorded.

As mentioned above, this paper might well have stimulated further interest in the littoral regions not only around Sydney but also in other parts of Australia. A possible reason for its not doing so lies in the tremendous taxonomic difficulties encountered in work of this nature.

(c) Ecological Notes on the Fauna and Flora of Caloundra, Queensland

Johnston, T. H. Queensland Naturalist II., 2, 1917, pp. 53-63

The habitats are those recognised by Hedley (1915). The zones described as occurring on the rocky coast are more numerous than those mentioned by Hedley. The author describes five zones, the first three of which correspond to the Upper zones of Hedley, while the last corresponds to the Lower zone of that author. The zones recognised are *Tectarius* at the top of the shore, followed in descending order by an Upper *Melaraphe* zone, a Lower *Melaraphe* or *Chthamalus* zone; *Tetraclita rosea-Liolophasa queenslandica* zone and at low water a *Sargassum-Ornithochiton* zone.

No consideration is given to the physical environment and most of the paper is devoted to lists of the plants and animals in the various habitats.

(d) Animal and Plant Communities of the Coastal Rock Platform at Long Reef, New South Wales

Pope, E. C. Proc. Linn. Soc., N.S.W., LXVIII., 5-6, 1943, pp. 221-54

The data given for the physical environment are intended to supplement those of Hedley (1915). Even with this addition the data are still weak, especially in relation to tides. The observations of sea temperatures taken on the reef over a considerable period throw some light on the differences between sea temperatures at several stations. The observations are summarised in a table. The greater variation in the temperatures at the reef than at other stations is attributed to the reef rock being affected by atmospheric temperatures.

The migrations of *Heliocidaris erithogrammus* and Nudibranchs are noted as being into shallow water in summer and *vice versa* in winter.

The nomenclature adopted shows only three major divisions of the shore. These are the Supralittoral above mean high water spring tides (M.H.W.S.T.), the Tidal from below M.H.W.S.T. to mean low water neap tides (M.L.W.N.T.) and the Sublittoral which is exposed at extreme low water spring tides (E.L.W.S.T.). The author points out that King and Russell (1909) noted the importance of the lower sides of stones as habitats. Each habitat is described as having a fauna and flora on the upper and lower surfaces, but the author does not consider the fauna in terms of the epibiose, hypobiose and endobiose of Gislén (1930).

The Supralittoral is not fully developed and the zoning of the Littorinidae is not apparent due to the lack of vertical height. The algae present are very poor and small in numbers and do not supply sufficient for the mollusca, which points to the fact that there must be microscopic food available. The temperature range on the reef in this region is considerable. The fauna inhabiting the top and bottom of rock surfaces is described. The fauna below boulders in sand is also listed. On sand there is a belt of decaying plants and animals.

Most of the area studied is in the Littoral region. There are no plants in the upper part, though *Ectocarpus* appears seasonally. *Hormosira banksii* is dominant lower down the shore. *Corallina* is found at the lower limits of the littoral region. The animals of the region are of the mollusc-barnacle type (Clements and Shelford, 1939). They have spread so that it is difficult to find their limits. The distribution of the salient types is given and so is the zonation of the different groups. The lower rock surface fauna is described and classified as an *Ophionereis-Ischnochiton versicolor* community. The species inhabiting this are listed. The description of the littoral region concludes with notes on the small *Zostera* beds encountered and a list of fish and crustacea roving the reef at high tide.

The Sublittoral fringe is considered in some detail. The animals dwelling above and below rock surfaces are noted. These notes are of considerable interest and the various associations encountered in this region are discussed. The density of populations of certain species is also listed.

A most interesting feature of the part of coast which is described in the absence of the *Pyura praeputialis* association. This is attributed to the flatness of the reef and the shelter from fierce wave action. Some forms which are characteristic of still water are found, such as *Zostera*.

(e) A Zoological Sketch of Adelaide Beaches

Johnston, T. H., and Mawson, P. M. Handbook of South Australia. 25th Meeting, A.N.Z.A.A.S., Adelaide, 1946, pp. 42-7

This short paper contains notes on the different types of coast encountered near Adelaide. These are mangrove swamps, sandy mud, zosteretum, sandy flats, coastal jetties, sandy beach and rocky reefs. The forms inhabitating these habitats are listed.

On the reefs of the zones recognised are the Upper Littoral, Mid-Littoral, and Lower Littoral. The fauna and flora of these zones is then listed.

(f) Studies on the Marine Algae of South Australia. Part 1

The genera Isactis *Tjeoret and* Rivularia *C. Agardh.*

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 70, 1, 1946, pp. 127-136

This paper traces the history of phycology in Australia. The ecological notes are confined to those on distribution.

(g) Studies on the Marine Algae of South Australia. Part 2

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 70, 1, 1946, pp. 137-144

This paper contains a description of a new species of Dasyopsis and has no ecological notes.

(h) The Marine Algae of Kangaroo Island. Part 1

General Account of the Algal Ecology.

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 71, 2, 1947, pp. 228-252

The paper deals with four years' work and covers the physical environment. The general topographic features of the area are described and notes on the geology of the area are given.

The South and West coasts of the island are exposed and wave action is intense, and in the absence of any measurements of wave forces the alga *Cystophora intermedia* is taken as the index of heavy wave action.

The tides are of a semi-diurnal nature and exhibit diurnal inequality. There are no regular tidal records. The spring tide on the South coast is of some 2½ feet, but is 4 to 4½ feet elsewhere. Neap tides are 1½ feet to 2½ feet at similar places. Winter mean sea level is 4 inches to 6 inches above that of summer at Port Adelaide. The surface currents are those described in the Australia Pilot (1944).

The records of sea temperatures are not complete, but on-shore temperatures are given as varying between 13·5° C. and 19-20° C. The off-shore temperature was approximately 1° C. lower in summer than the on-shore figures. In the North of the island the off-shore temperature in summer was approximately 1° C. lower than the corresponding on-shore temperature. In winter the off-shore temperature was 1 to 2° warmer.

The air temperatures are fairly uniform throughout the year. The yearly average mean maximum temperature was 18·4° C. and the yearly average mean minimum temperature was 11·7° C. The average relative humidity was 76 per cent. Full tables of these records are given.

The salinity of the sea in the South is given as 35·4 to 35·9 grs./mille. (Cl = 19·6 to 19·9°/oo). The North coast has a slightly higher salinity of 37 grs./mille. The nitrate content of the sea is low, being less than $1/10^9$ and the phosphate varied from 14 to 23 p.p. 10^9. The pH, determined by colorimetric methods, varied from 8·2 to 8·3. The oxygen content varied from 110 per cent saturation during the day to 50-70 per cent at night.

The author recommends that littoral ecologists use terms which are suited to their own conditions and not try to follow the terms used by land ecologists. An association is defined as a grouping of organisms distinct in species composition and facies from another grouping.

The formations recognised are the rocky shore, sand and sandy mud, saltmarsh, vegetation of river mouths and the vegetation of brackish bays. The author does not recommend the use of formations based on dominants as they may be altered by migrations.

The Littoral zone is defined as extending from L.W.N.T. to the upper algal limit. The term Supralittoral is discarded and splash and spray used instead. The Sublittoral is described as extending from the lower limit of the Littoral zone down to the limit of algal vegetation. The Sublittoral fringe is to be regarded as a useful development of the Sublittoral in certain areas.

A general account of the algal ecology is given and the basic algal zonation has been worked out and is shown in a figure.

The rocky coast formation and the sandy and sandy mud formation each receive detailed attention and the various algal associations occurring in the different zones on the shore are described.

(i) A Study of Certain Aspects of the Ecology of the Intertidal Zone of the New South Wales Coast

Dakin, W. J., Bennett, I., and Pope, E. C. Austr. Jour. Sci. Res., Ser. B, I., No. 2, May, 1948, pp. 176-230

This article is concerned with the features of the New South Wales coast and the form of the basic zonation found thereon. Indicator types are named and discussed.

The sea temperature on the rocky coasts under consideration is taken as being similar to that found four miles out to sea from Sydney. This is rather surprising in view of the fact that one of the authors (Pope, 1943) showed that there was considerable variation between reef sea temperatures and open sea temperatures. The temperature differences of bays and enclosed waters varies very much. An enclosed bay with no fresh water contamination frequently shows a temperature in the summer which is 5° C. above that of the outer sea (Guiler, 1945). In lagoons, this difference is even greater (see later in this work). Hedley (1915) noted the effect of the on-shore swing of the Notonectian current in summer and, consequently, care would have to be taken that a current off-shore, in which the temperature observations were taken, was also running along the coast. There is no substitute for shore observations. The authors note that there is no satisfactory means of comparing the temperature of the ocean with that of pools until a record of shore sea temperatures is available.

The tidal range is greater than at Hobart. No data are available other than those for Sydney Harbour. There is little difference in tidal range between North and South New South Wales.

The coast of New South Wales is described by deduction as suffering rougher seas for longer periods than any other closely studied coast. This raises the levels of zones to greater heights and also alters the position of some species in exposed places, e.g., *Tetraclita purpurascens* Darwin may be found in the Melaraphe zone. *Pyura praeputialis* (Heller) doesn't alter its position with the exposure and so it may be used as an indicator species.

The nomenclature used shows four divisions of the coast, namely, the Supralittoral, Littoral, Littoral-Sublittoral fringe and the Sublittoral. The Littoral covers the intertidal region from H.W.S.T. to L.W.S.T. The Supralittoral is the zone above the Littoral and is mostly inhabited by Littorinids. The Sublittoral is covered at all times. The Littoral-Sublittoral fringe is very sharply differentiated and is exposed at very low tides. It is marked by *Phyllospora* and *Ecklonia,* and is described as definitely intertidal, especially in sheltered places. At the margin of the Littoral and Sublittoral is found *Pyura praeputialis* (Heller).

The zones are then discussed in detail. The Littoral-Sublittoral fringe is characterised by *Pyura praeputialis* (Heller), which is described as liking rough, open water. The range of this species is from 28° S. to 38° N. Above this species there is found *Galeolaria caespitosa* Lam. This species occurs isolated or in tube masses up to 8 inches thick. At Fort Denison it is found about 2 feet above zero tide mark and 1 foot in depth. Under certain conditions this may be altered. In the tube masses there are many small animals, notably *Ibla quadrivalvis, Onchidium patelloides, Lasaea australis, Desis crosslandi* and a flatworm. This zone is absent in South Africa, though it is represented by *Hermella* in New Zealand.

The lowest of the barnacle zones is that of *Chamaesipho columna.* This species occurs at a density of 3000 per square foot. It is replaced by *Chthamalus antennatus.* Where surf is heaviest, *Catophragmus polymerus* and *Tetraclita rosea* are found. The latter occurs up to 2 feet above high water, due to the spray effects. The sequence of zonation of the Balanoid zone is summed up below.

Exposed Coast	Sheltered Rocks
Chamaesipho-Chthamalus	*Chthamalus*
Tetraclita	
Catophragmus-Tetraclita	*Chamaesipho*
Galeolaria	*Galeolaria*

There also occurs a community of limpets on vertical, moist upper rocks.

In the Supralittoral *Melaraphe unifasciata* and *Nodilittorina* are characteristic. The latter species is found up to 40 feet above sea level.

The geographic range of the basic associations shows very little change. Only nine animal and two algal species disappear in the stretch of coast under consideration.

The animals living in the various associations are then listed and notes describing them are given.

(j) *The Commoner Species of Animals and their Distribution on an Intertidal Platform at Pennington Bay, Kangaroo Island, South Australia*

Edmonds, S. J. Trans. Roy. Soc. S. Austr. 72, 1, 1948, pp. 167-177

The author gives a brief description of the reef, but refers the reader to Womersley (1948). The wave action on the platform at high tide is described as strong. The substratum is of rock and most animals live firmly attached to rocks or algae.

For a description of the physical environment, reference is given to Womersley (1947 and 1948). The reef temperature is stated as being within 1° C. of the sea temperature. The latter varies between 19° C. in summer and 13·5° C. in winter. The salinity is variable between 35·2 grs./mille. and 35·4 grs./mille. The pH varies between 8·2 and 8·3.

The terms Supralittoral, Littoral and Sublittoral fringe are used to designate the regions of the shore. The author follows Cranwell and Moore (1938) and Oliver (1923) and considers the littoral zone to be from the highest wash of the waves to L.W.S.T. The Supralittoral is the spray zone and the Sublittoral fringe is the narrow region exposed at very low tides. The average height of H.W.S.T. is described as impossible to determine due to the small range of tides at Kangaroo Island. Hence the classification adopted by Pope (1943) cannot be used.

The Supralittoral is populated by *Melaraphe unifasciata* with a *Lichina* sp. and *Nodilittorina tuberculata* above it. Pools in this region have been found to have a temperature of 35° C. and a salinity of 40·2 grs./mille. with *Melaraphe unifasciata, Bembicium melanostomum, Galeolaria caespitosa* and *Siphonaria* sps. living in them.

The Littoral comprises most of the reef and consists of a vertical cliff face and the platform. The latter is of two levels and is penetrated by a channel.

The cliff face animals are barnacles, serpulids and molluscs. The zoning of the barnacles from the top of the shore is *Chthamalus antennatus, Chthamalus* + *Chamaeosipho columna, Tetraclita purpurascens*; *Catophragmus polymerus* occurs in exposed surf with a few *Balanus nigrescens.*

The molluscs form two bands, an upper *Notoacmaea-Siphonaria* type band and a lower *Modiolus pulex (?Brachyodontes rostratus)* band. The zonation of the upper band has not been determined with satisfaction, but notes on the forms living in the lower are given.

Four algal associations are found on the rock platform. These are *Cystophyllum muricatum* association, *Cystophora* complex, *Hormosira banksii* and a *Cystophora-Corallina* association. These algal associations have characteristic weed feeding molluscs. A list is given of the Gasteropods, starfish, chitons and other animals found living there.

The Sublittoral fringe was rarely examined. In 4 or 5 square yards there were encountered 40 to 50 algal species. The commonest animal is *Boltenia australis*. There is no *Pyura praeputialis* bed similar to that found in N.S.W.

A table of densities of animals per 0·5 metre square is given, as well as a list of species.

(k) The Marine Algae of Kangaroo Island, II. The Pennington Bay Region

Womersley, H. B. S. Trans. Roy. Soc. S. Austr. 72, 1, 1948, pp. 134-66

This paper is a continuation of the work described in Womersley (1947), being the study of the algal ecology of one area. The substratum is composed of reefs of horizontally wave cut platforms of calcareous sandstone with a vertical drop at their edge into water 10 or more feet in depth.

The tidal range is 2½ feet at springs and 1½ feet at neaps. Winds can considerably modify the tidal range. The outer parts of the reef are always rough. but with a West wind and a calm sea the waves are only 1 to 2 feet in height. Most of the reef is washed by small waves.

The temperatures on the reef are within 1° C. of the sea temperatures. The range of variation of sea temperatures is from 13·5° C. in July to 19° C. in January. Pools may reach 30° C. in summer. Summer air temperatures of 37° C. with a North wind and low tides are important to the ecology of algae. No harmful winter effects have been noted. The prevalent winds are South to West. The Cl is 19·5 to 19·6°/oo, with little annual change expected. The pH of the sea varies from 8·2 to 8·3.

The small tides and heavy wave action give no marked horizontal zones, but algal zones do occur, a change of 2 inches or 3 inches in reef level causes profound alterations in algal associations.

All the reef lies in the Littoral zone. Due to the conformation of the reef few of the algae are ever completely exposed. It is only at the Rearlittoral that the algae are exposed for any length of time.

A *Prasiola* community is the only algal community which is Supralittoral and it is only found where penguin colonies occur.

The various algal associations are described in full and biocenoses of *Symploca hydnoides* with *Tetraclita purpurascens* and *Gelidium pusillum* and *Galeolaria caespitosa* are described.

The zones recognised are the Supralittoral. Littoral, Sublittoral fringe and the Sublittoral. The Littoral is further considered as the Rearlittoral and the Littoral.

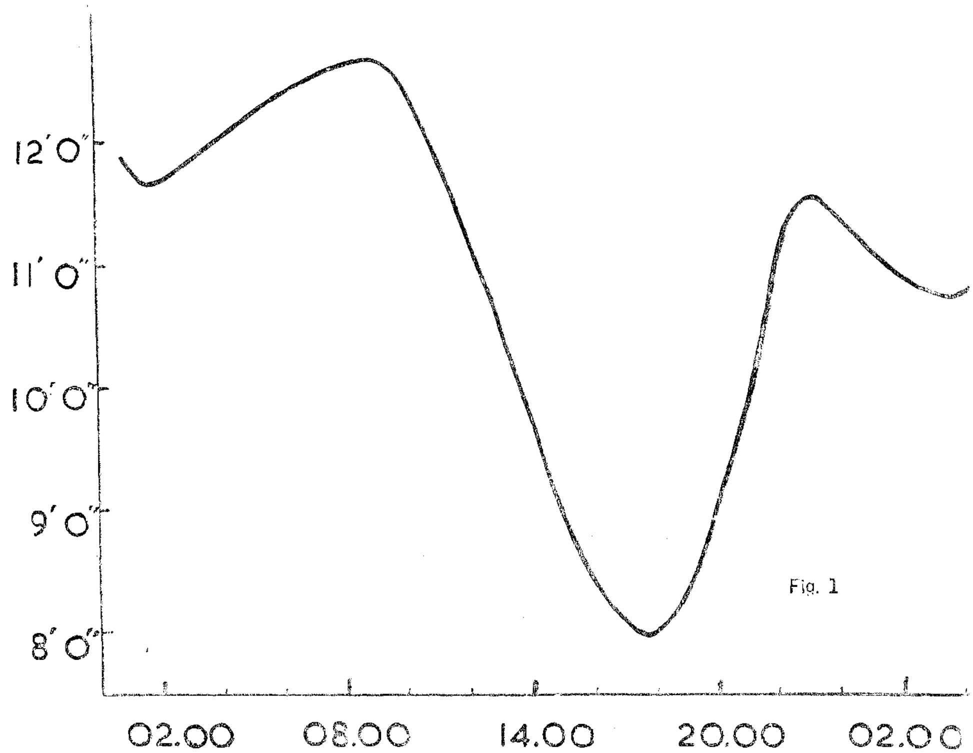
Seasonal variations in the algal flora are noted and discussed. Observations are also made on the variations under wave action, parasitism, epiphytism and the vertical distribution in relation to the intensity of light.

PART III.—THE PHYSICAL ENVIRONMENT

(a) The Tides

(1) In the South of Tasmania

The only available records of the tides in the South of the Island are those made by the automatic recorder maintained by the Marine Board of Hobart. This apparatus is situated on one of the piers at the port of Hobart. By courtesy of the Harbourmaster, Captain Bowerman, I have had access to the readings of the recorder and have taken records over a period of twelve months from the beginning of November, 1947, until the end of October, 1948.



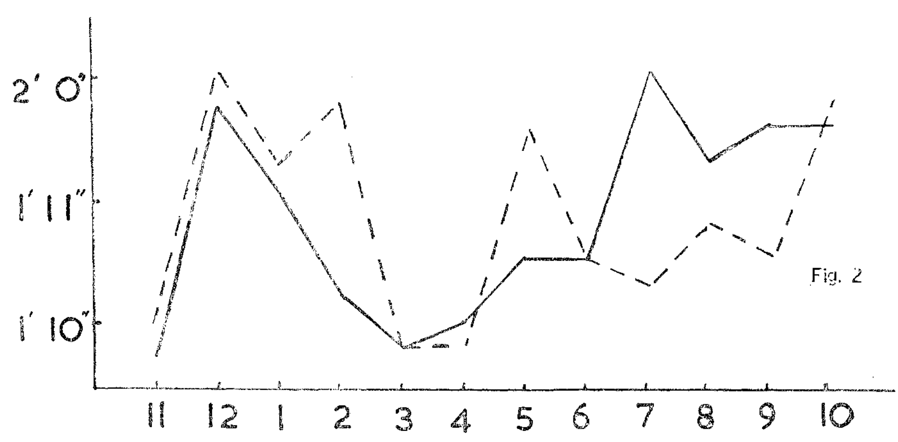


FIG. 1.—Tidal curve from 01.00 hrs., 30th December, 1947, to 04.00 hrs., 31 December, 1947. The record is taken from the trace of the automatic recorder at Hobart. The figures indicating the heights of the tides have not been altered from those on the recorder for reasons stated later in the text.

FIG. 2.—The average monthly rise and fall of the tides over the period November, 1947, to October, 1948. The unbroken line represents the fall while the broken line shows the rise.

The tides at Hobart are of the semi-diurnal type common to the Australian coasts. Figure 1 shows a typical tidal curve for a 28-hour period. This curve has been modified from the trace of the recorder. It will be seen that there occur during this period one very high tide and one very low tide and three tides the heights of which are very similar. Of these latter tides high and low tides can be differentiated. I propose to follow Chapman (1938) and call these tides 'high high', 'low low', 'low high', and 'high low' respectively. The term 'dodger' is used for the latter tides in many places when for a considerable period the tide gives the appearance of remaining nearly full.

Chapman (1938) discusses the different theories of the origin and prediction of Australian tides and points out that the only feasible method of explaining or predicting the tides is by harmonic analysis. Unfortunately, this has never been attempted successfully for Hobart. There are three probable reasons for this failure. The first reason lies in the smallness of the tidal range and the consequent relative amount of correction to be applied for such factors as change of barometric pressure, prevailing wind, &c. Another reason is the lack of economic necessity for such an accurate prediction. Due to the depth of water in the harbour, a difference of a few feet is of little importance. The third reason lies in the fact that there is a double entry for the tides at Hobart. It is unfortunate that the recorder is situated in a position where it shows this inaccuracy. The first entry is across Storm Bay and straight up the estuary of the River Derwent, while the second entry is up D'Entrecasteaux Channel and so into the estuary of the river. The traces of high water frequently show two high waters which may be over an hour part though the average is less than 45 minutes. The second wave from the Channel supplements the first and gives the reading which is used in this work.

