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The Intertidal Ecology of Pipe Clay Lagoon

By

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WITH 2 PLATES AND 8 TEXT FIGURES

SUMMARY

This paper is the second dealing with various aspects of the intertidal ecology of Tasmania. Pipe Clay Lagoon is a sheltered area of water which is populated by a fauna characteristic of such places. The main deductions of the effect of climate on the intertidal organisms (see Guiler, 1950) are applied to the lagoon. The detailed zonation of the lagoon is described. There exist a series of belts on the shore from an *Arthrocnemon* scrub at the Supralittoral to *Pyura* on the floor of the lagoon. In many cases the dominant species is difficult to separate from other species and population counts have to be made. For this and other reasons enumerated in the text it has been found that for most practical purposes, other than detailed surveys, it is possible to consider the zoning of the shore as being the Upper Shore with *Arthrocnemon*, the Supra *Zostera*, the *Zostera*, the Infra *Zostera* and the Lagoon Bottom.

A detailed description of a transect is given and comparisons made with other places on the shore of the lagoon. The prevailing wind has an interesting effect on the distribution of *Zostera* beds, the plant being found much further up the shore at the southern end of the lagoon, the prevailing winds being in the North quarter.

The entrance to the lagoon is narrow and there is a considerable tidal current in this strip of water. In spite of this there is no luxuriance of forms, the probable reason for this poverty being the presence of a very considerable amount of silt.

A feature of the shore in certain parts of the lagoon is the presence of the soldier crab, *Mictyris platycheles* Milne Edwards. This crab lives in very large numbers in the lagoon but it was found that it is confined to a certain type of substratum. The muddy substratum is characterised by the crab *Paragrapsus gaimardii* (Milne Edwards) while *Mictyris* lives in more sandy mud. It is possible to classify the lagoon shore into two types of substratum, a *Mictyris* sand and a *Paragrapsus* mud. Some reasonably accurate faunal predictions can be made from the substratum encountered.

An attempt is made to correlate the zoning seen in a lagoon with that on other types of coast. A food chain for organisms living in the lagoon is given.

INTRODUCTION

This is the second of a series of papers dealing with various aspects of the intertidal ecology of Tasmania. The first paper described the features of a semi-exposed coast at Blackman's Bay (Guiler, 1950) and the present paper deals with the intertidal areas of Pipe Clay Lagoon.

Pipe Clay Lagoon was chosen as the first place to study the ecology of enclosed areas of water and this paper embodies the results of numerous visits to the lagoon.

The list of species found in the lagoon is not complete. All of the large forms found dwelling on the surface of the lagoon are listed but subsurface species have not been fully investigated. Some of the burrowing animals are mentioned but many others have not been identified due to lack of studies on several groups of Tasmanian animals.

Pipe Clay Lagoon is a small area of sea water which is almost entirely surrounded by land. The lagoon opens by a narrow strip of water at its north-eastern side into the western side of Frederick Henry Bay (Text figure 1). The water in the lagoon is very shallow and large areas of shore are exposed at low tide (see Plate I).