The greatest rise noted for the period under consideration was 3 feet 6 inches on the 2nd December, 1947, the average rise for the year being 1 foot 10 inches, and the minimum rise was ½ inch on the 4th May, 1948. The greatest fall noted was 5 feet on the 8th July, 1948. The average fall for the year was 1 foot 11½ inches and the minimum fall was 0 inches on the 9th January, 1948. Figure 2 and Table I show the average rise and fall.

TABLE I

Monthly average rise of tide, fall of tide, and rise and fall of tides for the period November, 1947, to October, 1948.

	Rise of Tide	Fall of Tide	Rise and Fall of tide/2
November, 1947	1′ 10″	1′ 9¾″	1′ 10″
December, 1947	2′ 0″	1′ 11¾″	2′ 0″
January, 1948	1′ 11¼″	1′ 11″	1′ 11″
February, 1948	1′ 11¾″	1′ 10¼″	1′ 11″
March, 1948	1′ 9¾″	1′ 9¾″	1′ 9¾″
April, 1948	1′ 9¾″	1′ 10″	1′ 10″
May, 1948	1′ 11½″	1′ 10½″	1′ 11″
June, 1948	1′ 10½″	1′ 10½″	1′ 10½″
July, 1948	1′ 10¼″	2′ 0″	1′ 11″
August, 1948	1′ 10¾″	1′ 11¼″	1′ 11″
September, 1948	1′ 10½″	1′ 11¼″	1′ 10¾″
October, 1948	1′ 11½″	1′ 11½″	1′ 11½″

The tides exhibit diurnal inequality of both high and low tides. In figure 1 the morning tides are higher than the afternoon tides, due to the position of the sun being South of the Equator. Figure 3 shows the reverse when the sun is North of the Equator. The change over from one condition to the other takes place about the equinoxes. In 1948 the changes took place on 22nd April and the

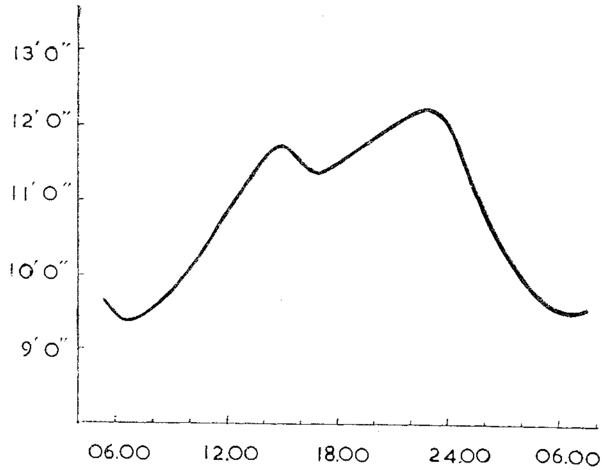


FIG. 3.—Tidal curve for the period 06.00 hrs. 26th June, 1948, to 06.30 hrs., 27th June, 1948. The curve is smoothed from the trace on the Hobart recorder. The heights of the tides are also those shown on the recorder.

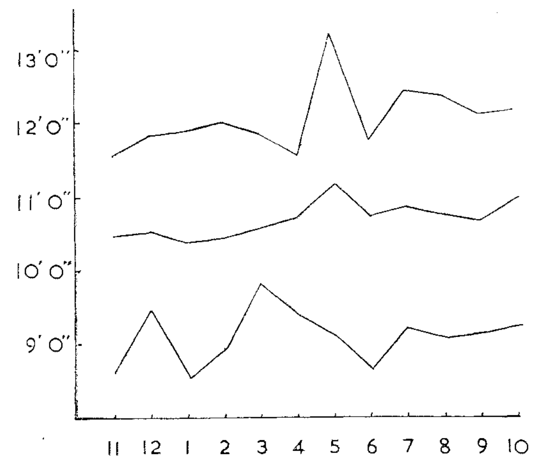


FIG. 4.—The average monthly heights of the tides for the period November, 1947, to October, 1948. The upper, middle, and lower lines represent the 'high high', 'high low + low high/2', and 'low low' tides respectively. The figures for the tidal heights are those of the Hobart recorder.

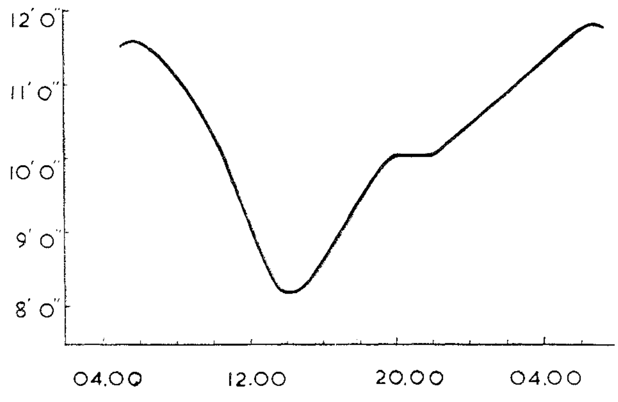


FIG. 5.—Tidal curve from 04.00 hrs., 9th January, 1948, to 08.00 hrs., 10th January, 1948. The curve is smoothed from that of the Hobart recorder and the tidal heights are those shown on that apparatus. The tide on this date showed complete suppression of the 'high low' tide.

27th October. The April change was foreshadowed by very great irregularity of the tides dating from the 28th March. From that date until the 22nd April the morning tide was larger than the afternoon for several days. Then the afternoon tide became dominant for a few days. There was no such disturbance at the October change.

As regards general behaviour, the tides act in a similar manner to those described for Port Adelaide by Chapman (1938). Due to the absence of an analysis and the great effects of the wind, barometric pressure and the double tidal entry, it is difficult to get a true picture of the effects of the various tidal components. For that reason the following remarks and those in Part V. of this work refer only to the recorded tides.

At neaps there is frequently a single fall in the tide in a 24-hour period, probably due to the reduction of the M and S elements. Figure 5 shows a modification of this condition in that the ascending afternoon curve is flattened out to give the negative rise or fall mentioned above on the 8th January, 1948. It must be noted that a single low tide in a day does not necessarily mean that it is an extreme neap tide. Single low tides occurred on the 16th November, 1947, and on the 19th of the same month. At neaps the time of the tide is very irregular. On the 17th November, 1947, the times of the tides were L.H.W 01.00 hrs.; H.L.W. 04.15 hrs.; H.H.W. 09.00 hrs.; L.L.W. 18.30 hrs. On the 2nd December, 1947, the times of the tides were H.L.W. 02.30 hrs.; H.H.W. 09.30 hrs.; L.L.W. 18.30 hrs. At springs there is very little difference between 'low high' and 'high low' tides. On the 8th July, 1948, the difference was 3 inches. In that month the average fall of the tide was two feet. The monthly heights of the tides are shown in Fig. 4 and Table II.

TABLE II

Mean Sea Level for the period November, 1947, to October, 1948.

November, 1947	10′ 4½″	May, 1948	11′ 1½″
December, 1947	10′ 7″	June, 1948	10′ 5¼″
January, 1948	10′ 4½″	July, 1948	10′ 9″
February, 1948	10′ 5½″	August, 1948	10′ 8½″
March, 1948	10′ 6″	September, 1948	10′ 7¾″
April, 1948	10′ 5¾″	October, 1948	10′ 9½″

Mean Sea Level for the twelve months, 10′ 7¼″.

The time interval separating the tides may be regular or irregular, irrespective of the phase of the moon. On the 7th June, 1948, the times of the tides were very irregular. L.L.W. 01.00 hrs.; L.H.W. 07.00 hrs.; H.L.W. 12.30 hrs.; H.H.W. 19.40 hrs., while on the following day the times for the corresponding tides were 03.00 hrs.; 11.30 hrs.; 13.00 hrs. and 20.30 hrs. respectively. The 'low high' and 'high low' tides are nearly always irregular in the time of their occurrence. These irregularities are probably due to non-lunar and non-solar influences. (Fig. 5, also illustrates this irregularity.)

The method used for the prediction of the tides is the 'establishment', which at Hobart is 08.15. This is subject to numerous inaccuracies and is of very little use in planning shore collecting trips.

(2) The Tides in the North of Tasmania

Tidal records are available at Launceston where there is an automatic recorder maintained by the authorities of that port. The tides in this part of Tasmania will be considered at a future date in connection with the survey of the North of the Island.

(b) *Climatic Factors.*

(1) Relative Humidity

The mean monthly relative humidity over the period November, 1947, to October, 1948, shows a series of sharp monthly differences (figure 6). A rise in the index for the period November-December was followed by a drop in January with a sharp rise again in February. In March the index fell to the November figure (61 per cent), but rose again in April. The highest figure was in June, and from that month until September there was a gradual fall in the relative humidity, but in October it rose again. For these figures, on which this graph is based, I am indebted to the Weather Bureau, Hobart.

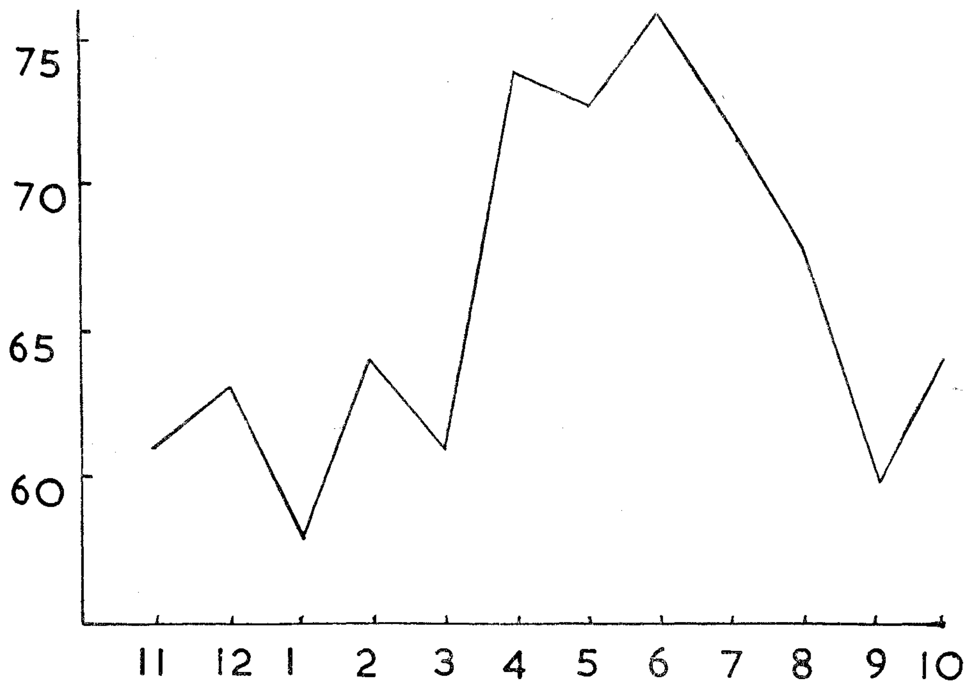


FIG. 6.—Mean monthly relative humidity at Hobart for the period November, 1947, to October, 1948. Data supplied by the Weather Bureau, Hobart.

(2) Barometric Pressure

The mean monthly barometric pressure has been calculated from the mean daily reading, which is one-half of the sum of the readings taken at 09.00 hrs. and 15.00 hrs. I am indebted to the Weather Bureau, Hobart, for these figures. The period for which the figures were obtained was November, 1947, to October, 1948. Over this period the lowest monthly average was recorded in October, 1948, although the minimum recording for that month was considerably above that for the preceding month. In September, the lowest average monthly minimum reading was recorded. The highest mean monthly minimum was recorded in April, 1948 (figure 7).

The highest mean monthly average pressure was recorded in June, 1948, while the lowest was recorded in October, 1948. The former does not correspond with either the maximum mean monthly minimum or the maximum mean monthly maximum. The lowest mean monthly maximum was recorded in October, 1948, and the highest mean monthly minimum was recorded in July, 1948.

The fluctuation in the mean monthly average pressure from November, 1947, to October, 1948, was largely due to the effect of a varying mean monthly minimum pressure as the mean monthly maximum was fairly constant throughout this period. From April, 1948, until October of the same year the mean monthly average pressure followed a similar pattern to that of the mean monthly maximum and minimum pressures.

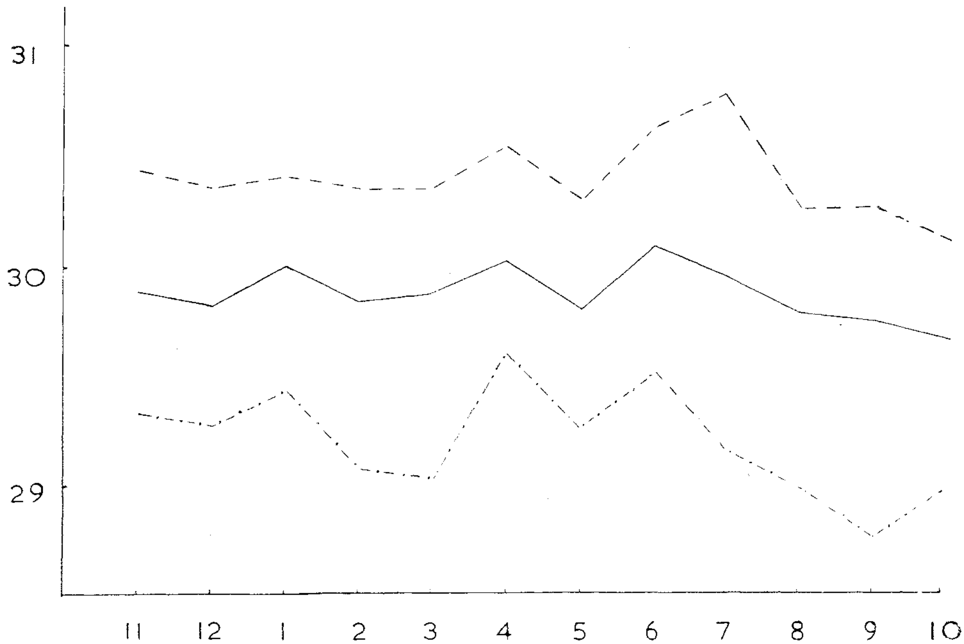


FIG. 7.—Monthly barometric pressure at Hobart for the period November, 1947, to October, 1948. The upper, middle, and lower curves show the mean monthly maximum, mean monthly average, and mean monthly minimum pressures respectively. The mean monthly average pressure is based on the average of daily readings at 09.00 hrs. and 15.00 hrs. Data supplied by the Weather Bureau, Hobart. The pressure is in inches of mercury.

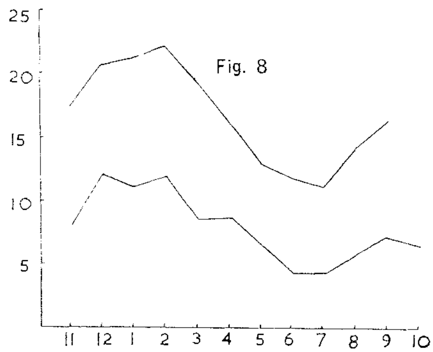
(3) Wind

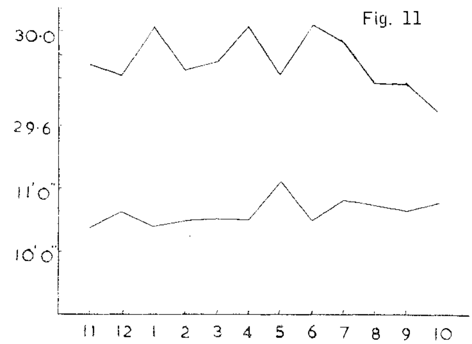
The prevailing winds in Southern Tasmania are Northerlies and North-Westerlies. These winds usually are warm and in summer can be hot and must have a considerable desiccating effect of the littoral fauna.

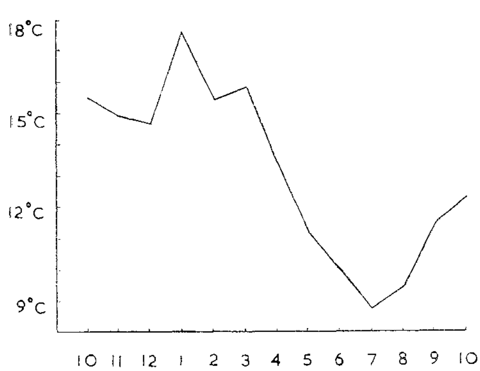
During the summer a local Southerly wind springs up usually around mid-day. This wind is cold and can be fairly strong and gives rise to short steep waves. As noted above, the East shore of the Estuary does not suffer to the same extent as the West from these local seas.

(4) Air Temperatures

The mean monthly air temperatures for the period November, 1947, to October, 1948, are shown in figure 8. I am indebted to the Weather Bureau, Hobart, for these figures. There is a fairly close correlation between the mean monthly







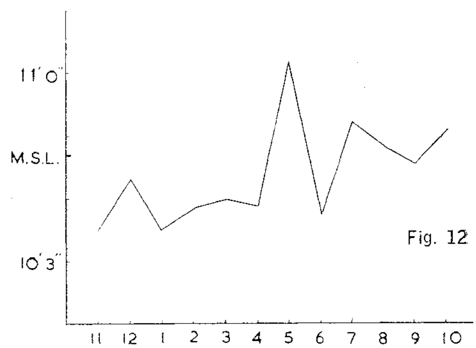


Fig. 9

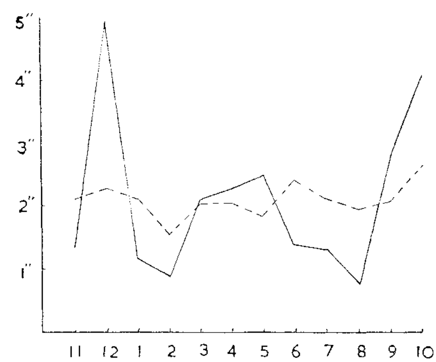


Fig. 10

FIG. 8.—Mean monthly maximum and minimum air temperature at Hobart. The temperature is in degrees Centigrade. Data for Hobart supplied by the Weather Bureau. The period of observation was November, 1947, to October, 1948.

FIG. 9.—Mean monthly sea temperatures at Hobart for the period October, 1948, to October, 1949. The temperature is in degrees Centigrade and was taken at Station 37, Derwent Estuary.

FIG. 10.—Rainfall at Hobart for the period November, 1947, to October, 1948. The continuous curve shows the actual rainfall while the broken line shows the average rainfall over the last 66 years. Data supplied by the Weather Bureau, Hobart.

FIG. 11.—Relation between the height of Mean Sea Level and the barometric pressure. The period under consideration is November, 1947, to October, 1948. The height of M.S.L. is expressed in recorder datum (R.D.) and the barometric pressure in inches of mercury.

FIG. 12.—Variations in the monthly levels of M.S.L., Hobart, for the period November, 1947, to October, 1948. Heights in R.D.

maximum and the mean monthly minimum temperatures. In April, 1947, this correlation breaks down slightly, the minimum temperature for that month being slightly above that of the preceding month, although the general trend of the graph at that period is downwards.

The maximum monthly air temperature was recorded in February, 1948 (21·83° C.), and the minimum in August, 1948 (4·11° C.). The minimum maximum monthly temperature was 10·94° C. in July and the maximum minimum monthly temperature was 11·94° C. in February.

During the period under consideration, the absolute maximum temperature recorded at Hobart was 35·26° C. and the minimum temperature was −4·4° C. These temperatures were recorded on the 12th February and the 18th August respectively.

(5) Sea Temperatures

There are no available records for the temperature of off-shore sea waters in Tasmania. This is a great lack in view of the interesting comparisons between on-shore, reef and off-shore water temperatures given by Pope (1943).

The figures which have been graphed in figure 9 were compiled by the author for purely on-shore waters. The station at which the records were made is at the seaward end of a small concrete outfall of a small creek at the Sandy Bay site of the University. This is Derwent hydrological Station No. 37. There are several objections to this station. The first is that the readings taken there will be subject to serious error due to fresh water contamination. To a large extent this has been reduced by taking the temperature at the extreme seaward end of the outfall and at a point where there was a minimum of fresh water. The flow down the creek is very small, except at times of heavy rains. It may be said that the error is only present at a time of very wet weather. A further objection is that the sea at this station is shallow and at 'low low' water an area of sandy mud is exposed. A flow tide on a warm or cold day will be affected to some degree by this flat stretch of sand. To some extent this error was eliminated by taking the temperature before 10.00 hrs., by which time the sand was not warmed very much by the sun. There was no satisfactory method of eliminating the error for cold water other than by taking the readings at high water. It might be pointed out that these errors are not very serious as usually 'low low' tides were avoided during the observations.

The range of temperatures is from 8·8° C. for July, 1949, to a maximum of 17·6° C. in January of the same year. The period of observation was from October, 1948, to October, 1949 (Table III). The extremes of temperature recorded were 19° C. on 2nd January, 1949, and a minimum of 6·3° C. on 22nd July, 1949.

TABLE III

Sea temperatures at Hobart from the period October, 1948, to October, 1949, recorded at Station 37, River Derwent.

	Temperature (°C)		Temperature (°C)
October, 1948	15.5	April, 1949	13.4
November, 1948	14.9	May, 1949	11.2
December, 1948	14.7	June, 1949	9.9
January, 1949	17.6	July, 1949	8.8
February, 1949	15.4	August, 1949	9.5
March, 1949	15.8	September, 1949	11.5
		October, 1949	12.3

Further observations on the temperature of the sea will be given in a later part of this work.

(6) Salinity and other Chemical Factors

The salinity and other chemical factors will be discussed at some length in the Derwent hydrological survey. It is sufficient to state here that the salinity varies around 34·8 grs./mille. for open sea. The figure for the estuary of the Derwent is very variable and much lower than that quoted above for open sea.

(7) Insolation and Light Intensity

It is not possible to obtain accurate details as to the amount of insolation to which littoral organisms are exposed in Tasmania. One of the features of summer weather in Hobart is the sea breeze which springs up about mid-day. As well as being a cold wind, this change brings cloud on Mount Wellington, especially on the Southern aspect. This cloud has the effect of casting shadow over certain parts of the coast and Hobart so that figures given for sun-hours in Hobart need not necessarily apply for more than three miles from Hobart where the recording station is situated.

The light intensities to which littoral organisms are subjected vary considerably with the habitat favoured by the organism. The intensities of light in various habitats will be considered in the sections of this work dealing with the detailed ecology of restricted areas.

(8) Currents

Not sufficient is known about the influence of currents on the littoral fauna of Tasmania. The detailed behaviour of the currents has not been fully studied. The sudden drop in sea temperatures in June and the equally sudden rise in September might suggest that either a warm current leaves Tasmanian waters in June or that a cold one arrives. The converse might be happening in September.

(9) Rainfall

Over a period of 66 years for which records are available at Hobart the rainfall averages about 2 inches per month. Figures for the average rainfall and for the period November, 1947, to October, 1948, were obtained from the Weather Bureau, Hobart (figure 10).

The month of February is 0·6″ below this average and must be considered to be the driest month of the year. August and February are the two driest months, while December is the wettest.

(c) Geological Features

It is not proposed to enter into the details of the geology of the coastal areas of Southern Tasmania. A large proportion of the areas studied have been composed of mudstone. The mudstone frequently weathers into wave platforms. Dolerite is found in places on the coast. By contrast, this latter rock usually does not weather into platforms. Full details of the geology of the Hobart area can be found in Carey and Banks (1949).

In any future parts of this work where it is necessary to describe the geological features of a region a brief description of these will be given at the beginning of that part.

Discussion

The physical environment as far as it has been described above may be compared with that of other parts of Australia. The comparisons are not complete due to the lack of much data in both Tasmania and the mainland States.

The tides in South Tasmania are considerably smaller than those which have been described by several ecological workers as prevailing in the Sydney area. This remark does not apply to the tides in the North of Tasmania, which have a much greater rise and fall than those in the South. There have been no detailed figures published relating to tidal data for the Sydney area. Hedley (1915) was very vague on the subject and Dakin and Colefax (1940), Pope (1943) and Dakin, Bennett and Pope (1948) all state that the tidal range is about 3 to 4 feet with extremes of about 6 feet at springs. Chapman (1938) does give some figures for New South Wales, but these are not sufficient to warrant any ecological conclusions. It is obvious, however, that the tides at Hobart are much less in magnitude than are those at Sydney.

The tides at Kangaroo Island are of a similar magnitude to Hobart tides (Chapman, 1938, and Womersley, 1947). In general behaviour the tides at Hobart are like those at Port Adelaide (Chapman, *loc. cit.*).

The mean monthly sea temperatures at Hobart, subject to the errors and conditions given in section 5 above, have a range of 7·8° C. This is similar to the range found for surface off-shore waters at Sydney by Dakin and Colefax (1940). On the other hand, the temperatures within this range at Hobart are very much colder than at Sydney. The average temperature for February, 1932, at the latter place was 23° C. The absolute maximum recorded over a 12-month period at Hobart on 2nd January, 1948, was 19° C. The Hobart absolute minimum is well below the corresponding Sydney figures. There are no off-shore temperature figures available for Tasmania.

The average relative humidity at Hobart is appreciably less than at Kangaroo Island, Womersley giving 76 as an average annual figure at that place, while the Hobart annual average is about 68.

The mean air temperatures are cooler that at Sydney or Kangaroo Island. The Hobart annual average maximum and minimum temperatures are less than those at Kangaroo Island by 2° C. and 5° C. respectively.

Figure 11 shows the relation between the variations in Mean Sea Level (M.S.L.) and the barometric pressure. An increase in the average monthly barometric pressure is reflected by a corresponding decrease in the level of M.S.L. (Table IV and Fig. 12).

TABLE IV

Variations in Mean Sea Level (M.S.L.) for the period November, 1947, to October, 1948. M.S.L. calculated from the traces of the Hobart automatic recorder.

November, 1947	10′ 4½″	May, 1948	11′ 1¼″
December, 1947	10′ 7″	June, 1948	10′ 5¼″
January, 1948	10′ 4½″	July, 1948	10′ 9¾″
February, 1948	10′ 5½″	August, 1948	10′ 8½″
March, 1948	10′ 6″	September, 1948	10′ 7¾″
April, 1948	10′ 5¾″	October, 1948	10′ 9½″

Mean Sea Level for the twelve months, 10′ 7¼″.

PART IV.—THE TIDES AS AN ECOLOGICAL FACTOR

(a) Introduction

In view of the important work on tidal exposures at different levels of the shore which has been carried out in various overseas countries, it is surprising that no comparable efforts have been made in Australia. As is obvious from the literature reviewed in Part II of this work, the tides in many cases have received only passing attention. The lack of study of the tides may be explained in part by the until recently undeveloped state of littoral ecology in Australia. The lack of tidal data over large areas of the coast serves as a further deterrent to work of this nature.

The conclusions formulated in this discussion of tidal phenomena must be regarded as local in application. The tides in Northern Tasmania are of much greater magnitude than those in the South and therefore require separate treatment. The results must further be regarded as approximate, even for the local area to which they apply. The reason for this lies in the fact, as outlined in the section on tides, that the Hobart recorder is subject to 'estuarine inaccuracies' such as wind, &c. The double entry of the tides is another source of inaccuracy.

It is necessary to note that the statement made by Colman (1933) that the ecological tidal level is not that shown on the recorder, but that reached by the surf, is especially valid on the exposed and semi-exposed coasts of Tasmania where, even in summer, choppy seas are frequently encountered.

(b) Literature

As mentioned above, there is no Australian literature on this aspect of littoral ecology.

The pioneer work on the effect of exposure on littoral organisms is that of Colman (1933). This author stressed the importance of 'critical' levels. The number of species appearing at different levels of the shore was considered in relation to the percentage exposure they suffered. It was found that for sedentary species critical levels existed between M.S.T. and E.L.W.S.T. (5 per cent exposed per annum); between M.L.W.N.T. and M.L.W.S.T. (20 per cent exposed per annum) and at E.H.W.N.T. (60 per cent exposed per annum).

It was realised before the work of Colman that exposure controlled algal distribution on the shore. For example, Johnston and York (1915) stated 'the vertical distribution of littoral algae depends on the period of emergence and submergence'. It was Colman who first considered this factor quantitatively.

Grubb (1936) using the technique of Colman found that each algal species at Peveril Point, Dorset, has 'a definite range of exposure above or below which it does not flourish successfully'. The vertical distribution of various algae was plotted against the exposure curve and a very close similarity to Colman's results was found.

Zanefeld (1937) working in Holland found that the tidal levels of algae at several localities were very similar. In passing it is worth noting that the numerous levels into which Zanefeld split the tidal region are not practicable in Tasmania due to the small tidal range. The factors controlling the desiccation of algae were analysed. In general it was shown that the higher up the shore a species grows the greater is the water loss but the slower the rate. Also, long exposed species have a higher fat content and a thicker cell wall than those species which are not exposed for long periods.

David (1941), working at Aberystwyth, found four critical levels only one of which was the same as any of those found by Colman. The levels found by David were at M.H.W.S.T.; M.H.W.N.T.; E.(L.)H.W.N.T. and E.(H.)H.W.N.T.

It is not proposed to give detailed accounts of the numerous papers published on littoral algae and the factors governing their distribution. A review of this aspect of ecology is given by Chapman (1941).

Several other workers have used the exposure method of approach to littoral problems and in each case the exposure curve obtained is very similar to that of Colman (e.g., Evans, 1947*a*, and 1947*b*).

Doty (1946) was among the first to apply this technique to tides exhibiting diurnal inequality. The form of the curve obtained is similar to that of Colman but differs in that the exposure increased more rapidly at certain levels of the shore. The station at which the tidal records were made was the entrance to San Francisco Bay where the tidal range is much greater than at Hobart. The terms used to designate the different tides were those of the U.S. Coast and Geodetic Survey. There were 6 or 7 zones on the shore but sudden increases in exposure were found to occur at 3 feet 5 inches, three feet and one foot above chart datum. Doty further noted that M.S.L. is varied in height on the shore by wind action. He pointed out that 'variation in vertical distribution seems to be correlated with daily, monthly or annual variations in the levels at which the tidal phenomena occur and with variations in the time the algae reproduce, after account is taken of the local topography'.

(c) *Exposure at Hobart*

The general behaviour of the tides at Hobart has been described above (Part IV).

The method used in obtaining the exposure factor may be described here. Using the figures obtained from the automatic recorder in Hobart, the average exposure at different levels of the shore was obtained for each month of a year. The period for which the tides were studied was from November, 1947, to October, 1948. The method used by Colman (1933) was not employed mainly for the reason that the smallness of the range of tides makes it impossible to determine whether a tide, say the H.W.S.T., is a true H.W.S.T. or one that has become depressed or supplemented by changes in barometric pressure, wind or other local effects. Admittedly we are concerned with the actual tide and not the theoretical tides, but in view of the likelihood of considerable error in using a few tides for analysis, I consider it advisable to use the average of the tides for a month. The dominant factor in considering tides in Tasmania is that the mean tidal range is only 1 foot 10 inches so that a tide supplemented by local effects by 4 inches represents a considerable percentage error. Local effects of 6 inches are common.

Mean sea level fluctuates considerably (figure 12). The relation between the variations in M.S.L. and barometric pressure has been noted above (figure 11). It is not suggested that barometric pressure is the sole factor responsible for the fluctuations of M.S.L., but it is probably the major factor.

Considerable difficulty has been experienced in reducing the tidal data to some fixed base line. Chart datum (C.D.) for Hobart is 'approximately Indian Low Springs'. M.S.L. is noted on the charts as being 3¼ feet above C.D. (Admiralty, 1944). Subtraction of this figure from the observed M.S.L. gives a level for L.W.S.T. which is never less than 5 inches below the minimum extreme reading of spring tides for that particular month. At equinoctial springs in 1948 the error was in the magnitude of 9 inches. The effect of this is that the C.D. cannot be used in a satisfactory fashion as a tidal constant since the extreme low spring tides cannot be shown as a negative tide.

In the figures showing the exposure for the 12-month period the heights on the shore are given as above or below M.S.L., and also in their relation to the arbitrary scale of the recorder traces.

The general form of the exposure curve is similar to that found by Doty (1946). Around M.S.L. the exposure increases or decreases rapidly and there is a gradual increase to the maximum and minimum exposures.

(d) Monthly Exposures for November, 1947-October, 1948

(1) November, 1947. (Figure 13)

M.S.L. for this month was at 10 feet 4½ inches Recorder datum (R.D.). Zero exposure was at M.S.L. minus 1 foot 7 inches, and 100 per cent exposure was at 1 foot 4 inches above M.S.L. The zero exposure on the shore was at a low level but this was not likely to be serious to littoral organisms in view of the moderate climatic conditions encountered in that month. Exposure at M.S.L. was 50 per cent.

(2) December, 1947. (Figure 14)

M.S.L. for this month was 10 feet 7 inches. The zero exposure was slightly further up the shore than for November (minus 1 foot 6 inches) and the 100 per cent exposure occurred at 1 foot 3 inches above M.S.L. In spite of these figures some very low tides were recorded towards the latter part of the month. This month must be regarded as one of great trial for littoral organisms as the average monthly rainfall is high (2·28 inches), and in this particular year 4·91 inches was recorded. The maximum air temperatures were not high but the minimum air temperatures were the highest for the year. The sea was cool. When exposed an organism had to endure warm temperatures and high rainfall and when the tide came in, cool seas. The lowest tide for the year occurred this month (7 feet 4 inches R.D.). The exposure at M.S.L. was 46 per cent.

(3) January, 1948. (Figure 15)

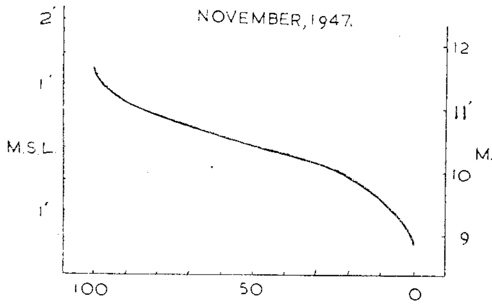
M.S.L. for this month was 10 feet 4½ inches R.D. Zero exposure occurred at the lowest on the shore for the twelve months under consideration (8 feet 6½ inches R.D.) At 1 foot 6 inches above M.S.L. is the 100 per cent exposure level. This month must be regarded as the month of maximum desiccation, especially at the lower tidal levels. The 'low low' tides reached their lowest monthly average height this month. The air temperature was high, relative humidity low and the sea temperatures at their maximum. The waters left by the tide would thus evaporate quickly. It is worth noting that the afternoon tide during this time of the year is the 'low low' tide which allows the maximum effect of the desiccation factor to operate at the lower tide levels. The exposure at M.S.L. was 54 per cent.

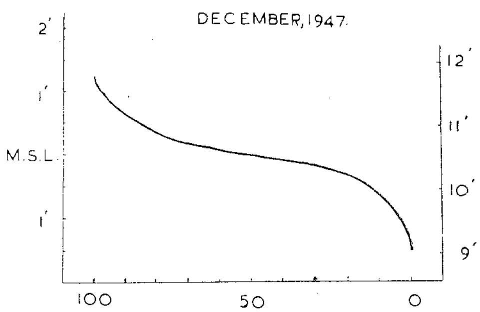
(4) February, 1948. (Figure 16)

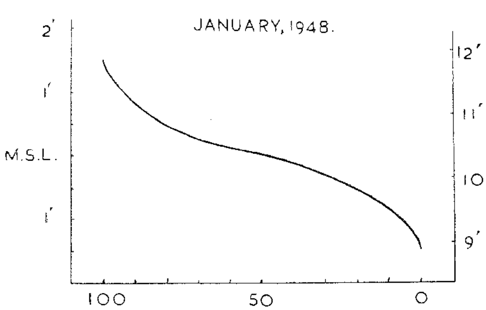
M.S.L. for this month was 10 feet 5½ inches. The maximum and minimum exposures were found to be at 1 foot 6 inches above and below M.S.L. respectively. The maximum air temperature was recorded this month and the average monthly rainfall was at its lowest. The seas were cooler and the relative humidity higher than last month. Although the air temperatures for this month were higher I do not consider it to have such a high desiccation effect as January due to the slightly higher M.S.L., the raising of the zero exposure level and the less evaporation of water. Exposure at M.S.L. was 57 per cent.

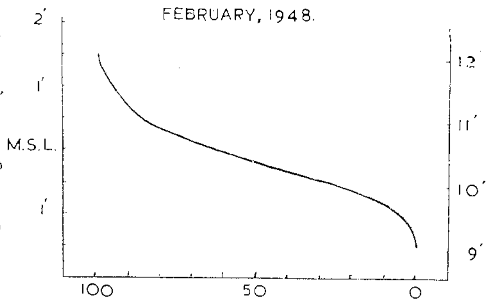
(5) March, 1948. (Figure 17)

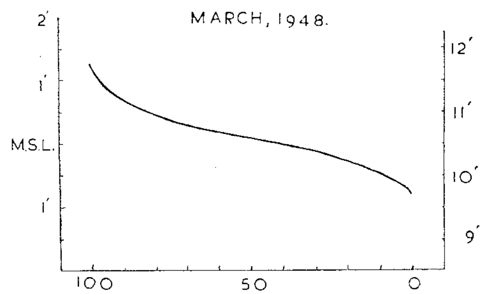
M.S.L. for this month was 10 feet 6 inches (R.D.). The most noticeable feature of this month was the level of the zero exposure mark at 9 inches below M.S.L. This month might be described as a very moderate month from the nature of the weather to which the organisms were exposed. Those organisms living low down in the intertidal region were not exposed very much and if they were exposed it was to relatively mild conditions. The exposure at M.S.L. was 38 per cent.











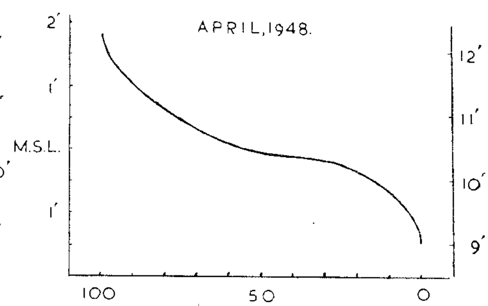


FIG. 13.—Exposure curve for November, 1947. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 14.—Exposure curve for December, 1947. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 15.—Exposure curve for January, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 16.—Exposure curve for February, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 17.—Exposure curve for March, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 18.—Exposure curve for April, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

(6) April, 1948. (Figure 18)

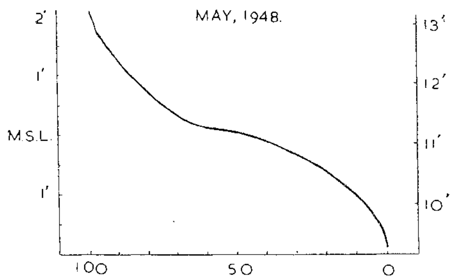
M.S.L. for this month was 10 feet 5 inches (R.D.). This month saw great tidal disturbances which culminated in the equinoctial change which made the early morning tide the 'low low' tide. The operative temperature factor during this part of the year must be the minimum temperature which would occur sometime during the early hours of the day. Hedley (1915) noted that for Sydney the critical time for littoral organisms was a low spring tide on a winter night. The minimum exposure was not as high on the shore as in March. The exposure curve has a slightly different form from that of the other months of the year. This may be due to incomplete records for the month as three days are missing from the recorder trace. This month saw sharply falling sea temperatures and maximum air temperatures also fell sharply. The minimum air temperature rose slightly from that of March. The rainfall average is similar to that of March but the relative humidity had risen very sharply. This month is to be regarded as a time of stress for littoral organisms, not on account of extremes of temperature, but because of the equinoctial change from low water maximum exposure to warmth to low water exposure to cool conditions. This will not affect animals living high up the shore. This change may serve as an indication to forms dwelling in the sublittoral fringe that it is time for the off-shore migration to commence. The exposure at M.S.L. was 56 per cent.

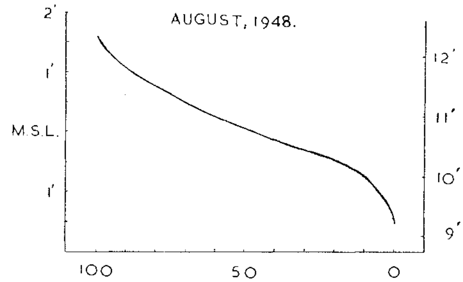
(7) May, 1948. (Figure 19)

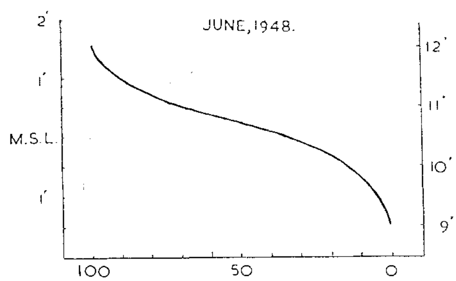
M.S.L. for this month was at the remarkably high level of 11 feet 1½ inches R.D. This may be correlated with the general fall in barometric pressures for that month (figure 7). While this fall in pressures may account for some of the rise in M.S.L. a combination of local factors must be taken into consideration. Zero exposure was correspondingly high up on the shore at 9 feet 2 inches R.D. This means that the extreme low water for the month must have only rarely exposed those organisms dwelling at the lower intertidal levels. Sea and air temperatures fell during the month. The average rainfall for the month is lower than for April but the actual rainfall recorded was above that for April. The relative humidity remained high. This month is not a time of stress to those organisms which enjoy submersion but for those with an optimum immersion there may be some difficulty in surviving. The exposure at M.S.L. was 50 per cent.

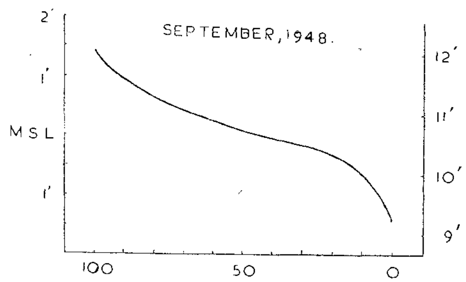
(8) June, 1948. (Figure 20)

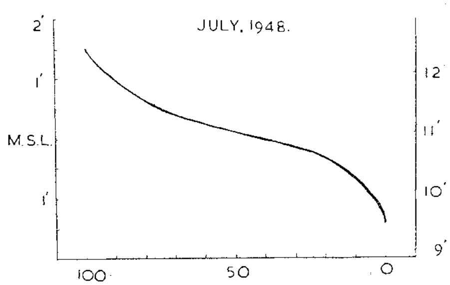
M.S.L. for this month reverted to 10 feet 5¼ inches R.D. The zero exposure was 1 foot 7 inches below M.S.L. 100 per cent exposure was at 1 foot 8 inches above M.S.L. The relative humidity for the twelve months was at the maximum of 76 per cent. The average rainfall is high though the actual rainfall for the month was low, the minimum air temperature was at the second lowest for the twelve months. The sea temperature was also low. This month is one of endurance to cold for littoral organisms. As mentioned above the 'low low' tide occurs during the early hours of the morning and this must often be accompanied by frosts. We have also noted Hedley's remark that a low spring tide on a winter morning is critical for littoral organisms. The most critical time of all is when a low spring tide coincides with low temperatures and a strong wind. Under exceptional circumstances this wind can cause virtual extermination of some littoral species but if sheltered from the wind individuals of the same species











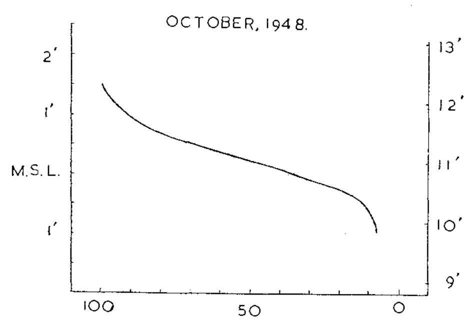


FIG. 19.—Exposure curve for May, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 20.—Exposure curve for June, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 21.—Exposure curve for July, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 22.—Exposure curve for August, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 23.—Exposure curve for September, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

FIG. 24.—Exposure curve for October, 1948. Heights expressed in terms of above or below M.S.L. and also in relation to R.D.

will survive. This was noted during the freeze-up of the British coasts in 1947 when the ice-sheet protected organisms from the wind but when the sheet was ruptured and the wind allowed to penetrate into the littoral zone great slaughter ensued. Forms dwelling at L.W.S.T. had no covering ice-sheet and were virtually exterminated (Guiler, 1949). Exposure at M.S.L. was 38 per cent.