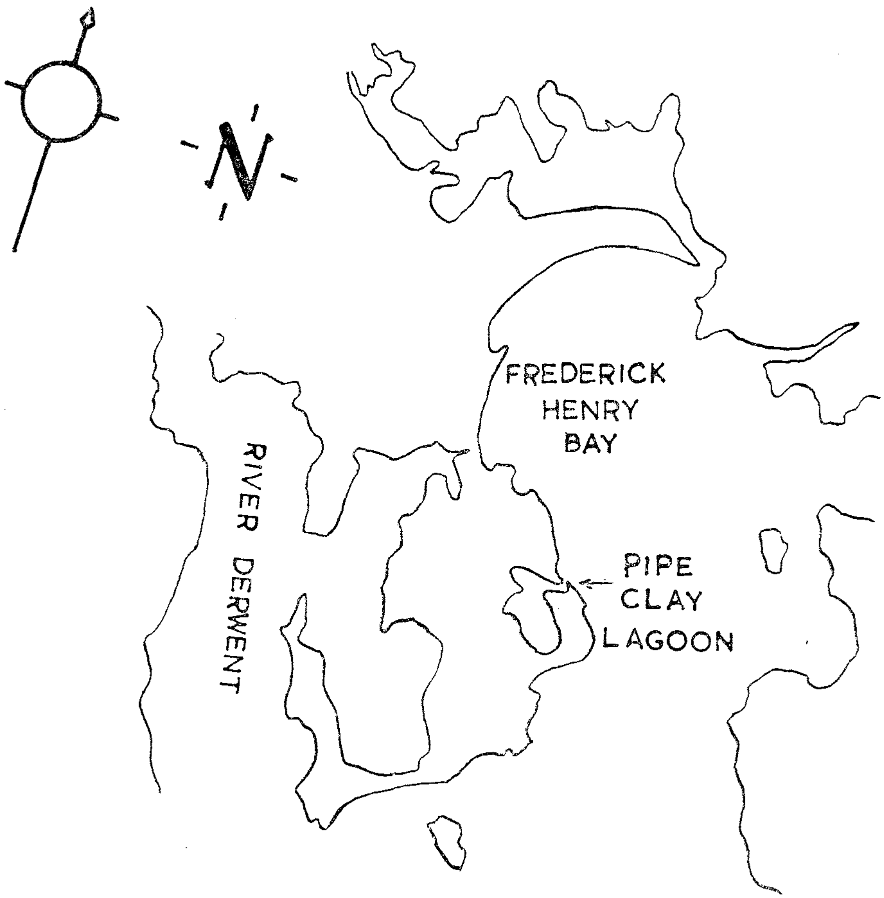

FIG. 1.—General map of part of southern Tasmania showing the location of Pipe Clay Lagoon. Scale approx. 4 miles to · inch.

Transects were examined at the northern and southern ends of the lagoon and examinations of the shore were carried out at all other places of the lagoon. The narrow entrance to the lagoon received particular attention. Transects were not examined at this place but the shore was intensely searched in a direction parallel, rather than transverse, to the shoreline.

The terminology used is the same as that employed in the previous papers of this series and follows that of Stephenson & Stephenson (1949). The tidal terminology is that of Chapman (1938).

Pipe Clay Lagoon lies approximately in 42° 57′ S., 147° 34′ E. It forms a feature of the small peninsula lying between the estuary of the Derwent on the West and Frederick Henry Bay on the East. The lagoon is over two miles in length and three-quarters of a mile in width. The four main features of the lagoon to be considered are the north, west and south bays and the narrow channel connecting the lagoon with the open sea.

The shore of the lagoon is level, with the low land immediately above it often marshy. On the southern side of the entrance channel there are low cliffs. The nature of the bottom of the lagoon will receive attention in the sections on substratum.

PHYSICAL ENVIRONMENT

(1) *Tides*: The tides have the same behaviour as those described for Hobart (Guiler, 1950). There is, however, a considerable difference in time between the various phases of the tides in the lagoon and those in the Derwent Estuary. This interval may be as much as three hours.

(2) *Wind:* The wind has a marked effect on tidal levels in the lagoon, and may act in two ways. Firstly, it may blow water in or out of the lagoon causing very high tides or very low tides, with consequent variation in exposures. Secondly, it may have a purely local effect on one area of the shore. A slight breeze has been noticed to cause water in the lagoon to advance for three feet or more over the exposed lagoon floor. The effect of this on a larger scale will be seen in relation to the distribution of the *Zostera* beds.

(3) *Climatic Factors:* The climate of this area resembles that of Hobart with the exception of rainfall, which is less on the eastern side of the Derwent than on the western side. The rainfall at Hobart and Sandford over 68 and 47 years respectively, as given in the Weather Bureau records (1936), show that the rainfall at Sandford is about two inches less that at Hobart.

The lower salinities experienced during rainfall are counteracted by the amounts of salt water retained on the lagoon shore.

In a previous paper (Guiler, 1950) it was noted that December, January and July are critical months for intertidal organisms at Blackman's Bay and there is no reason for modifying this conclusion for Pipe Clay Lagoon.