(9) July, 1948. (Figure 21)

M.S.L. was at 10 feet 9 inches R.D. The zero exposure was at 1 foot 6 inches below M.S.L., i.e., fairly high on the shore. The 100 per cent exposure was at 1 foot 6 inches above M.S.L. Air maximum and minimum temperatures were at the lowest for the twelve months. The rainfall was low and the relative humidity was much lower than in June. The month is to be regarded as one of greatest cold although the absolute minimum air temperature was not recorded until next month. To some extent those organisms dwelling lower down on the shore were protected by the elevation of the zero exposure. The highest tide for the twelve months (13 feet 10 inches R.D.) was recorded this month. Exposure at M.S.L. was 41 per cent.

(10) August, 1948. (Figure 22)

M.S.L. for this month was 10 feet 8½ inches R.D. The maximum and minimum exposures were at 1 foot 7½ inches and 1 foot 7 inches above and below M.S.L. respectively. In spite of the absolute minimum temperature for the year being recorded on the 18th of the month there was a general warming up of temperatures. The relative humidity was still falling. Exposure at M.S.L. was 46 per cent.

(11) September, 1948. (Figure 23)

M.S.L. for this month was 10 feet 7 inches. The exposure limits were still fairly high on the shore being 1 foot 5 inches above and below M.S.L. The temperatures of air and sea showed an increase and the relative humidity fell further. There was a sharp increase in rainfall. The sea temperature rose sharply and this factor alone must make this month one of growth and recovery for littoral organisms. The exposure at M.S.L. was 43 per cent.

(12) October, 1948. (Figure 24)

M.S.L. for this month was 10 feet 9 inches R.D. Maximum and minimum exposures were at 1 foot 6 inches above and 1 foot 7 inches below M.S.L. respectively. The minimum air temperature fell for the month compared with September while the maximum air temperature rose in comparison with that month. The sea temperature and rainfall continued to rise. The latter was very high at 4·11 inches for the month. In general this month may be considered to be fairly mild, the organisms not being exposed to extremes of temperature. Exposure at M.S.L. was 38 per cent. This latter would serve to protect those animals dwelling low down on the shore. This month showed the equinoctial change over of the 'low low' tides and the remarks for April will also apply to this month.

(d) Discussion and Conclusions

It can be seen from the above that the exposure at the same point on the shore varies considerably from month to month. Comparison of two months in which the M.S.L. is the same shows considerable difference in the exposure at say, 10 feet 0 inches R.D. (November, 1947, and January, 1948, have the same M.S.L.). This variation in exposure is not therefore entirely due to the variation in M.S.L., but the composition of the tide for the month is an important factor. There is reason to assume that the exposure will also vary considerably from year to year as Zanefeld (1937) has shown that tidal levels may alter considerably from one year to the next. As regards the effect of exposure on littoral organisms it can be seen that the level of the organism on the shore must be noted accurately in relation to tidal levels and that the exposure is governed by two variables: the M.S.L. and the composition of the monthly tides and their relation to M.S.L.

The month of December is one of great trial for littoral animals and plants due to the variable weather liable to be encountered during that month. With low tides and heavy rainfall those animals and plants which are stenohalic must have a trying time. January showed itself to be a critical month for stenothermal organisms. April and October will greatly eliminate those organisms of low individual adaptability due to the equinoctial change over of the 'low low' tide. July is the month of maximum cold and stenothermal organisms must again suffer in this month.

In conclusion we find that December, January, April, July and October are months of some trial for littoral animals in Southern Tasmania. In this the emphasis lies on December, January and July which are critical months. These conclusions may apply in a general sense throughout Southern Australia. Further, it has been shown that the M.S.L. and the exposure at a point on the shore vary from month to month.

PART V.—SHORE TOPOGRAPHY

(a) The Estuary of the River Derwent

The river is tidal to beyond New Norfolk. For much of this distance the river is composed mainly of fresh water with a layer of salt water on the bed of the river. The banks of the Derwent in the upper tidal reaches are of a fresh water facies and show little or no evidence of saltwater. For the purposes of this work it is intended that upper limit of the area surveyed shall be at Bridgewater and the lower limit is the mouth of the estuary on an imaginary line drawn between Pierson Point on the West bank of the river and Cape Direction on the East shore.

(1) The West Shore

The upper part of the stretch of shore under consideration has marshes on this bank and at low tide considerable areas of mud flats are exposed, with a miximum exposure at the bird sanctuary above the bridge at Bridgewater. There are numerous muddy shoals in the stretch of river immediately below the bridge.

Between Bridgewater and Cadbury's (Dogsear Point) the river is of varying width with low headlands and several large bays. There is a deep water channel with a depth of not less than 4 fathoms. The bays are mostly shallow with shoals, reefs and sunken logs. There are certain exceptions as some of the bays, e.g., Claremont, are of 3 or 4 fathoms depth. The bank of the river is low-lying and composed of marshes and muddy sand beaches with low points of mudstone.

At Cadbury's the river swings sharply East, then West before flowing South again. This diversion is caused by a ridge of mudstone where the factory is situated. The water at this point is deeper than usual being 36 feet to the bottom. Beyond Cadbury's the river is broad and of uniform depth as far downstream as the Zinc Works. Prince of Wales Bay opens by a narrow entrance into the main channel immediately North of the Zinc Works. It is an enclosed bay of a fairly uniform depth of four fathoms and has two small streams entering it. The bay suffers from pollution from the refuse dump of the Glenorchy Municipality, open drains and to a lesser extent from factory effluvia from the development area at Derwent Park.

The Zinc Works is situated on a point some 225 feet in height. The estuary at this point is narrow being less than one half of a mile in width. The Zinc Works uses electrolytic processes and there is very little effluvia or pollution of the river. The water is of sufficient depth to permit ocean going vessels to berth at the wharf at the Works. Here there are 10 fathoms of water.

From the Zinc Works to the open sea at Storm Bay the river flows due South and is of gradually increasing width to a maximum of 3½ miles at the mouth.

Immediately beyond the Zinc Works, New Town Bay extends in a Westerly direction. The maximum depth of this river is four fathoms. The North shore is of rocks with low cliffs. At the head of the bay New Town Creek enters the bay and here also is the Hobart City refuse dump. The South shore has flat reefs of decomposed igneous material which are covered by a thin film of mud supporting a large Nereid fauna. There are low cliffs at the top of the shore and they form the next promontory, Cemetery Point. The reefs do not extend beyond the entrance to New Town Bay.

The next bay, Cornelian Bay, is of coarse sand at the Cemetery Point end and is composed of sandy mud at the Railway end. There is a negligible amount of fresh water entering the bay. The shore line from Cornelian Bay to the next point, Macquarie Point, is of stones with a muddy substratum. In places the stones are replaced by a gravel bottom on a substratum of mud. There are jetties and wharves on this stretch of coast and several slipways. Hobart bridge, a floating pontoon structure, spans the river below the Newsprint Mills' wharf. The shipyards and Naval Station lie half-a-mile downstream from the bridge.

The Hobart Rivulet enters the Derwent River just upstream from the oil jetty at Macquarie Point. A few yards out from the oil jetty a large sewage outfall causes a considerable upwelling of water. At the time of writing the Marine Board of Hobart are carrying out construction work on the stretch of shore between the oil jetty and the port of Hobart. This shore line is composed of an artificial wall but this will probably undergo some alteration in view of the extension work.

The port of Hobart lies in Sullivan's Cove. Ocean Pier lies at the Northern end and Prince's Pier at the Southern end of the Cove. A true shore line is not visible anywhere on this stretch of shore as most of this area is reclaimed. At extreme low water a line of stones is exposed at the Arygle Street end of Constitution Dock. Fresh water from street drainage enters this dock.

An artificial shore line extends around Battery Point. Below this wall is a foreshore of boulders. The wall is replaced by a low cliff at the Port Huon Fruitgrowers Factory. This cliff continues for some distance being broken by several small inlets which have a very muddy substratum with a number of small stones embedded in the mud. The cliffs terminate just before the outlet of the Wellington Rivulet.

At the Wellington Rivulet a coarse sand-shingle beach with a few loose stones extends almost as far as the Sandy Bay site of the University. A new promenade of loose stones and soil is in the course of construction at this point. It is not yet possible to judge what effects this will have on the shore facies. Immediately off-shore the substratum at the University end is composed of a sandy mud with a large Nereid fauna. A small amount of fresh water enters the sea at this spot and flows down a concrete channel for the last few yards of the outfall.

A low sea wall runs alongside the Sandy Bay Road for a hundred yards and this is replaced by a series of low cliffs which terminate at Dunkley's Point, better known as Wrest Point. The substratum is of sand. Beyond the point the road runs alongside the beach for some distance with a wall 20 feet high separating it from the sea. This wall is intertidal in the lower portions. Following on this wall there is a stretch of coast with sandy bottom and rocky cliffs varying between 5 and 20 feet in height. A long sandy beach forms most of the intertidal region and this terminates in a sandy spit at Long Point which is backed by sand dunes. Long Beach is of sand and separates Long Point from Blinking Billy Point. The latter is composed of large boulders of sedimentary and igneous material lying on a rock outcrop of dolerite. The main sewage outfall for Hobart lies off this point.

Next there is a sandy beach which runs for about one hundred yards to another small point. Above extreme high water mark there is a belt of pebbles which extends along the length of the beach. Above the pebbles are sheer cliffs of mudstone which are never less than 30 feet high.

This general type of coast, a rocky point followed by a beach, continues as far as Crayfish Point near Taroona. The upper regions of the beaches are usually of a rocky nature. The most noticeable feature of the coast is the absence of any kind of rock platform such as is common further down the coast although there are several large rocky masses on various parts of the foreshore.

At Crayfish Point the coast swings sharply through a right angle and runs in a westerly direction. The beach on this stretch of coast is composed of sand with several rocky outcrops. At the end of this sandy stretch there are high vertical cliffs which follow the general North-South trend of the shoreline. At the bottom of the cliffs are screes and small rock platforms. These high cliffs continue as far along the shore as Kingston.

At Kingston there is a long beach of some half-a-mile in length with fine sand and no rocks. A river, Brown's River, enters the estuary at approximately a quarter of the distance along the beach from the Hobart end. Between Kingston and the next bay, Blackman's Bay, there are further steep cliffs. These at first have no rock platforms but approaching Blackman's Bay platforms, all of which are of mudstone, are found. These platforms extend up to 50 yards out from the base of the cliffs and are penetrated by several wave-cut openings of which the largest is at the Blow Hole. Perameles Bay is a small indentation just to the North of the Blow Hole.

Blackman's Bay, not to be confused with the Blackman's Bay on the East Coast at the East end of the Dunalley Cut, is of sand extending for about a third-of-a-mile. The Northern headland is formed of the Southern end of the rock platforms. At the Southern end of the beach there is another rock platform with a stack called the Pinnacle at the shoreward side of it. The cliffs are high and composed of mudstone. Following on Pinnacle Point is a bay which I call Boulder Bay on account of the type of foreshore, which is about three hundred yards in length, having an outcrop of mudstone in the middle and ending in a rocky point of dolerite.

A very deep wave cut opening, which has vertical sides and terminates in a cave at the landward end, separates this point from the next bay which I have called Inaccessible Bay. The shore is of boulders with sheer steep cliffs on the landward side. The coast from this bay as far as Pierson Point is of a similar nature with steep cliffs and a stony or rocky substratum. Much of the coast is difficult of access. Many of the bays are more in the nature of indentations than true bays such as Blackman's Bay. A noticeable feature is the lack of rock platforms. This is not due to a change in rock formation. This part of the shore is characterised by a large belt of kelp at a distance of some twenty yards off-shore.

(2) The East Shore

In the upper reaches this shore is similar in form to that described above for the West side of the river. About a mile below Bridgewater the River Jordan enters the main stream. This river is of considerable width but in summer the amount of fresh water being added by it to the main stream is very small.

Below this river the East bank of the estuary is of a more uniform nature than the West. Opposite Cadbury's the bank of the river is steep but the rest of the shore is of gentle slopes with stony beaches. This type of bank continues as far as Risdon Cove, an inlet with a small stream at the head of it. Almost opposite the Zinc Works there is a vertical slope of rock known as Bedlam Walls. Between Risdon and Lindisfarne Bay there are two long narrow indentations each with a small stream at the head of it. The smaller of the indentations is Shag Bay and the larger is Geilston Bay.

Lindisfarne Bay is of a muddy substratum with boulders and rocky outcrops at high tide level. The coast after Lindisfarne is of low rocky cliffs with a sandy bottom. This continues beyond Hobart Bridge to Montagu Bay, which is similar to Lindisfarne Bay. Montagu Point, a low rocky promontory, separates Montagu Bay from Kangaroo Bay. This bay is also of a similar nature to Lindisfarne Bay but has a rubbish tip at the head of it with a small stream entering beside the tip. A low headland of mudstone with a narrow rock platform at the foot forms Kangaroo Bluff. Beyond this headland is Bellerive Beach, with low sand dunes behind the beach. It is composed of sand and is about a mile in length. A small point of rocks separates this beach from Howrah Beach, another sandy bay about half-a-mile in length with a rocky prominence at the South end.

From this latter low point the coast is of a fairly uniform character being composed of low rocky prominences with bays having a substratum of sandy mud and loose boulders with some rocky outcrops. This type of coast terminates at Droughty Point which forms the Northern side of the entrance to Ralph's Bay.

Ralph's Bay is large and of an enclosed nature. It has a Northern and Southern arm. The Northern arm extends in an Easterly direction for about half-a-mile almost reaching Frederick Henry Bay. It has been joined to this bay by a canal. A further arm runs in a Southern direction forming a very shallow bay, much of which is only covered by the tide at high water. At the head of the bay there is a salt marsh which is now practically cut off by a road and is drying out. The larger Southern arm of the bay extends for several miles being separated from Storm Bay only by a narrow neck of sand dunes. There is a small bay on the East side of the Southern arm, Mortimer or Henry William Bay. The Southern side of the entrance to Ralph's Bay is formed by Gellibrand Point, which is higher than Droughty Point and has a loose boulder foreshore.

The shore of the Northern arm is of a sandy mud, while the Southern arm ranges from almost pure sand and with a shingle admixture to muddy sand, and at some places low rocky cliffs are to be found. In both arms there are large shell and shell fragment beds to be encountered at high water level.

The estuarine side of Gellibrand Point has a shingle beach followed by a few rocky outcrops and then Mary Ann Bay which has a foreshore of sand. A rocky coastline extends from this bay to Opossum Bay. This latter is of sand with a few low dunes and is three-quarters-of-a-mile in length. A low rocky headland separates it from another sandy beach, forming the shore of Half Moon Bay, which is very similar to Opossum Bay both as regards length and nature. A rocky headland with a narrow rock platform extends from the South end of Half Moon Bay. This is followed by several small beaches separated by mudstone areas. This type of shore terminates in Cape Direction which is also of mudstone.

The most striking feature of the topography of the estuary is the difference between the two sides. The East is of a more sheltered nature than the West. This is seen from the larger amount of mud in the shore deposits of the East bank. The Western side is of the more exposed nature as is seen from the absence of mud in the lower regions of the river, and the presence of cliffs and rock platforms. The rock platforms are characteristic of mudstone and are worn along the bedding planes of that rock and so dip at a varying angle, rarely more than twenty degrees to the West.

The difference between the shores can be attributed to the effect of a Southerly or South-Easterly sea. There is no island or any form of breakwater in the entrance to the estuary between the Iron Pot (off Cape Direction) and the North end of Bruni Island. The full force of the waves of a Southerly or South-Easterly sea is thus expended on a stretch of shore from just North of Kingston to somewhere South of Inaccessible Bay. A lesser force is felt for considerable distances on either side of this stretch of coast. This can easily be seen on a calm day with a slight Southerly swell, when the surf will be breaking on the rocks at Blackman's Bay, the depth of the waves being as much as four feet from crest to trough. Under the same conditions the East side of the estuary would be calm with only small waves. This difference is further accentuated by the very common Southerly sea breeze which springs up somewhere about mid-day in summer. Short steep seas are whipped up by the breeze and these beat on the West shore while the East shore enjoys calm.

The East shore is not affected similarly by a South-Westerly swell or gale as Bruni Island and Cape Direction between them form a bar to any heavy seas breaking on the East shore.

PART VI.—THE ECOLOGY OF THE BLACKMAN'S BAY AREA

(a) Introduction

The area under consideration extends from Kingston Beach at the North to Pierson's Point at the South. The most intensely studied area is at Blackman's Bay. Blackman's Bay lies on the West side of the estuary of the River Derwent near the entrance to the river from Storm Bay and D'Entrecasteaux Channel.

Blackman's Bay was chosen as the first area to be studied as it is convenient to Hobart and can be visited frequently throughout the year. It is sufficiently far down the estuary to be free from fresh water influences. It does not suffer pollution by sewage or factory effluvia. Blackman's Bay was the operational base for short excursions along the coast in either direction.

The coast may be described as semi-exposed. Greatest wave action is experienced in the Pierson's Point to Lucas Point area. This is of moderate severity during a South or South-East swell or gale.

The zonation exhibited in this area is studied in some detail and some attention has been given to the colonization of rock surfaces.

It is not intended to give full lists of the flora and fauna of each of the belts examined. In the case of the upper regions of the shore the lists will be full but the lower regions will only have index and obvious species mentioned. Lists of the marine fauna of Tasmania are in preparation.

(b) Terminology

The terms used in the classification of the intertidal region vary according to the views of every author. Kjellman (1877) described the Littoral region as being from E.H.W.S.T. to E.L.W.S.T., the sublittoral from E.L.W.S.T. to 20 fathoms and the Elittoral as being below 20 fathoms. Sernander (1917) considered the region above the littoral to be the Epilittoral. Bright (1938*a* and 1938*b*) recognized the Supralittoral, Tidal and Sublittoral. Zanefeld (1937) combined the Epilittoral of Sernander with the classification of Kjellman but with many more subdivisions of the Littoral. Stephenson, Stephenson and duToit (1937) recognised three zones based on the dominant forms found there namely an upper Littorina zone, a median Balanoid and a lower Patella cochlear zone. Below the latter was the Sublittoral fringe which belongs to the Sublittoral area.

In Australia, Hedley (1915) found Upper, Median and Lower zones at Maroubra and Johnston (1917) found four or five zones at Caloundra. Pope (1943) and Dakin, Bennett and Pope (1948) all followed the South African workers. Edmonds (1948) recognised similar zones but based the limits of these zones on the work of Cranwell and Moore (1938) and Oliver (1933).

While it is necessary to consider the sub-zones recognised on the shore in view of local conditions, it has to be borne in mind that there exists an overall zonation which is common to most parts of the world. This has been pointed out in a most timely paper by Stephenson and Stephenson (1949). The basic zonation throughout the world is described. The terminology adopted by these authors is that which will be followed in this, and all subsequent parts, of the present work. The Supralittoral is that zone above the upper limit of Littorinids. The Supralittoral fringe extends from the upper limit of Littorinids to the upper limit of the barnacles. The Midlittoral is the barnacle zone extending down as far as the upper limit of the Laminarians. The Infralittoral fringe is from the upper limit of the Laminarians to E.L.W.S.T., and the Infralittoral zone is below the extreme limit of tides.

The littoral region extends from E.H.W.S.T. to E.L.W.S.T. but authors do not favour the retention of the term littoral due to too much ambiguity as to its actual meaning.

The level of E.L.W.S.T. in Tasmania is considered to be the level of extreme low water spring tides plus the extreme effects produced by wind and barometric pressure. This is the level shown on the tidal recorder and it is this level with which we are concerned.

(c) The Physical Environment

This has already been described in some detail in Parts III and IV of this work. The details noted in the earlier parts apply at Blackman's Bay without very much modification from those described for Hobart. There may be more insolation experienced due to the effect of the summer sea breezes on Mount Wellington. As noted previously cloud forms on Mount Wellington in summer when the afternoon sea breeze blows up the river. This shades the South part of Hobart but Blackman's Bay and further South are not in the area covered by the clouds.

(d) Topography

Blackman's Bay lies on the West side of the Derwent estuary. The general relationships of the bay to the shore as a whole have been noted in Part III of this work.

At both the North and South ends of the bay there are low headlands of mudstone. Rock platforms extend out for some distance from the bases of the cliffs. The bay is composed of a sandy beach about a third of a mile in extent. A very small stream enters the sea about half-way along the beach. The influence of the water brought down by this stream is negligible.

The rock platform at both the North and South ends of the beach are formed by erosion along the bedding planes of the mudstone. This rock dips to the West at varying small angles. The platforms at the South of the bay are not as extensive as those at the North end.

To the North of Blackman's Bay the coast is composed of cliffs with rock platforms. This type of coast extends nearly as far as Kingston where dolerite appears. The igneous rock has no rock platform. Perameles Bay is a small indentation beyond the Blow Hole at Blackman's Bay. It is reached by a small path from the cliff top.

The next point beyond Blackman's Bay is of igneous material. This has given rise to steep cliffs without rock platforms. Beyond this there are steep cliffs of mudstone or tillite, but without rock platform. Where beaches are found they are composed of boulders or gravel. This type of coast continues as far as Pierson's Point. The bay to the South of Blackman's Bay I have called Boulder Bay. Lucas Point lies about half-way between Blackman's Bay and Pierson's Point.

(c) *Wave Action*

At no time could the wave action on the shore be considered as intense. The most severe wave action is experienced when a South or South-East swell is running. This swell comes in between the Iron Pot and the North end of Bruni Island and crashes on the shore, especially severely in the Pierson's Point area. The waves are not of full oceanic strength but are modified by the shallow waters of Storm Bay and by the narrow entrance to the river.

Very choppy seas are experienced off Pierson's Point when the wind coming up the D'Entrecasteaux Channel crosses the 'run' of the sea at the North end of Bruni Island.

The quantitative measurement of the intensity of wave action is impossible to determine. The reasons for this lie in the number of unknown physical factors concerned with the effect of winds of different strengths on varying lengths of water. The necessities of war produced some researches into this problem. The studies were based on the analysis of wave curves but quantitative measures of wave forces are not given ('Discovery', 1949). In the absence of any quantitative data some comparative method of describing the intensity of wave action is all that can be undertaken.

Fischer-Piette (1932) recognised four degrees of exposure to wave action. These are 'très battu, peu battu mais encore dépourvu de Fucacées, abrité et couvert de Fucacées et très abrité'. Moore (1935) defines a factor for exposure to wave action as the number of days per hundred days in which any wind blows into the exposed aperture of the locality in question, the opening being the seawards aperture measured at a distance of half a mile.

The degrees of exposure as described by Fischer-Piette cannot be applied to Tasmania where there is a general poverty of Fucoids irrespective of the wave action encountered. Moore (1935) points out that the important factors of the effect of a shallow bottom near the shore, the distance the wind has blown over the sea are not considered in the definition as given above. Other factors not considered are the size of wave produced when the strength of wind and/or length of water traversed by the wind are not sufficient to produce the maximum wave force.

The formula proposed below does not answer the precise quantitative measurement of wave action but it is hoped that it will be of use in the comparative study of wave forces in different parts of the world. It can also be applied to giving an indication of the relative strengths of wave action on a restricted part of a coast or in a small area.

In the formula of Moore (1935) the wave action considered is the average. The average amount of wave action is important in maintaining the spray for intertidal organisms but it is the extremes of action that will kill or injure intertidal organisms. Heavy gales or protracted calms will both have a deleterious effect on the flora and fauna. For this reason averages have been kept out of the proposed formula as much as possible. Similarly meteorological data have been kept to the minimum, as figures of this nature may not be readily available in many places that are being studied.

The formula proposed is based on sea depth and character, M, wind force encountered (either recorded at any time or observed at time of visiting), W, the distance covered by the wind over water, D, and the topography, T.

Three types of sea are recognised—oceanic, *o*, continental shelf or other moderate depth, *c*, and shallow water less than 10 fathoms in depth *s*. Each of these types usually has its own characteristic wave types, the long oceanic swell of great power, the sharp seas of a continental shelf and the comparatively weak seas of shallow water. The *s* factor is included to provide for such places as lagoons, land locked bays and shallow estuaries. Coral lagoons which are usually of 25 to 30 fathoms depth would also be included under the *s* factor.

The wind factor is expressed in terms of the speed of wind observed in terms of the Beaufort Scale. This is the only quantitative force used but it is impossible to avoid doing so. If, in a general work, it is not desired to give an actual observed figure for wind strength, a comparative force can be given which will show the approximate wind strengths liable to be encountered in a yearly period. To ensure that this is not to be taken for a wind variation over a short period the Beaufort Scale readings should be placed in brackets, e.g. (2-8).

The distance covered by the wind over water is defined fully below.

The topographic factor is the most difficult to define. There are two easily recognised types of coast, the open coast and the sheltered coast. The former comprises such places as rocky headlands while the latter includes bays, estuaries, lochs, &c. Within each of these two major groups there can be recognised three further topographical types of coast. These are the fully exposed rock face and the sand-surf beach, semi-protected localities and protected places such as rock clefts. For the purposes of this work the fully exposed rock face and the sand-surf beach are defined as having no protection whatsoever. A semi-protected position is one which is protected from full wave action, e.g., a surf beach with an off-shore reef, a headland-protected bay on an open coast, &c. A protected place is one in which there is little wave action, e.g., a shore facing rock face.

The factors are thus—

M (marine)	*o*, oceanic.	
	c, continental shelf.	
	s, shallow waters of less than 10 fathoms.	
W (wind)	The force of wind given in Beaufort Scale. This is given as an absolute figure for the time of observation or as a range encountered over 1 year (in brackets).	
D (distance)	0, less than 100 yards.	
	1, 100 yards to 1 mile.	
	2, 1 mile to 20 miles.	
	3, 20 miles to 100 miles.	
	4, greater than 100 miles.	
T (topographic)	*a*, exposed coast;	3, fully exposed surfaces.
		2, semi-exposed surfaces.
		1, fully protected surfaces.
	b, sheltered coast;	3, exposed surfaces.
		2, semi-exposed surfaces.
		1, fully protected surfaces.

The factors *a*, 1, 2, 3 and *b*, 1, 2, 3, being factors of degree of wave action have been given in the above order for convenience in working and to avoid a division factor.

A few hypothetical examples will illustrate the operation of this formula.

Example 1.—An open rocky coast on a volcanic island in mid-ocean in a gale force wind will suffer wave action equivalent to *o* 8 4, *a* 3. These factors should never be multiplied out.

Example 2.—A shore on the leeward side of the same island would have a wave action equivalent to *o* 0 0, *b* 1. In this case the shore, being completely protected by an off-shore wind would be suffering virtually no wave action which justifies it being placed in a *b* 1 category.

Example 3.—A semi-protected place in a bay of 5 fathoms depth on a sheltered coast with light airs would have an equivalent of *s* 1 0, *b* 1.

Flexibility has to be allowed in the choice of the category of the coast, as indicated in Example 2. In this example an off-shore rock would have a very different equivalent.

While there exist many disadvantages to this formula it does give some factor which is of comparative value. It may be cumbersome but practice in use soon overcomes difficulty of this nature. It has been used in several places in Tasmania and has been found to function satisfactorily. With practice one can read off the actual position and relation of an organism to its immediate environment.

The personal element will figure in all estimations as to whether an area is protected or exposed. The author has in mind for a protected place some area or spot where the wave action is never more intense than that produced by 6 inch waves. In a comparative work it is suggested that the formula should include the maximum exposure conditions liable to be encountered in the area being studied.

(f) Zonation

Fischer (1940) recognised two major zones on the shore at Hobart. The upper of these was populated by *Melaraphe unifasciata* (Gray) and the lower had *Galeolaria caespitosa* Lam. as the dominant form. He further states that these zones are certainly comparable to those defined for Sydney by Hedley (1915). He was not able to describe the zone separating the *Galeolaria* zone from the *Laminarias*, in this case *Macrocystis pyrifera* (Turn.).

The coast falls into the Supralittoral zone, the Supralittoral fringe, the Mid-littoral zone, the Infralittoral fringe and the Infralittoral zone as defined by Stephenson and Stephenson (1949).

METHODS

The rocky parts of the shore were divided into a series of transects, each of which was studied in detail. The transects were taken at varying distances from each other along the shore. Only the more interesting of these are described. In many instances the transects were too close together and they merely served as checks on previous sections. The method broadly followed that described by King and Russell (1909). The relation of the zoning to the tidal levels was studied. Population counts were taken at various levels on the shore. The method of doing this was by the use of four rulers placed in the form of a square. By this method a variable area could be studied without the necessity of constructing wooden squares of various sizes. Certain difficulties were experienced on vertical faces but the use of elastic bands to hold the rulers together was found satisfactory. Attempts were made to dredge the Infralittoral zone but these were not successful. Due to the steep gradient into deep water at the edge of the platform it is doubtful if the results, had they been obtained, would have been valid.

TRANSECT 1. (PLATE 2)

Station	On rock platform at the seaward edge of Pinnacle Point at the South end of Blackman's Bay.
Dates	20th June, 1948, and various dates subsequent to this.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	Transect runs from the North end of the base of the Pinnacle straight out across the platform towards the East side of the estuary (Plate 2). The platform is not wholly covered by the sea at H.H.W. (For tidal terms see Part IV of this work.) If there is a heavy swell surf crashes over most of the platform at nearly all phases of the tide. The line of transect is intersected by three channels which are to be regarded as sublittoral fringe in affinities.
Geology	The platform is worn along the bedding planes of the mudstone which dips at varying small angles to the West.
Tidal data	From the Hobart Recorder.
Physical environment	As in Parts III and IV and subsection *c* above, page 168.
Zonation	The basic zonation of the transect is as follows:— *Melaraphe unifasciata* (Gray), *Bembicium nanum* (Lam.) barnacle sps., *Galeolaria caespitosa* (Lam.). 'Patelloid' zone, *Mytilus planulatus* (Lam.) and *Laurencia botryoides* Gaillathoid.

The correlation of these belts with tidal levels is shown in Table V.

TABLE V

The basic zonation, Transect 1, Blackman's Bay area, and its relation to the major intertidal zones and tidal levels. Tidal levels are in terms of Recorder Datum.

Melaraphe unifasciata (Gray)	Supralittoral Fringe	Above 11 feet 7 inches.
Bembicium nanum (Lam.)	Midlittoral Zone	This zone is obscured in lower levels.
Barnacle species	Midlittoral Zone	10 feet 5 inches to 11 feet 7 inches.
Galeolaria caespitosa (Lam.)	Midlittoral Zone	9 feet 10 inches to 10 feet 5 inches.
Patelloid	Midlittoral Zone	9 feet 1 inch to 9 feet 10 inches.
Mytilus planulatus (Lam.)	Midlittoral Zone	7 feet 11 inches to 8 feet 7 inches.
Laurencia botryoides (Gaill.)	Infralittoral Fringe	Below 7 feet 11 inches.

Detailed Description of Transect

In the Transect (Fig. 25) *Bembicium nanum* does not occur at the edge of the platform. The reason for this is possibly that there is greater wave action at the edge of the platform and this species does not favour such action. The species is found at the upper end of the platform where wave action is much less severe. The extreme seaward edge of the platform is approximately two feet above the level of the rest of the platform. This portion of the transect is not covered by the tide but surf breaks over it during heavy weather. The effect of this wave action is seen in the raised levels at which the forms living there are found. The *Melaraphe unifasciata* living on the top of this ridge is not a pure population being mixed with some *Enteromorpha* and a few barnacles. The ridge is just high enough to permit the existence of the Gasteropod.

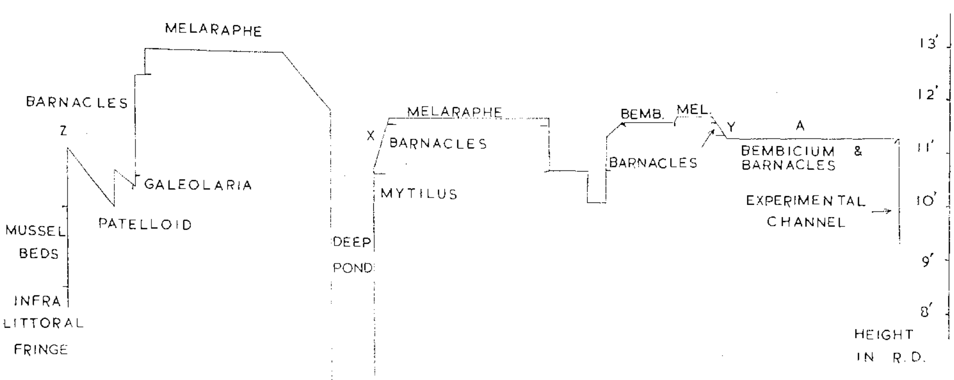


FIG. 25.—Transect 1, Pinnacle Point, Blackman's Bay. Only the major features of the zonation are shown. Horizontal scale, 1″ = 3′; Vertical scale, 1″ = 12′.

(1) The Supralittoral Zone

In the transect under consideration the Supralittoral zone is composed of bare rock with no lichens. One or two small stunted plants of *Salicornia* sp. are found around the base of the Pinnacle while on the cliff face are *Mesembryanthemum acquilaterale* Han., *Tetragona inflexicorna* Hook. and *Casuarina distyla* Vent. Numerous small terrestrial animals inhabit the cliff face such as lizards, rabbits and bandicoots.

(2) The Supralittoral Fringe

The sole mollusc inhabitating this belt is *Melaraphe unifasciata* (Gray). This species shows a very great salinity toleration having been collected in pools from which all water had evaporated leaving salt crystals. It has also been collected in rain water pools. The species seems to be able to remain alive for considerable periods without immersion in water.

Experiment 1.—Determination of the period for which *Melaraphe unifasciata* can remain alive without water.

Individuals of this species have been kept in glass jars without water for various periods of time. No attempt was made to desiccate the air in the jars as it was desired to obtain the period the animals could live under natural conditions. The air used was that in the laboratory and it must be regarded as drier than that encountered in nature, which is often spray laden. Controls were kept living in an aquarium tank half filled with sea water which was being aerated. A few individuals were removed from the experimental jars and control aquaria after varying periods of time. On placing these individuals in sea water the foot was always extended, usually almost immediately. Some individuals took up to five minutes to extend the foot. This greater time did not bear any relation to the length of time the molluscs were without water. It is probably an individual characteristic and stresses the importance of using at least half a dozen specimens at each examination. After a period of 70 days without water, specimens placed in sea water all took nearly 5 minutes to extend the foot. After 74 days without water some individuals extended the foot only after 10 hours. Others were dead. It is therefore concluded that a period of over 70 days without water is likely to lead to individual deaths and that specific death will ensue after a period of more than 74 days. This is a much longer period without water than would ever be encountered under natural conditions.

From the combination of observations in nature and the above experiments it can be concluded that *Melaraphe unifasciata* is not mortally affected by short term extremes of salinity and it can resist any period without water which it is likely to encounter naturally. Broekhuysen (1940) has shown that there exists a close correlation between the salinity at which a species ceases to crawl and the vertical distribution of that species. In *Melaraphe unifasciata* crawling was greatly inhibited at a salinity of 16·0 grs./mille. and ceased at approximately 14·0 grs./mille. These figures are not as low as those given for *Littorina knysnaensis* Philippi by Broekhuysen (1940).

In the particular transect under consideration there are no other macroscopic animals occurring in this belt. A lichen, which I have been unable to identify, is found very sparsely in the belt. It is the only plant species found.

Exposure in the Supralittoral fringe varies from 100 per cent to 98 per cent in January (the month of maximum exposure) to 74 per cent to 90 per cent in May (the month of minimum exposure). These figures are based on the levels at the landward end of the transect and not the elevated levels at the end of the platform. The percentage exposure is obtained from the monthly exposure curves in Part IV of this work.

(3) The Midlittoral Zone

Within this zone there are five belts. Reading from the top of the zone down they are the belts of *Bembicium nanum*, a barnacle belt, *Galeolaria* belt, a *Patelloid* belt and a *Mytilus planulatus* belt. Distributed throughout the belt is the lichen noted above. It reaches maximum development in the barnacle belt.

Bembicium nanum is dominant in the upper region of the Midlittoral. It follows immediately below *Melaraphe unifasciata*. At the junction of these two belts there is a mixing of the two species forming a narrow mixed band of some 3 inches vertical width. This mixing is a feature of the upper and lower limits of most of the belts seen.

The belt may be submerged at 'high high' water with the minimum exposure in May (51 per cent) and the maximum exposure in January (98 per cent).

A parallel experiment to that described above (Exp. 1) was carried out on individuals of *Bembicium nanum*. The results of Experiment 2 showed that specimens of *Bembicium nanum* died at various times between 51 and 59 days after their last immersion in water.

Individuals of *Bembicium nanum* have been collected well down in the barnacle belt which follows below their normal zone.

The barnacles are chiefly of three species, *Elminius modestus* Darwin, *Chamaesipho columna* (Spengler) and *Chthamalus* sp. The barnacles are found on the surface and on the seaward edge of the platform. The species on the latter place are mostly *Chamaesipho columna* and *Chthamalus* sp., but those on the surface of the platform are of the three species noted above. The *Chthamalus* sp. extends further up the shore than does *Elminius modestus* while *Chamaesipho columna* is the most restricted in distribution, being confined to the lower parts of the zone. The upper limit of *Elminius modestus* is about the lichen patches described below.

The barnacles prefer places which are sheltered from strong insolation and, at the same time, exposed to some wave action. The barnacles are largest and most numerous on the seaward face of the platform. Here they experience early morning sun and are exposed to the full amount of wave action. Where there are similar conditions of sun exposure but less wave action the barnacles are small.

The barnacles on the exposed face reach their maximum development at a height of 11 feet 2 inches, Recorder Datum (R.D.). Above or below this level they decrease in size (Table VI and Fig. 26). The theoretical exposure at this level varies from 90 per cent in January to 62 per cent in May, but is of very little value as spray from waves must alter the exposure considerably. While spray is able to reduce the amount of desiccation that a species has to suffer, it does not offer the same opportunity for feeding as does constant immersion. In the case of plankton feeders such as barnacles the upper limit of their vertical distribution will be controlled by the factors of desiccation and exposure in the most general sense and also by the time available for the obtaining of food. In the particular case under consideration the increase in exposure during the summer will be to some extent off-set by the shelter obtained from the sun.

TABLE VI

Relation between the size of barnacle and the level on the shore at which it is found.

Size of barnacle in mms.	Level on shore in R.D.	Size of barnacle in mms.	Height on shore in R.D.
5.0	13′ 2″	14.1	11′ 8″
5.75	12′ 11″	15.5	11′ 5″
6.90	12′ 8″	16.9	11′ 2″
7.75	12′ 5″	13.0	10′ 11″
10.0	12′ 2″	10.9	10′ 8″
12.0	11′ 11″	7.75	10′ 5″

Individual barnacles living at the same or even lower levels than those on the face of the platform are much smaller in size than the exposed barnacles. Those which are subjected to isolation on the horizontal rock surfaces are rarely more than 5·0 mm. in height.

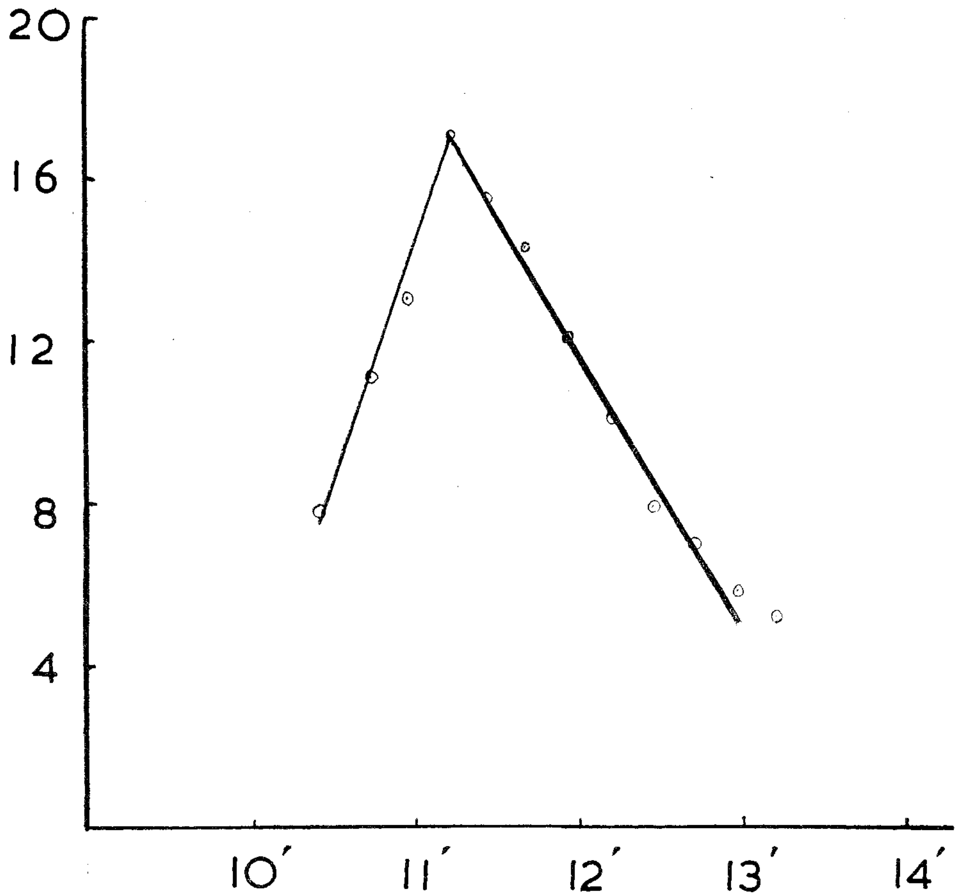


FIG. 26.—Graph of the relation between the size of barnacle in mms. and the height on the shore at which it is found.

The lateral plates of the barnacles on the seaward face of the platform project above the terga. There is a correlation between the amount of this projection and the height of the barnacle on the shore (Table VII and Fig. 27). There is also some correlation between the size of the barnacle and the amount of the above projection but this is obscured by the fact that many of the lateral plates have been broken. In all the above cases the figures are based on an average of a count of 10 individuals in a restricted area. It is not possible to count more individuals as a change in the conformation of the rock gives a change in the form of the barnacle. A barnacle growing on a cleft in the rocks is larger than one growing on a level surface. Specimens growing on a vertical surface may differ from either of the above.

TABLE VII

The height of the lateral plates of barnacles above the terga in relation to the level on the shore at which the barnacles are found.