(4) *Sea Temperature:* The only observations made on the temperature of the sea are a few readings taken to show the effect of hot weather on the incoming tide. Ordinary sea temperature being about 19° C., the temperature of water left in hollows in the sand reached 27·5° C. and the temperature at one inch depth in the sand was 25° C. The temperature of the incoming tide varied considerably with the local currents. In some places a temperature of 23° C. was recorded at the water's edge. This is caused by a cooling of the water retained on the foreshore rather than by a heating of tidal waters. In general, however, tidal waters were heated to a more or less extent for some 50 feet from the advancing edge of the water.

(5) *Currents:* Strong tidal currents are set up in the channel connecting the lagoon to the open sea. This channel is deep and is rocky on the southern side. In the lagoon there are certain well defined channels by which water enters or leaves the area. (Plate I.) Since 1948 these channels have varied slightly in position.

(6) *Substratum:* Most of the lagoon is covered by a sandy mud, but the southern bay is more shaley than the other two bays. Throughout the bays the surface layer of sandy mud or muddy sand is only about two inches deep. Below this is a bed of black organic mud containing some shell fragments and below this is a stratum of shells.

In the southern bay of the lagoon there is some difference in the substratum in the higher levels of the shore, white sand being found above the black organic mud. At G (Text fig. 2), the substratum is composed of a surface, one-quarter of

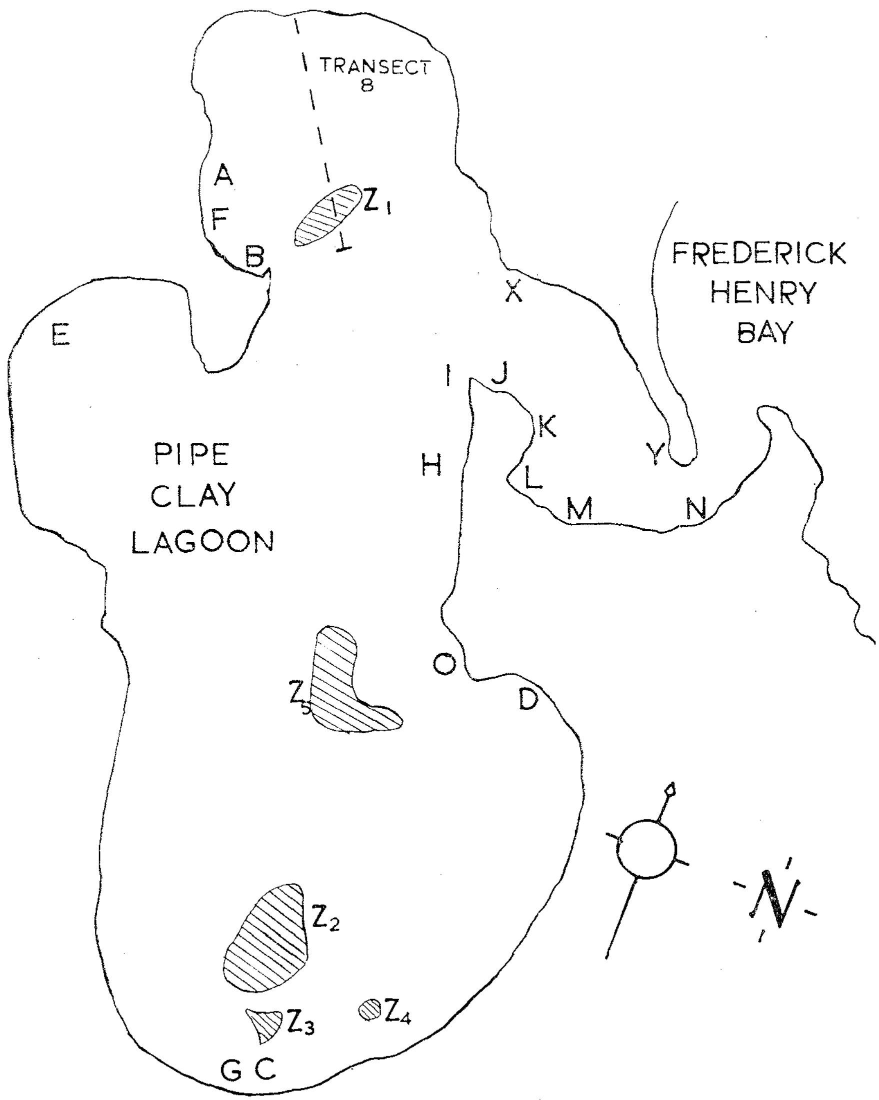

FIG. 2.—Detailed map of Pipe Clay Lagoon. Scale approximately 1 mile to 4 inches.