Height on Shore in R.D.	Overlap of plates in mms.	Height on Shore in R.D.	Overlap of plates in mms.
13′ 2″	1.8	11′ 8″	3.2
12′ 11″	2.0	11′ 5″	4.0
12′ 8″	2.0	11′ 2″	5.0
12′ 5″	1.8	10′ 11″	5.5
12′ 2″	2.2	10′ 8″	6.75
11′ 11″	2.5	10′ 5″	7.75

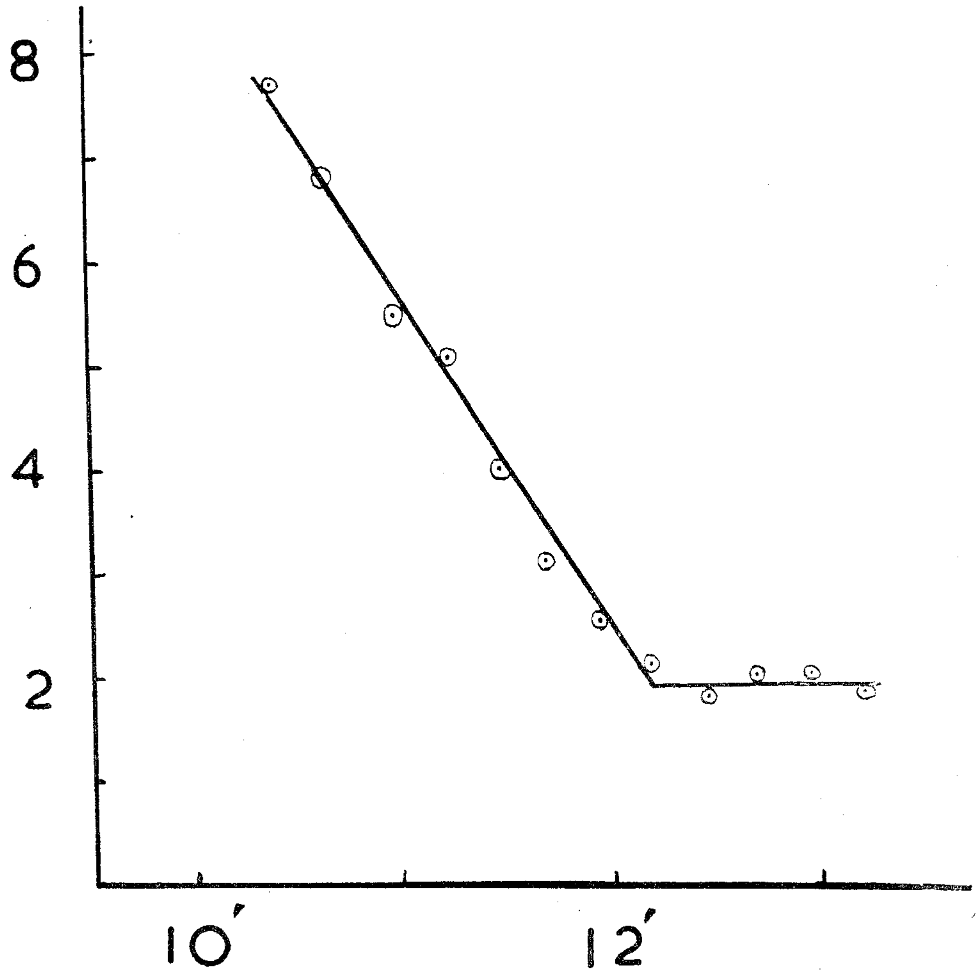


FIG. 27.—Relation between the height at which a barnacle is found on the shore and the distance the lateral plates project above the terga (in mms.).

Barnacles are most numerous at the seaward end of the platform, an average of three 'picked random' counts being 210 individuals per 10 cm. square. A 'picked random' count may be defined as a count taken at random in an area picked out as not showing any specialized or abnormal features. On the top of the platform at the seaward edge, where the spray must not be very much less than that experienced by the vertical face, the number of individuals per 10 cm. square is only 45.

On the upper surface of the platform, at A on the transect (Fig. 25), in a mixed belt of *Bembicium nanum* and *Chthamalus* sp., there occurs an irregular patch of lichen. This patch is approximately 4 feet in length and 5 feet in width. The rock between the lichen is densely populated by *Elminius modestus*, *Chthamalus* sp., *Bembicium nanum*, young *Melaraphe unifasciata* and the Lamellibranch *Lasaea australis* (Lam.). The density of population of the various species both in the lichen patch and on the surrounding rock is shown in Table VIII.

TABLE VIII

The density of population of certain animal species on a lichen patch compared with those on nearby bare rock.

Species	Numbers on lichen	Numbers on bare rock
Elminius modestus Darwin and *Chthamalus* sp.	100 to 146 per 10 cm. sq.	29 per 10 cm. sq.
Bembicium nanum (Lam.)	12 per 30 cm. sq.	1 to 3 per 30 cm. sq.
Melaraphe unifasciata (Gray)	90 per 10 cm. sq.	Nil
Lasaea australis (Lam.)	40 per 10 cm. sq.	Nil

The lichen only formed dense patches at two places on the whole platform. The reasons for this limited distribution are somewhat obscure. The substratum chosen by the lichen for dense colonization is pitted by numerous hollows up to 3 inches in diameter. Similar areas of rock at the same level are to be found on the platform but the dense lichen only occurs at one other place with a smoother substratum.

As the barnacles *Elminius modestus* and *Chthamalus* sp. are widespread on the platform at the level of the lichen patches, the increase of numbers per unit area in these patches must be regarded as correlated with the presence of the densely packed lichen. Where the lichen occurs as very small patches there is no increase in the numbers of barnacles per unit area. The retention of moisture by the lichens is the probable reason for the increase in the population of the barnacles and other species. The lichen would further give assistance to the barnacles at the most critical period of their life history, namely at the time of settling of the cyprid larvae. The lichen would act as a sieve which would arrest the larvae prior to their settling. It would also assist the larvae to remain in the one area when, as has been shown by Visscher (1928), they are testing the substratum before fixation. Shelter from insolation would give a greater percentage successful spatfall. Pyefinch (1948) has shown that in the case of *Balanus balanoides* the settlement is confined primarily to cracks, crevices and other irregularities of the surface. The lichen will virtually increase the number of crevices on the platform surface.

The lichen also offers protection for the Gastropods and *Lasaea australis*. This Lamellibranch does not occur on the surrounding platform and its presence here in such large numbers gives some indication of the intertidal population, that might be encountered, if there were some algae capable of colonizing the region.

The exposure in the belt is 18 per cent to 100 per cent in May and 48 per cent to 100 per cent in January. It must be emphasised that these figures are based on the barnacles situated on the vertical face at the end of the platform. More valid figures may be obtained by considering the barnacles further back on the shelf towards the Pinnacle. The exposure for barnacles at X (Fig. 25), a sun- and wave-sheltered channel, are 18 per cent to 58 per cent in May and 48 per cent to 90 per cent in January. At Y, a sun exposed and wave sheltered place, the figures for May are 40 per cent to 58 per cent and in January 82 per cent to 90 per cent. These figures, being based on average tidal levels for a month, do not take into account the extremely high tides which may be encountered, nor do they allow for the above average normal high tide.

The barnacle *Ibla quadrivalvis* Cuvier is found in clefts in this belt. It is not common and occurs within the range of *Elminius modestus*.

The serpulid worm *Galeolaria caespitosa* (Lam.) forms a belt of calcareous tubes below the barnacles (Plate 1). The upper limit of the *Galeolaria* belt is mixed with barnacles. The lower limit extends down into the *Mytilus planulatus* belt.

The belt is not extensively colonized by other forms. This is due partly to the intensity of serpulid colonization and to other reasons which will be discussed below. The worm tubes do not produce masses up to 6 inches deep such as have been found in other places in Tasmania, but form a thin continuous incrustation not more than two tubes thick. On a vertical face the width of the pure belt rarely exceeds 4 inches.

Exposure in the *Galeolaria* belt is from 15 per cent to 22 per cent in May and 60 per cent to 73 per cent in January.

The worm tubes extend into the next belt, that of several *Patella*-like organisms, namely *Patelloida alticostata* Angas, *Siphonaria diemenensis* Quoy and Gaim. and *Cellana variegata* (Blainville).

The zone is well defined. The upper levels are invaded by *Galeolaria* and a few *Elminius modestus* and *Chthaimus* sp. The lower levels are invaded by a few small *Catophragmus polymerus* Darwin. In the lower part of this belt there is to be found a sub-belt of *Brachyodontes rostratus* Dunker. The belt is not continuous but occurs regularly at this level on different parts of the coast and is of sufficient importance to warrant inclusion as a sub-belt. These mussels prefer to live in clefts but are also found on flat rock surfaces. The sub-belt is not more than 6 inches in vertical height. *Lasaea australis* occurs very plentifully among the byssus strands of the mussel, as do also occasional individuals of the crab *Helice haswellianus* (Whitelegge).

Other species encountered in the belt are *Tetraclita purpurascens* (Wood), *Patelloida marmorata* Gaim., *Patelloida conoidea* Quoy and Gaim. and *Patelloida cantharus* (Reeve).

The density of population of this belt is not very high. *Siphonaria diemenensis* numbering 26 per 30 cm. sq. and *Brachyodontes rostratus* 10 per 10 cm. sq. Where *B. rostratus* does occur it is usually closely packed but the area thus occupied may be very small. The barnacle *Tetraclita purpurascens* is very rare, only one being noted during the examination of the whole platform.

The exposure in the *Patelloid* belt is 8 per cent to 38 per cent in May and 26 per cent to 82 per cent in January. As the belt is only found where there is some wave action the upper limits of exposure are modified by splash.

The lower limit of the Midlittoral is marked by large beds of the mussel *Mytilus planulatus* Lam. These beds occur mainly on the shelf at the seaward end of the platform (Plate 2). It is possible to collect on these beds only at 'low low' water with a calm sea. Only a few mussels are found in the channels which intersect the platform.

The mussels are closely packed and several layers deep. They form a protective layer to a varied fauna living below them and also serve for the attachment of other sedentary forms. A space of about 1 inch separates the mussels from the rock. The substratum is covered by a thin layer of silt, debris, valves of Lamellibranchs and excreta. The efficiency of the mussels in reducing wave action can be seen from the presence of this fine deposit.

The mussel association may be considered in terms of the epibiose, hypobiose and endobiose of Gislén (1930). The epibiose fauna and flora consists of those forms dwelling on the mussels, the hypobiose is formed of animals dwelling below the mussels and the endobiose comprises a few burrowing forms which live in the silt. To these must be added a few forms dwelling inside the mussels. The hypobiose contains most of the fauna of the mussel beds.

The forms dwelling on the outer surfaces of the mussels are mainly barnacles and algae. The most common barnacles are *Elminius modestus*, *Chthalmus* sp. and *Catophragmus polymerus*. Other species to be found are *Tetraclita purpurascens*, *Elminius simplex* Darwin and *Chamaesipho columna*. The lateral plates of the barnacles living on mussels in the lowest part of the beds have a red-brown microscopic alga living on them. The alga does not form the 'age indicators' as described by Parke and Moore (1935) nor does it appear to be penetrative.

Algae are not common living on the outside of the mussel shells. *Ulva lactuca* L., *Polysiphonia* sps., *Gigartina* sps. and *Laurencia botryoides* (Gaill.) are the most common species to be found. *Ulva* sps. are very frequently found associated with mussel beds in different parts of the world. Cotton (1910) noted that the mussels formed a suitable substratum for this alga.

Inhabiting the algae are several species of annelid worms, mostly of the genus *Nereis* and *Leptonereis*, numerous amphipods, including *Megamoera diemenensis* Haswell and a tanaid. The tanaid is very common. One small *Polysiphonia* plant about 5 inches in height harboured thirty of these crustaceans.

Dwelling below the mussels are very large numbers of a crab of the family *Porcellanidae (?Petrolisthes* sp.*)*. There are more than 100 individuals of this species to the 30 cm. sq. Various species of amphipods are very numerous. These crustaceans swim in the water when it is still and as soon as a wave comes in they seize hold of whatever firm object happens to be at hand.

The flatworm *Leptoplana australis* Laidlaw is very plentiful in dead mussel shells. As many as 12 have been taken from one shell but not all of the dead shells are inhabited by them.

Other species found below the mussels are *Cominella lineolata* (Lam.), *Patelloida alticostata* Angas, *Patelloida conoidea* Quoy and Gaim., *Venerupsis diemenensis* Quoy and Gaim., *Ostrea virescens* Angas, *Monia ione* Gray, *Helice haswellianus* and a *Cancrid* Decapod. There are also many species which I have not found possible to identify, such as several isopods, three species of anemone and some simple ascidians. It is worth recording that these latter are not *Pyura praeputialis* (Heller).

The endobiose consists of several burrowing worms which live in the silty deposit below the mussels. The only other burrowing form present is *Saxicava australis* (Lam.).

Living inside the mussels are numerous specimens of the pea crab *Fabia hickmani* Guiler. A considerable proportion of the mussels are infected by these crabs (Guiler, 1949). Two specimens of the crab *Halicarcinus ovatus* (Stimpson) have been found inside mussels. It is thought that this infestation was accidental as the crab is common below the mussels and has also been found on *Corallina*. An amphipod was found on one occasion living on the edge of the mantle of a mussel. Only one specimen was noted in this habitat. Its occurrence there may have been accidental.

The lower limit of the mussels is very sharp. They are replaced by a thick mat of *Laurencia* sps. The conclusions of Kitching (1937) that slow growing perennials choke other forms and eventually dominate colonization of the upper Sublittoral probably apply to the area under consideration.

The depredations of certain non-intertidal echinoderm species are suggested by Newcombe (1935) as the reason for the sudden lower limit of the mussels in some East Canadian beds. In the absence of similar species on the Tasmanian beds the conclusions of Kitching offer the only possible explanation for the sharp delineation of the mussels in Tasmania.

The mussel community can be compared with that described by Newcombe (*loc. cit.*). The most salient feature is the richness of the algae of the Canadian mussel beds in comparison with the poverty of the Tasmanian beds. Newcombe records 17 species, some of which, such as *Fucus vesiculosus* L. and *Ascophyllum nodosum* Le Jol are very common and rank as co-dominants. The Canadian beds are preyed upon by many more carnivorous types than have yet been found on the Tasmanian beds. The majority of mussel deaths on the former are attributed to starfishes, urchins and *Nucella lapillus* (L.).

It may be noted here that all the mussels in Southern Tasmania are not intertidal. Individuals of the same species as the majority of the intertidal specimens, *Mytilus planulatus*, are found in several fathoms of water, mostly in sheltered bays. The lack of air exposure does not seem to have any deleterious effect on the mussels, though it has been shown by Young (1946) that exposure to air assists spawning.

The time of the year at which the Tasmanian mussel spawns is not known. It may be noted that the North Pacific mussel, *Mytilus californianus*, spawns all the year round with maxima in October and the spring (Whedon, 1936, and Young, 1946).

Mussel beds are not found in sheltered places. Some wave action is essential to the well-being of mussels. Fox and Coe (1943) have shown that finely divided detritus constitutes more than four-fifths of the food of *Mytilus californianus*. In the beds under consideration the sea is rarely completely calm and there is also a quantity of suspended matter brought down by the river. The sea is also fairly rich in coastal plankton. These conclusions could not be applied to dredged mussels from sheltered inlets. The problem there is different due to the lack of algae to restrict growth. There is little wave action to stimulate the mussels but there is usually a considerable amount of suspended matter.

The exposure of the mussel beds varies from 0 per cent to 8 per cent in May to 0 per cent to 27 per cent in January.

(4) *The Infralittoral Fringe*

The Infralittoral fringe is represented by two distinct types of shore. The exposed end of the platform and the exposed channels at the South end of the platform are both very similar in appearance but the channels at the North end are sheltered from the most severe weather and present a very different facies from the exposed places.

The exposed channels and the edge of the platform are characterized by the sudden appearance of the algae as the dominant type. A dense algal mat of *Laurencia* sps., *Polysiphonia* sps. and several red algae immediately replaces the mussels. As an overcurtain to this there is a forest *Xiphophora* sp., *Macrocystis pyrifera* (Turn.) Agardh. and the ascidian *Boltenia pachydermatina* Herdm. The detailed fauna of these channels and the vertical face of the platform is difficult to examine as there is deep water immediately off the edge of the platform.

The channels on the North side of the platform are all, with the exception of one, short and shallow. The exceptional one crosses the platform from North to South but is very high up on the shore and is only filled at 'low high' and 'high high' tides. There are boulders of varying sizes in the bottom of these channels which furnish protection for a varied fauna.

The great majority of the fauna of the Northern channels falls very sharply into the hypobiose of Gislén. Among these species are *Plaxiphora albida* (Blainville), *Scutus antipodes* Montfort, *Subninella undulatus* (Martyn), *Macrochisma tasmaniae* Sowerby, *Haliotis noevosa* Martyn, *Cominella lineolata* (Lam.), *Patelloida inradiata* (Reeve), *Patelloida conoidea* Quoy and Gaim., *Fusinus novaehollandiae* Reeve, *Halicarcinus ovatus* (Stimpson), *Astacilla derwenti* Guiler (on *Polysiphonia* sp.), *Strongylocentrotus erithrogrammus* (Val.), *Coscinasterias calamaria* (Gray), *Stichopus mollis* (Hutton), *Tosia australis* Gray, *Patiriella calcar* (Lam.), *Patiriella exigua* (Lam.), *Tedania bispinata* Hentschel, *Tethya diploderma* Schmidt, *Hymeniacidon perlevis* (Montagu), *Actinia tenebrosa* Farqu. and *?Oulactis muscosa* Andrés. Among many unidentified species are an *Aplysia* sp., bryzoans, isopods, amphipods, hydroids, a crinoid, tanaids, a *?Petrolisthes* sp. crab, polynoid worms, a tectibranch and an anemone *(Sagartidae)*.

The algae are mainly of several species of *Polysiphonia*, *Cystophosa*, *Ulva lactuca*, *Corallina* sps. and *Lithothamnia*. The term *Lithothamnia* is used to cover all *Lithothamnion*-like forms.

TRANSECT 2

Station	At the North end of Blackman's Bay on the rock platform beside the deep channel.
Date	June, 1948, and various suhsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The transect runs in a Southerly direction to the sea from the low cliffs at the seaward side of the channel near the road. The platform is of a different nature from that described in Transect 1, since the waves sweep across it in rough weather. The platform has been formed by action at approximately right angles to the dip of the beds.
Geology	Mudstone. The beds are weathered along the strike.
Tidal data	From Hobart Recorder.
Physical environment	As in Parts III and IV.
Zonation	It is not intended to give full details of the zonation and associations of this and the following transects but to concentrate on the differences between the transects and that described above.

The poverty of the population of the upper Midlittoral zone and the Supralittoral fringe is further accentuated in this transect by the absence of a belt of *Bembicium nanum.* At the seaward end of Transect 1 it was seen that the barnacles are immediately replaced by *Melaraphe unifasciata.* This was attributed to wave action. The sweeping effect of the waves across this platform has resulted in the elimination of the zone of *B. nanum.* The probable reason for the lack of toleration of wave action of this species lies in the comparative inability to remain in position under heavy surf or waves. The shell is much larger than that of *Melaraphe unifasciata* and the animal cannot hide in small clefts and so avoid most of the wave forces.

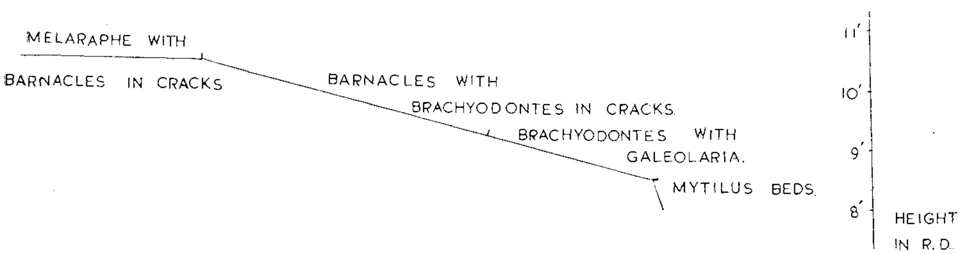


FIG. 28.—Transect 2, South end of Blackman's Bay. Scale as in Fig. 25.

In spite of the increase in wave action over the platform in rough weather compared with that encountered in Transect 1, the levels at which organisms are encountered are very much lower than in that transect (Fig. 28). Some species, such as *Brachyodontes rostratus*, are found high up on the shore living in clefts. The latter species is found at 10 feet 6 inches R.D. It is immediately replaced by *Melaraphe unifasciata* with *Chthamalus* sp. in clefts. The majority of species are found at a lower level than in Transect 1. This general depression of zones can be correlated with the fact that the dessication encountered in calm weather is greater than that met with in Transect 1.

In calm conditions there is little spray or wave action on this platform. The difference of exposure at the edge of the platform at Pinnacle Point as compared with the exposure at this platform is probably in the order of 20 per cent to 40 per cent. There is also a greater exposure to summer sun on this platform and the angle of inclination of the platform is such that the rays of the sun strike the rock at an angle which is nearer to a right angle than on the platform at the other end of the bay. The presence of *Brachyodontes rostratus* at such high levels is a feature for which there is no obvious explanation.

To the seaward edge of this platform is a vertical face of rock which is fully exposed to waves (Fig. 29). The lower part of the barnacle belt is populated by *Melaraphe praetermissa* May. Below this is a thin belt of *Brachyodontes rostratus* which is followed by *Mytilus planulatus.* There is no serpulid belt.

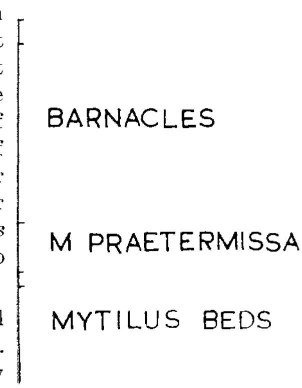


FIG. 29.—Section at seaward end of the platform at Transect 2.

Transect 3

Station	On the second platform North of the Blow Hole at Blackman's Bay.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The transect runs to seaward from the foot of the high cliffs at the North end of the platform. A deep water channel runs in beside the platform. Where the platform has been worn down to the level of the water in this channel waves sweep on to the platform (Plate 1).
Geology	On West dipping mudstone.
Tidal data	From Hobart Recorder.
Physical environment	As in Parts III and IV of this work.

The salient feature of this transect is the sweeping action of the waves on to the platform at the places where the mudstone has been worn along the bedding planes and has reached the level of the water in the deep channels bounding the platform. The extreme of this is seen at the cliff foot. The end of the deep channel being at the foot of the cliffs there is a ' build up ' of water at each wave. This causes a rush of water across the platform at the base of the cliff. Thus we find a modified lower Midlittoral zone at the foot of the cliffs. This zone is populated by *Mytilus planulatus, Catophragmus polymerus, Hormosira banksii, Corallina* sps., *Actinia tenebrosa* and a few *Galeolaria caespitosa.* The mussels are of average size but do not form beds, preferring to live in clusters. A few *Halicarcinus ovatus* crabs are found among the byssus strands of the mussels. The mussels are found at a height of 11 feet 1 inch R.D., or three feet above those at the edge of the platform. To some degree the mussels are assisted to live at this level by the shelter afforded by the high cliffs which reduce insolation and possibly rainfall. In the transect waves wash the platform in three places which are indicated by the presence of *Coralline* algae.

At the foot of the cliffs the barnacle zone is greatly reduced. Barnacles are only found in clefts and even in this habitat they are rare. The decrease in numbers takes place quite suddenly just above the top of the *Galeolaria* belt at about 12 feet 6 inches R.D. This is due to the very poor splash effect of waves travelling parallel to a cliff face. The effect is further accentuated by the fact that the cliff is undercut to a depth of about 1 foot.

The chiton, *Sypharochiton pellis-serpentis* (Quoy and Gaim.), occurs very plentifully on this platform. In the two previous sections it was found in pools and clefts but here it is dominant on one of the rock faces. It occurs in the *Patelloid* belt.

In the more wave sheltered parts of this platform *Actinia tenebrosa* has become established in the mussel beds. This anemone occupies small areas of rock in the mussel beds which it keeps free of other forms. The anemones must move around the cleared area.

Transect 4

Station	On the rock platform at Perameles Bay.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.

Description	The transect runs out from the base of the cliffs to the right of the path down to the shore. Most of the platform is covered by the sea at 'high high' water.
Geology	Mudstone.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

It may be noted here that this bay, Perameles Bay, is reached by a steep cliff path which runs down a gully beyond the Blow Hole.

The basic zonation seen on this transect is the same as that seen on Transect 1. Once again, the absence of *Bembicium nanum* is to be noted due to the sweeping action of the waves surging across the platform. The most interesting feature is to be seen at the foot of the cliffs at the landward end of the transect. Here the belt of *Patelloida alticostata* appears above that of *Elminius modestus*. In the actual section the reason for this is not immediately apparent. The belt of *Patelloida alticostata* commences at a height of approximately 12 feet R.D. and ends at 12 feet 6 inches R.D. This would give an exposure in January of 100 per cent which the limpet could not tolerate. The reason for the reversal of zones is to be seen in the general topography of the area to the South of the transect.

A deep channel cuts into the platform in an East to West direction immediately to the South of the transect. This platform ends at the foot of the cliffs. Waves sweep up the channel and cause considerable spray, without the waves themselves covering the base of the cliff. This spray has been sufficiently great to raise the faunal levels. Wave action also will raise the faunal levels but there is an important difference in the effects of the two factors. Spray acts in a differential fashion on the intertidal forms whereas wave action raises the general levels at which the species are to be found. Spray is of little use to plankton feeders in obtaining food and these types will be confined to wave washed areas but browsing species, algae and some carnivores will receive sufficient moisture to live well above the area washed by the waves. In this case the barnacles are limited in their vertical distribution, not by the amount of exposure to which they are subjected, but by the amount of feeding time they have at their disposal. The limpets are limited by the exposure toleration of themselves or their food. In places where wave action is not accompanied by exceptionally heavy spray, the vertical distribution of the intertidal forms is dominated by the wave action, but in places where the spray is greater than might be expected it is the latter that controls the distribution of species on the shore.

TRANSECT 5

Station	On the rocks between Kingston Beach and Blackman's Bay.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The section is nearly vertical on the first igneous intrusion along the shore from Kingston.
Geology	Dolerite.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

In this transect the Patelloid belt is absent. On all of the dolerite outcrop limpets are very rare and do not form a belt at any place. In the transects the serpulid belt is also greatly reduced and in some places it may be absent. When the serpulid belt is absent barnacles inhabit the space thus made available. In the transect the barnacle belt extends below the mussels and the dominant barnacle is *Catophragmus polymerus*. The density of the population of this species is 18 per 10 cm. sq. This apparent downward extension of barnacle zones is to be seen on all the igneous rock.

The igneous rock shows more diversity of zoning than does the sedimentary. As mentioned above the serpulid belt may be absent but in another nearby place the zoning is as follows:—

Barnacle belt.
Barnacles with *Galeolaria*, all densely packed.
Infralitoral fringe.

It is suggested that the reason for this distribution lies in intense inter-specific competition between barnacles, limpets, mussels and serpulids. This will be studied further when the transects are contrasted in the discussion.

The barnacles and serpulids, when present, are all much more closely packed together than on any of the mudstone transects. There is no obvious reason for the greater density of these species, other than the possibility that the dolerite offers a more suitable substratum for sedentary types. The exposure to wave action at this transect cannot be greater than that encountered at Transects 1, 3 and 4. All other physical conditions are very similar. Mudstone may chip or flake off under heavy wave action, whereas the igneous material offers a more stable substratum for colonization.

TRANSECT 6

Station	On a mudstone platform to the South of Kingston Beach and to the North of Transect 5.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 2, *b* 3.
Description	The transect is on the vertical face of a narrow platform at the base of the cliffs to the South of Kingston Beach. The platforms are not covered by the sea except in very rough weather. The zoning has been observed on the almost vertical seaward edge of the platform.
Geology	Mudstone.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

This transect was specially chosen to have the same wave exposure as Transect 5. The limpet belt is recognizable but there is no *Galeolaria* belt. Serpulids are present but in small numbers. They are mostly found between the belts of *Mytilus planulatus* and *Brachyodontes rostratus*. The barnacle, *Catophragmus polymerus*, is found in numbers in the *Brachyodontes* belt and this is indicative of the amount of wave action in the area. The barnacle belt is not well developed and individuals do not form a dense population.

Very few individuals of the ascidian *Pyura praeputialis* (Heller) are found at the same level as the mussels. The ascidians are small and only one occurs about every 50 feet of shore.

At one place the mussels formed the substratum for a dense mat of *Ulva lactuca*.

TRANSECT 7

Station	On a large boulder in the bay to the North of Lucas Point.
Date	August, 1948, and various subsequent dates.
Type	Semi-exposed rocky coast.
Maximum wave exposure	*c* (1-8) 4, *b* 3.
Description	The boulder lies to the North end of a stony bay to the North of Lucas Point. The transect is a vertical section down the side of the boulder. The sides of the rock are approximately 8 feet long.
Geology	Tillite.
Tidal data	From Hobart Recorder.
Physical environment	See Parts III and IV of this work.

The zonation exhibited here is very similar to that seen on the mudstone at Blackman's Bay with the exception that there is a well developed band separating the mussel belt from the Infralittoral fringe. Inhabiting this belt are barnacles, *Chthamalus* sp., *Catophragmus polymerus* and *Chamaesipho columna*. The Infralittoral fringe is much richer in *Lithothamnia* than in any other transect. The barnacle belt is not as wide as on the wave-sheltered side of the boulder. Correlated with this is a lowering of the lower limit of *Melaraphe unifasciata*. There are no algae in the mussel belt with the exception of a few small *Ulva* plants.

On small boulders there is a well developed flora and fauna in the Infralittoral fringe consisting of *Macrocystis pyrifera*, *Codium muelleri* Keutzing, *Laurencia* sps., *Ulva lactuca* and *Lithothamnia*. The animals found are *Ischnochiton lineolatus* (Blainville), *Cellana variegata*, *Patelloida alticostata*, *Patelloida conoidea*, *Cominella lineolata*, *Galeolaria çaespitosa*, *Catophragmus polymerus* and *Chthamalus* sp. Above this level there are only a few isolated barnacles and the crab *Leptograpsus variegatus* (Fabr.). The crabs run about below boulders and during rough weather are to be found well above the maximum distance reached by the waves on the shore.

Off-shore there is a large bed of kelp. This consists of two species, *Sarcophycus potatorum* (Labill.) Kütz and *Macrocystis pyrifera* (Turn.) Agardh. The width of the kelp bed is variable and it lies between 50 and 100 yards off-shore. The kelp extends from Pierson's Point to near Lucas Point. The presence of this forest is of considerable importance in modifying the intensity of wave action. Several other transects were considered on this stretch of coast. They were all very similar to No. 7 but show a progressive increase of the height of the upper zones on the shore towards Pierson's Point.

DISCUSSION

Taking Transect 1 as an example, the number of species recorded on the shore in terms of Recorder Datum show some interesting points (Table IX). In this table the levels on which the exposures have been calculated are not those on the wave exposed seaward face of the platform. For similar reasons the number of species inhabiting the barnacle belt does not include species living at the end of the platform.

The *Galeolaria* belt has a small number of animals inhabiting it for two reasons. The first reason lies in the fact that the distribution of animals on the shore is bimodal around M.S.L. This level occurs in the middle of the *Galeolaria* belt. This feature of littoral animal distribution was first shown by Colman (1933). The second reason lies in the fact that the belt is frequently very densely populated by serpulids. I have not found it possible to determine whether this is due to the fact that the space is suitable only for serpulid colonization or whether the serpulids establish dominance over all other forms in a suitable habitat. It is more probable that the worms crowd out other forms.

A feature of the zones, which is not obvious until detailed counts are made, is that, at about the middle of the mussel and *Patelloid* zones, there occurs a falling off in the number of species present. The upper part of the barnacle belt contains species which are to be found higher up on the shore.

TABLE IX

Number of species on the shore in Transect 1 and their relation to tidal levels.

Zone	Number of species	Height in R.D.	Exposure range %	Tidal Levels
Melaraphe	2	Above 11′ 6″	70 to 100	12′ 0½″ H.H.T.
Bembicium	3	11′ 3″ to 11′ 6″	59 to 90	....
Barnacle	8	10′ 9″ to 11′ 3″	27 to 88	10′ 11″ L.H.T.
Galeolaria	4	10′ 6″ to 10′ 9″	18 to 71	10′ 7¼″ M.S.L.
Patelloid	15	9′ 11″ to 10′ 6″	7 to 60	10′ 3″ H.L.T.
Mytilus	31+	8′ 4″ to 9′ 11″	0 to 26	9′ 1″ L.L.T.
Infralittoral Fringe	36+	Below 8′ 4″	0 to 2	....

The existence of 'critical levels' is shown by Table IX. Such levels, based on the numbers of forms inhabitating the shore, exist at about the middle of the mussel beds, the middle of the *Patelloid* belt just above the region of *Brachyodontes rostratus* and at the middle of the barnacle belt at the point where the species found at higher levels are encountered. These levels correspond to the tidal levels of the average annual height of 'low low', 'high low' and 'low high' tides respectively. For the tidal level in the *Mytilus* belt at which a very great diminution in the numbers of the fauna takes places the term 'lethal level' has been proposed (Guiler, 1949).

The distribution of *Galeolaria caespitosa* in relation to intense wave action is of interest. At the seaward end of Transect 1 the belt is fairly well developed (Plate 1) but in this case the full force of the waves is broken by the mussel beds which extend some 15 feet or more out from the worm tubes. In Transect 5, which is fully exposed to wave action, the *Galeolaria* belt may be greatly reduced or absent. On the same igneous rock the worms are very well developed on the wave-sheltered side of the outcrop. The mudstone of Transect 6, with the same exposure to wave action as Transect 5, shows no belt of *Galeolaria* but only occasional individuals. *Galeolaria* does not like wave action and a similar fact has been noted at Sydney by Dakin, Bennett and Pope (1948).

At a place where *Galeolaria* is absent there is, theoretically, a space available for colonization by other forms. There is evidence of intense inter-specific competition between barnacles, mussels and possibly limpets for this space. It has been shown by Hatton and Fischer-Piette (1932) that turbulent water suits barnacle attachment and that a wave exposed area has a dense barnacle population. Further, mussels like turbulent conditions for feeding (Fox and Coe, 1943) so that this species will also find a suitable habitat. Hewatt (1935) shows that on a large barnacle spatfall the limpets are driven further up the shore. On exposed places in Tasmania it is suggested that the limpets are eliminated by the barnacles because they cannot migrate further up the shore on account of their limited exposure toleration. Field evidence of the results of this inter-specific competition is to be seen on Transect 5 where *Galeolaria* dominates the wave-sheltered places to the detriment of limpets, mussels and barnacles. Mussels dominate some of the wave-exposed zones and barnacles dominate others. In the barnacle zones there are always a few mussels. The mussel zones have limpets and barnacles. The mussels may maintain themselves by eating a sufficient number of cyprid larvae to prevent a successful barnacle settlement, though this is against the findings of Fox and Coe *(loc. cit.)*.

In a wave-exposed area the suitability of the habitat may obscure the bi-modal distribution of the littoral fauna. In an area where there is virtually continuous spray the effect of critical tidal levels may be greatly altered by this.

The presence or absence of *Bembicium nanum* may be considered as an index of the intensity of wave action, the species being usually found in sheltered areas.

A comparison of the levels of the same organisms at different places reflects the intensity of wave action (Fig. 30). In Transects 1 and 7 wave action is most intense while Transect 2 shows the least wave action. Transects 5 and 6 have similar wave action with perhaps slightly greater spray in Transect 6. This diagram serves to emphasise that only a theoretical exposure can be obtained from tidal levels on an exposed coast. The amount of spray is the controlling factor. At 11 feet R.D. *Galeolaria*, barnacles or *Melaraphe* may be

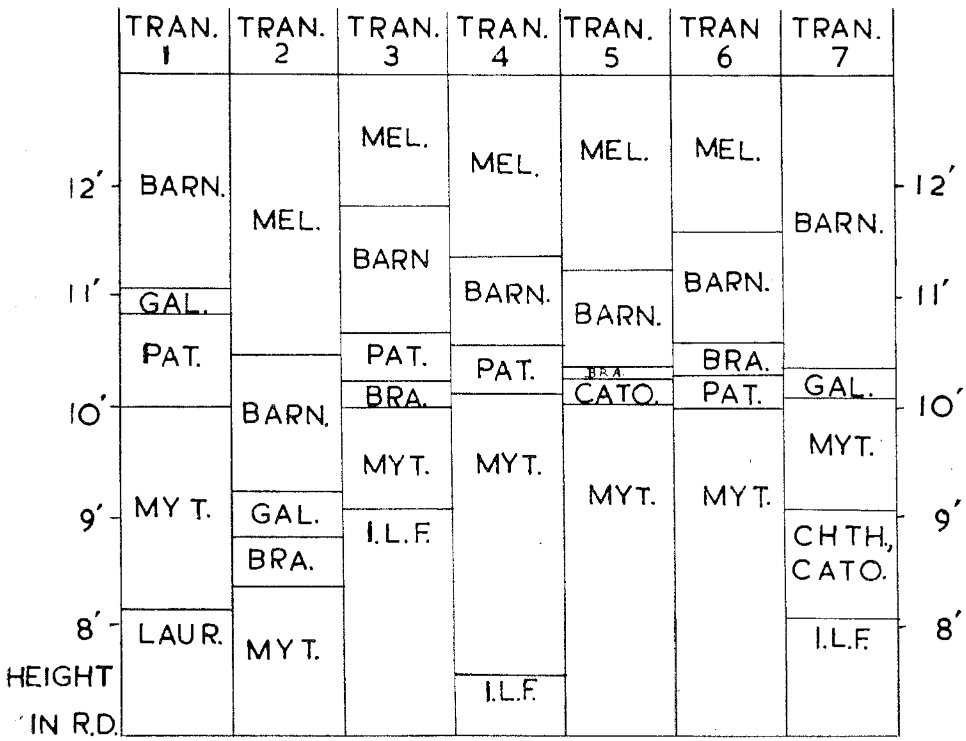


FIG. 30.—Comparison of the faunistic levels of Transects 1 to 7. The abbreviations used are:—BARN., barnacles; BRA., *Brachyodontes rostratus*; CATO., *Catophragmus polymerus*; CHTH., *Chthamalus* sp.; GAL., *Galeolaria caespitosa*; I.L.F., Infralittoral fringe; LAUR., *Laurencia* sps.; MEL., *Melaraphe unifasciata*; MYT., *Mytilus planulatus*; PAT., *Patelloid*.

encountered, depending on the intensity of wave action and the amount of spray. It is possible to use this fact as a means of obtaining an expression for the relative amounts of spray to which various places in an area are subjected. It is more accurate to consider this factor as an index of spray than of wave intensity, because the prevailing wind may alter the amount of spray without altering the amount of wave action.

To obtain this factor it is necessary to have available full tidal data for the area under examination and to have studied a number of transects in the area. The average upper limit for a species in the area is calculated in inches above C.D., or in this case R.D. The upper limit of the species at a specific place is then expressed as a factor of the average. The average upper limit of *Mytilus planulatus* in the Blackman's Bay area is 9 feet 9 inches R.D. and at Transect 2 the mussels are found at 8 feet 6 inches R.D. The spray encountered in this area is thus 102/117. By using the level of the upper limit of one species at two places a comparative figure can be derived as a ratio. *Galeolaria* at Transects 1 and 3 shows a spray intensity ratio of 133 : 111.

It is difficult to contrast the zonation at Blackman's Bay with that shown in other parts of Australia. Fischer (1940) has stated that the *Galeolaria* and *Melaraphe* zones at Hobart are comparable with those at Sydney. It is worthy of note that *Galeolaria* has a greater vertical range at Sydney than at Hobart. This may be due to the greater tidal range at the former place but in the absence of a correlation of animal zones with tidal levels it is impossible to decide this point. Fischer also makes a comparison of the zonation at exposed and less exposed points on the coast of New South Wales. This is of interest as showing the reversal of the *Cellana-Chthamalus* zones at two points, the barnacle being the lower at the less exposed place. This may be due to relatively heavier spray. The zonation at Sydney shows many points of resemblance to that found at Blackman's Bay. An important difference lies in the replacement of the Tasmanian mussel beds by *Pyura*.

The relation of the zones recognized in Australia by various workers to the classification suggested by Stephenson and Stephenson (1949) may be summarised as in Table X.

NEW SOUTH WALES		QUEENSLAND	S.AUSTRALIA.	S.TASMANIA	UNIVERSAL
HEDLEY, 1915.	D., B.& P., 1948.	JOHNSTON, 1917.	EDMONDS, 1948.	GUILER, 1949.	S.& S. 1949.
UPPER ZONE WITH TECTARIUS	SUPRALITT. WITH MELARAPHE.	TECTARIUS & UPPER MELARAPHE ZONES.	SUPRALITT. WITH MELARAPHE.	SUPRALITT FRINGE WITH MELARAPHE.	SUPRALITT. FRINGE WITH LITTORINIDS.
CHTHAMALUS MELARAPHE TETRACLITA.	UPPER LITT. WITH BARNACLES.	LOWER MEL. OR CHTHAMALUS.	BARNACLES.	BARNACLES.	MID LITTORAL.
MEDIAN ZONE WITH GALEOLARIA.	MIDLITT. WITH GALEOLARIA.	TETRACLITA	MOLLUSCS & GALEOLARIA.	GALEOLARIA PATELLOID. MYTILUS.	
LOWER ZONE WITH CYNTHIA.	LITT.-SUBLITT. FRINGE WITH PYURA.	SARGASSUM,	SUBLITT FRINGE WITH CYSTOPHORA.	INFRALITT. FRINGE WITH LAURENCIA ETC.	INFRALITT. FRINGE WITH LAMINARIA ETC.

TABLE X.—Relation of intertidal zones recognised by Australian authors to those proposed by Stephenson and Stephenson (1949). The abbreviations used are are INFRALITT., Infralittoral; LITT.-SUBLITT., Littoral sublittoral; MEL., *Melaraphe*; SUPRALITT., Supralittoral; UPPERLITT., Upperlittoral.

Note that Fischer (1940) followed the classification of Hedley (1915).

Although the index species of the Midlittoral zones in Tasmania are similar to those of other parts of Australia the deficiency of algae in Tasmania is to be noted both from text descriptions and photographs.

The absence of *Pyura* on exposed coasts in both South Tasmania and Queensland is probably due to the species approaching the extremities of its geographical range.

It can be concluded that there exists a lethal tidal level at which there occurs a very great reduction in the number of species inhabiting the shore. It is also shown that there is a bimodal distribution of intertidal species with a minimum at M.S.L. The presence of diurnally unequal tides does not complicate the critical tidal levels.

(*g*) *Colonization of Rock Surfaces*

Small scale experiments were carried out in an attempt to ascertain the sequence of colonization of bare rocky surfaces on the shore in the region of Pinnacle Point at the South end of Blackman's Bay. Blackman's Bay was chosen as the area in which to conduct the experiments because it could be visited at frequent intervals, is easy of access and its fauna is reasonably well known.

In order to throw some light on the poverty of the fauna of the Midlittoral zone the experiments were carried out in that region in the lower part of the barnacle and the upper part of the *Galeolaria* belts.

Literature

Work has been carried out in various parts of the world on the problems of intertidal colonization. In some cases the workers have been concerned with the colonization of new rock surfaces and in others the emphasis has been placed on the recolonization of denuded rock rurfaces. In Britain, Kitching (1937) and Pyefinch (1943) have been concerned with the latter aspect. In France, Fischer-Piette (1929 and 1932*b*), Hatton and Fischer-Piette (1932) and Hatton (1932) have studied the general aspects of the problem. Much work has been done in America on the season of attachment of sedentary marine organisms and their rates of growth. Among the American authors whose work bears on the recolonization problem are Visscher (1928), Visscher and Luce (1928), Pierron and Huang (1926), Coe (1932), Graham and Gay (1945) and Wilson (1925).

The colonization of new surfaces has been studied by several European workers. In many instances advantage has been taken of public works to supply the new surfaces. Brandt (1897) studied the colonization of the Kiel Canal, Herpin (1935*a* and 1935*b*) observed the colonization of beaches and wrecked ships and Rees (1940) noted the succession on a new sewage outfall. Moore (1939) and Moore and Sproston (1940) described the sequence of colonization of a new sea-wall at Plymouth.

Experiment 3.—To obtain a knowledge of the sequence of colonization of a bare rock in the Midlittoral zone.

Method of Experiment

Two rocks were chosen for the experiment. One was of dolerite and the other of mudstone. Both had to be of sufficient weight to remain stationary under conditions of the most intense wave action experienced in the site chosen. The rocks were approximately 1 foot cubes.

The rocks were examined ten times over a nine-month period. Each face of the rock was examined in detail and the results of these examinations were plotted on full size, or half size, reproductions of the faces of the rock. This simplified identification of previously recognized individuals.

In order to avoid crushing any forms dwelling on the bottom surface of the rocks a smaller rock was utilised for bottom surface examinations. This smaller rock was placed beside the larger rocks and only the fauna on the under side of it was examined. The rock was placed in such a position that the under surface of it was free from the substratum.

The experiment would have been continued for a longer period than nine months, if it had not been for the fact that the rocks were thrown into deep water by some unknown persons. I do not consider that wave action was responsible for the loss as during the period the rocks disappeared there were no gales of greater severity than had already been experienced.

The site selected was in a channel on the North side of the platform at Pinnacle Point at the South end of Blackman's Bay. The channel is completely uncovered at 'low low' tide and has a varied and numerous population. Wave action is not strong, the maximum being *s* (1-7) 1, *b* 2. Under certain conditions of bad weather heavy surf crashing across the platform pours into the channel but the force is mostly spent by the time it reaches the channel and the rock is only subjected to a cataract of water.

The channel was inhabited by *Hymeniacidon perlevis*, *Actinia tenebrosa*, *Elminius modestus*, *Chthamalus* sp., *Ibla quadrivalvis*, *Corallina* sps., *Hormosira banksii*, *Amaurochiton glaucus*, *Patelloida conoidea* and *Galeolaria caespitosa*.

Description of the Rocks Selected

It was originally intended to use rocks of dolerite and mudstone in different parts of the shore but pressure of other work restricted the experiment to the one site with two rock types. The rocks were put in position simultaneously, but the mudstone rock only remained in position for three weeks and then vanished. The rock was not replaced as strictly comparable results could not be obtained with a rock placed in position at a later date. The value of the experiment is not very great but it is included here as several points of interest are raised by the colonization processes.

The dolerite rock was selected from a pile of this rock lying above high water mark on the beach at Sandy Bay. The rock was removed to the laboratory and thoroughly scrubbed with hot water. Chemicals were avoided in this process to avoid reactions with the minerals of the rock. The rock was left to weather for a few weeks after which it was put in position. The smaller rock for the bottom surface experiments was similarly treated. The larger rock was known as Winter Rock A and the smaller as Winter Rock B.

The nature of the rock faces and their orientation can be best expressed in Table XI.

TABLE XI

Nature and area of the faces of Winter Rocks A and B.

Smooth, sea-sheltered vertical face with vertical and inclined ridges	Landward, 419 sq. cms.
Smooth, sea-exposed vertical face with exposed vertical and inclined ridges	Seaward, 494 sq. cms.
Semi-exposed vertical face with inclined and vertical ridges	Left hand, 637 sq. cms. Right hand, 708 sq. cms.
Sea and air-sheltered horizontal face with lateral ridges	Bottom, 271 sq. cms.
Sea and air-exposed horizontal face with lateral ridges	Top, 432 sq. cms.

The experiment was commenced on 18th April, 1948, and observations were made on 1st May, 12th May, 19th May, 29th May, 20th June, 26th June, 3rd July, 8th July, 15th July, 21st July, 14th August, 29th August, 21st September, 19th October, 3rd December, 10th January, 15th February. On the latter date only the bottom face of Winter Rock B was examined.

The first sessile organism to appear on the rocks was a small *Corallina* sp. on the landward face in May. Previous to this several errant species were seen on the faces of the rock, notably *Amaurochiton glaucus* (Gray), *Patiriella exigua* (Lam.), *Cominella lineolata* (Lam.) while below the rocks crabs *(?Petrolisthes* sp.*)* were sheltering. Amphipods were found in cracks on the rock. The first occasion on which large numbers of colonizing animals were noted was in June when 113 individuals appeared on the rocks. There were only 9 deaths noted during this period. Of these new individuals over 72 per cent were *Galeolaria*. These tubes were not confined to the lower part of the rock. About 25 per cent of them were found on the top surface. Barnacles appeared at the same time as the worms but in fewer numbers. A colonial diatom association, mainly of *Euschizonema* and *Melosira* sps. appeared at this time. These colonies were of a very short lived nature only two extending from one week to the next. These diatoms are discussed in section *(h)* below.

There were no macroscopic forms other than barnacles, *Galeolaria* and *Corallina* to successfully colonize the rock. *Actinia tenebrosa*, *Patelloida alticostata*, *Patelloida conoidea* and two errant annelids appeared but soon wandered away again. There was a constantly changing number of *Amaurochiton glaucus* on the rock. Several of these were marked and one was noted as returning to the rock at 2, 5 and 3 week intervals.

Table XII shows the number of new individuals settling each month and the number of deaths per month on each of the faces of the rocks. Although during certain months the rock was visited more frequently than others, thus giving a greater number of new settlements, there is no doubt that some faces of the rock were more densely populated during some months than others. The figures, although they show an overall increase of deaths and settlements during the more frequently visited months, reflect the true picture of the trends by the ratio of these numbers.

TABLE XII

The new settlings per month on each face of Winter Rock A and B.

	MAY		JUNE		JULY		AUGUST	
	Settlings	Deaths	Settlings	Deaths	Settlings	Deaths	Settlings	Deaths
Top	1	....	23	....	38	33	2	26
Seaward face	....	....	7	....	14	12	2	5
Landward face	1	....	1	2	26	10	4	18
Right-hand face	....	....	9	....	52	14	14	39
Left-hand face	...	....	31	....	11	37	2	6
Bottom	....	....	42	7	51	29	7	37
	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
Top	5	1	4	4	?	?	....	4
Seaward face	3	....	4	5	?	?	19	6
Landward face	2	....	5	1	?	?	2	6
Right-hand face	19	6	15	13	?	?	11	19
Left-hand face	2	0	3	3	?	?	1	2
Bottom	7	6	33	6	?	?	8	36
	JANUARY		FEBRUARY					
Bottom	5	13	8	6				

Table XIII and Fig. 31 shows the total number of individuals inhabiting the faces each month, while Table XIV and Fig. 32 show the new settlings and deaths of the various species per month.

From these tables and graphs it can be seen that there is a very great decrease in the total number of organisms on all faces between July 21st and August 14th and also between October and December. If the trends shown by the bottom face of Winter Rock B are true (Table XII) there is also a sharp diminution of numbers in December and January.

TABLE XIII

The total number of individuals of all species inhabiting the various faces of Winter Rocks A and B each month for the period June, 1948, to December, 1948.

	June	July	August	September	October	November	December	Totals
Top	23	27	3	7	7	?	3	70
Seaward face	....	9	6	9	8	?	21	53
Landward face	1	16	2	4	8	?	4	35
Right-hand face	9	47	22	35	37	?	27	177
Left-hand face	31	5	1	3	3	?	4	47
Bottom	35	57	27	28	55	?	27	229
Grand Totals	99	161	61	83	118	?	86	611

The bottom face only during January and February had 19 and 16 inhabitants respectively giving an absolute total of 646 organisms noted. These latter figures are not included in the table as they are only indications and may not be true records of actual populations.

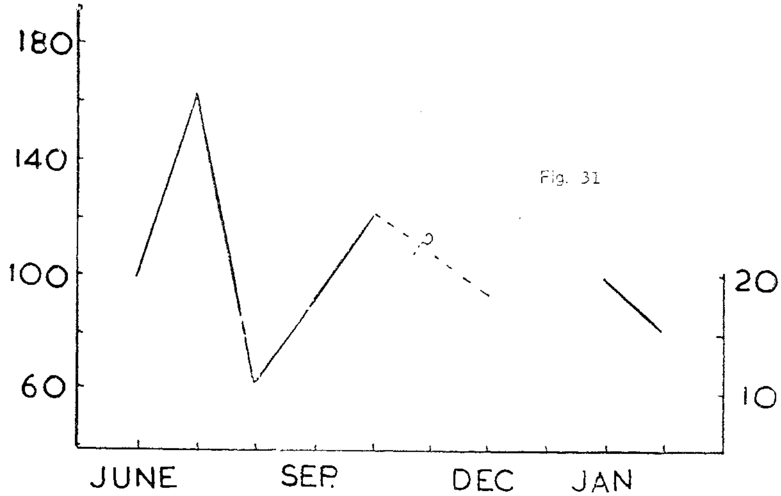
TABLE XIV

Total number of specific settlements and deaths per month.

Settlements	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Total
Barnacles	....	18	57	16	24	33	?	24	2	3	177
Serpulids	....	81	130	12	11	14	?	1	3	3	255
Anemones	....	1	....	1	....	....	?	2	....	....	4
Diatoms	....	10	17	2	....	....	?	....	....	....	29
P. alticostata	....	....	....	....	1	3	?	....	....	....	4
P. conoidea	....	....	....	....	....	1	?	3	....	....	4
Patella ustulata	....	....	....	....	....	1	?	....	....	....	1
Corallina	1	2	....	....	....	....	?	6	....	....	9
Nereids	....	1	2	....	....	....	?	....	....	....	3
Red algae	....	....	1	....	....	....	?	....	....	....	1
Chiton eggs	....	....	.	....	3	....	?	....	....	....	3
Totals	1	113	207	31	39	52	?	36	5	6	490
Deaths											
Barnacles	....	3	13	26	1	10	?	45	13	7	118
Serpulids	....	3	94	90	13	19	?	18	....	1	238
Anemones	....	1	....	....	1	....	?	....	....	....	2
Diatoms	....	1	23	5	....	....	?	....	....	....	29
P. alticostata	....	.	....	....	....	....	?	3	....	....	3
P. conoidea	....	.	....	....	....	....	?	1	....	....	1
Patella ustulata	....	.	....	....	....	....	?	1	....	....	1
Corallina	....	1	....	....	....	....	?	....	....	....	1
Nereids	....	.	2	....	....	....	?	....	....	....	2
Red algae	....	....	1	....	....	....	?	....	....	....	1
Chiton eggs	....	..		.	....	3	?	....	....	....	3
Totals	....	9	133	121	15	32	?	68	13	8	399

The number of forms successfully settling also shows a sharp diminution in August and January. The number of deaths in July and August is very high. The large number of settlings in July possibly came from a late autumn spawning.

The seaward and landward faces of the rock never had as dense a population as the other faces.



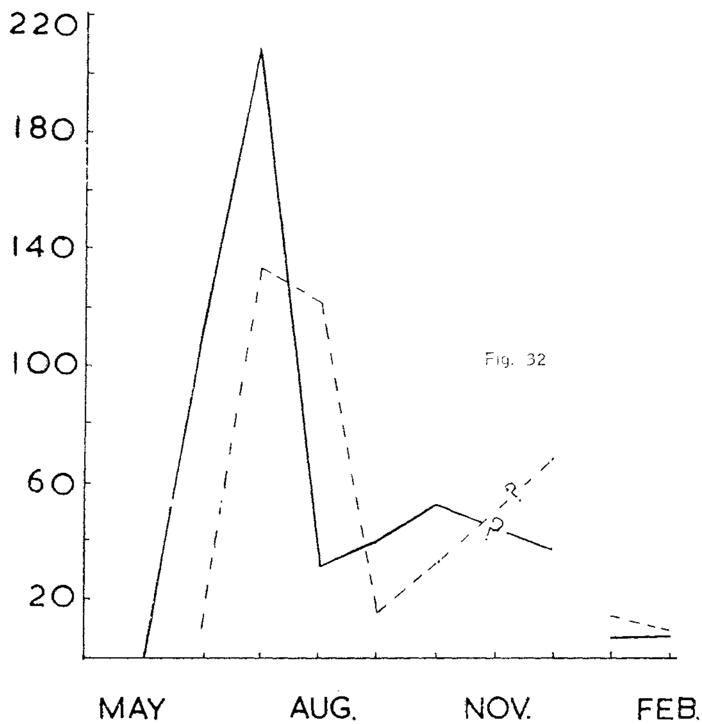


FIG. 31.—The total number of individuals inhabiting Winter Rocks A and B from June, 1948, to February, 1949.

FIG. 32.—The number of settlements and deaths per month on Winter Rocks A and B.

Discussion

From the above observations it can be seen that the rate of successful colonizing is very slow compared with the rate in other parts of the world where there is a much greater density of population per unit of time. It is proposed to examine some of the factors which may influence the settling of larvae on the experimental rocks.

There is a close correlation between the critical months for intertidal organisms as deduced from physical data in Part 4 of this work (see page 155) and the observed rates of settling and deaths on the experimental rocks. December, January and July are considered to be critical months for intertidal organisms due to the combination of adverse tidal and meteorological factors. April and October are regarded as months of slightly less strain due to the equinoctial change of tidal behaviour. From Tables XII and XIII it can be seen that there are times of high casualties and low spatfall between late July and early August and in October and December. It is further indicated by Winter Rock B (Tables XII and XIII) that January is also a month of stress, though this is not conclusive. March and April unfortunately are not included in the experiment for the reasons given above.

The black colour of the rock would certainly assist barnacle settling. The larvae being negatively phototropic (Visscher, 1928) would choose a dark surface in preference to the surrounding lighter coloured mudstone. The relative absence of surf would tend to reduce the number of successful barnacle settlings though it has been shown by Coe (1932) that test blocks exposed to heavy surf were cleared of barnacles measuring up to several millimeters in diameter. In the channel in which the experimental rocks were situated there was not nearly as great a barnacle population as there was on the exposed edge of the rocky platform. On the other hand, the seaward face of Winter Rock A, which would experience whatever wave action there might be, had very few barnacles on it. It had a very much smaller number than either of the lateral faces. In general, it might be concluded that the channel was not very highly suited to barnacle life, though barnacles were living there.

The poverty of barnacles on the seaward face of Winter Rock A is possibly explained by the fact that the face was towards the North, i.e., it was exposed to the sun. This would drive cyprid larvae round to the sides of the rock where they would find more congenial conditions. Any larvae which had settled on the seaward face would probably be killed by the sun before the metamorphosis was complete. The right hand face, because it is sheltered from all but the early morning sun, has a comparatively rich fauna.

It has been shown by Hopkins (1935) that oysters tend to form their densest colonies on the under surface of objects. The reason for this lies in the larval method of swimming with the velum upwards. There is little evidence of this behaviour being shown by any of the larval forms encountered during the experiment.

It has been noted by Coe (1932) that the degrees of roughness of surfaces influences the population inhabiting them. In this case the faces of the rock were all of equal smoothness and the factor is not applicable to the fauna of different rock faces.

The absence of any algal grazers permanently dwelling on the rocks points to the fact that an algal film was not formed on the rock. This may have been influenced by bacteriological factors (Zobell and Allen, 1935).

The failure of organisms to colonize the rocks is due to the integration of a number of factors. The orientation and siting of the rock and the relation of the faces to sun and wave exposure play some part. The lack of full wave action would reduce the number of barnacle settlements but ought to increase the number of *Galeolaria* settlements. The number of settlings by the worms was large but the death rate was also high. The high death rate was caused by the larvae settling in June or July and being unable to become established before the critical month of July.

Barnacle larvae settled throughout the year. This is in contrast to the situation described by Moore (1939). The critical months also caused a high death rate in this species. In no sense was a pioneer community established as described by Rees (1940). The nearest parallel to colonization in South Tasmania is that described by Pyefinch (1943) who found that no inter-specific competition existed.

(h) Diatom Colonization

During the winter of 1948 a diatom growth appeared on the shores of the Derwent Estuary. It was first noted on the shore on 12th June, 1948, when it appeared quite suddenly. By the 26th of June it was very plentiful in pools and on stones in the lower tidal areas. The diatoms formed filamentous growths on the shore in patches up to 12 square feet in area. Most of the diatoms were *Euschizonema* and *Melosira* sps. From the evidence shown on the experimental rocks it would appear that the life of each aggregation of colonies is short, lasting only about a week.

From June until the 20th August the diatom growths increased until most of the shore up to the *Bembicium* zone was covered with a brown slime. The exposure experienced by the diatoms at this level was 70 per cent in August. During June and July the exposure was 82 per cent and 68 per cent respectively. By the middle of September the diatoms were disappearing. Exposure during this month was 83 per cent.

Where the diatoms formed a more or less permanent mat on the shore a secondary algal association appeared. The algae only appeared where there was no interval of time separating the death of one diatom colony from the appearance of the next. The most common alga to appear was *Ulva lactuca* and this was followed by several small red algae *(Gelidium* sp.) and some small *Hormosira banksii*. On the extermination of the diatoms in September the reds and *Hormosira* disappeared very soon afterward, but the *Ulva* remained for two or more weeks. During this time the *Ulva* became bleached.

The effect of this increase of vegetation on animal life on the shore was not very marked. This is probably due to the fact that the change was so short lived. There was some increase in the number of *Bembicium nanum* while *Cominella lineolata* was found further up the channels than it normally occurs. The latter species, from observations in aquarium tanks, does not willingly leave water. There was no apparent change in the number of barnacles on the shore.

The reason for the appearance of the diatoms is not at all clear. They appeared during the most rigorous months of the year and when the exposure to which they were subjected was above 80 per cent. Insolation was most deleterious in its effect on the diatoms. During a warm sunny day at Kingston the sun-exposed rocks were rapidly cleared of diatoms whereas the shaded rocks were still coated with the slime. Recolonization was very rapid either from other stock or by regeneration of the old material.

The disappearance of the diatoms might be correlated with an increase in the number of sun hours and a warming up of sea and air temperatures.

There was no similar growth during the winter of 1949.

SUMMARY

In this paper the general status of marine ecology in Australia is discussed and the literature reviewed. The physical environment in South Tasmania is described in detail, the tides receiving particular attention. As a result of this treatment it is shown that July, December and January are critical months for shore animals. This is verified by some experiments carried out on the colonization of bare rocks. The zonation is examined in the Blackman's Bay area and compared as far as possible with that in other parts of Australia. A factor for comparing the intensity of wave action is given, also a spray intensity factor. The colonization of rocks is shown to depend on a number of factors, mainly sun and wave exposure and the relation of spatfalls to the critical months. An evanescent diatom colonization of the shore is described.

ACKNOWLEDGMENTS

I am indebted to Professor V. V. Hickman for checking the typescript of this article and also for his interest throughout the preparation of the material. I also thank Dr. J. Pearson for his interest and suggestions in the presentation of the matter. My thanks are also due to Captain Bowerman for permission to use the records of the Hobart Tide Recorder and to the Weather Bureau, Hobart, for most of the meteorological data. Dr. M. Burton of the British Museum kindly identified some sponges for me and Professor H. N. Barber identified some of the algae and the diatoms. I am also grateful to my wife for assistance in the typing and checking of this work.

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PLATE I

FIG. 1.—The barnacles at the seaward end of Transect 1. The *Galeolaria* tubes can be seen at the bottom of the photograph. The scale is one foot in length.

FIG. 2.—Transect 3, Perameles Bay, at a 'high high' tide.

FIG. 1

FIG. 2

PLATE II

FIG. 1.—The mussel beds at the end of Transect 1. The seaweed is *Macrocystis*.

FIG. 2.—Transect 1, Blackman's Bay. The dark line at the seaward end of the transect is the mussel beds.

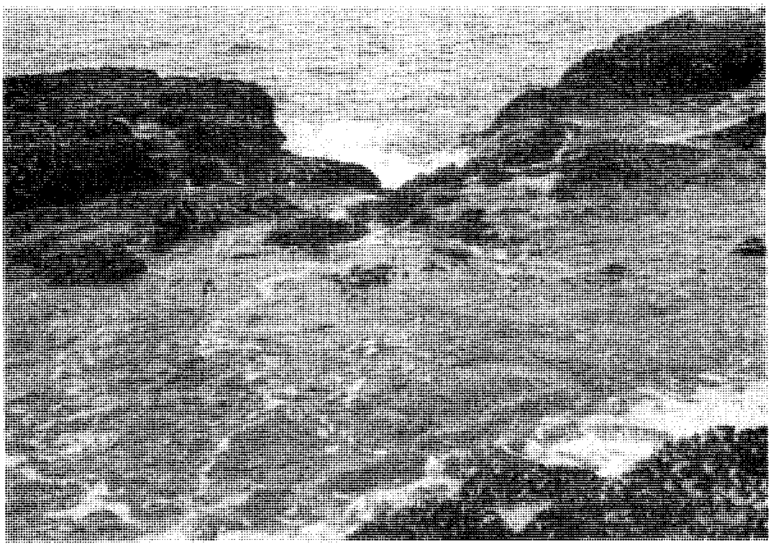

FIG. 1

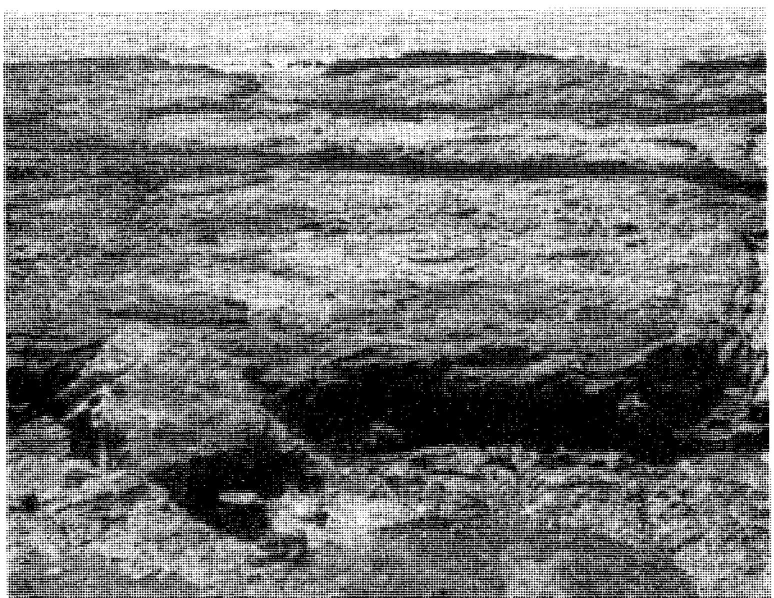

FIG. 2