an inch thick, of golden sand with a thin belt of organic mud below it. This alters into one and a half inches of white sand with another layer of mud. Below this is the shell bed which extends over all the lagoon at a depth of about three inches.

There are a few small rocky outcrops in the lagoon. These are of dolerite on the western side of the lagoon and mudstone on the east. The outcrops, except where they form fringing cliffs, do not project above the lagoon floor. They are recognized by the presence of numerous stones on the shore of the lagoon. The rock is usually covered by a thin film of muddy sand.

There is a very sharp difference in the topography of the northern and southern sides of the entrance to the lagoon. The north shore has a substratum of firm, fine hard sand which gradually changes into a muddy sand on mixing with the more muddy lagoon deposits. This muddy sand has few shell fragments. At X (Text fig. 2) the muddy sand changes into a sandy mud with numerous shell fragments. In the other direction the fine sand continues along the open sea shore known as Cremorne Beach.

On the southern side of the entrance the shore is rocky with a stony foreshore and low cliffs of mudstone. At the lagoon end of the rocky headland (at Y) the shore immediately changes into sandy mud. The point at the southern seaward end of the entrance to the lagoon is of dolerite and this rock continues along the ocean coast.

(7) *Salinity:* The lagoon has a higher salinity than the open sea. Full and regular observations have not been made but two analyses made during spring weather showed salinities of 36·5 grs./mille and 37·1 grs./mille. The salinities were determined by the titration as outlined by Harvey (1945, p. 20). The pH, determined by an electrometer, was 8·1.

ZONATION

The ecological features of the lagoon will be considered in two sections, A and B. Section A will include the features of the lagoon proper and Section B will describe the features of the entrance channel. For the purposes of this work the entrance channel will be assumed to extend from the entrance to the line X-Y (Text. fig. 2).

Section A

TRANSECT 8

Station	Pipe Clay Lagoon.
Date	December, 1948, and various subsequent dates.
Type	Lagoon.
Maximum Wave Exposure	*s* (1-6), 0, *b* 1.
Description	The transect lies in the northern bay of the lagoon and runs from just below a large obvious tree on the roadside, past the line of telegraph poles to beyond the *Zostera* bed.
Geology	Sandy mud with a few small outcrops of dolerite.
Tidal data	As for Hobart.
Physical Environment	As above.
Zonation	There undoubtedly exists a zonation of the forms found in the intertidal regions of the lagoon, but this zoning is difficult to identify. Certain species are dominant and may be used as indicators but in many cases their limits are so extended outside their dominant range that their value as indicators is greatly reduced (see *Bembicium* on Text fig. 3). Further, some of the dominant species are burrowing in habit and others are very small. Also, some species which are both obvious and numerous, never achieve dominance, e.g., *Paranassa pauperata* (Lam.). Therefore, while listing a zonation below, it must be borne in mind that this zoning may not be very obvious and considerable examination of the shore must be undertaken before it is possible to decide the dominant form in the zone being examined. For most practical purposes, other than detailed surveys, it is possible to divide the shore into five zones. These are the Upper Shore; the Supra *Zostera*; the *Zostera*; the Infra *Zostera* and the Lagoon Bottom. The detailed zonation is *Arthrocnemon arbusculum* (R. Br.) Moq., *Salinator solida* von Martens, *Bembicium melanostoma* (Gmelin), *Bittium lawleyanum* Crosse, *Anapella cycladea* (Lam.), *Zostera nana* Roth., *Marcia corrugata* (Lam.), *Austrocochlea obtusa* (Dillwyn).

The features of each of these zones will now be described.

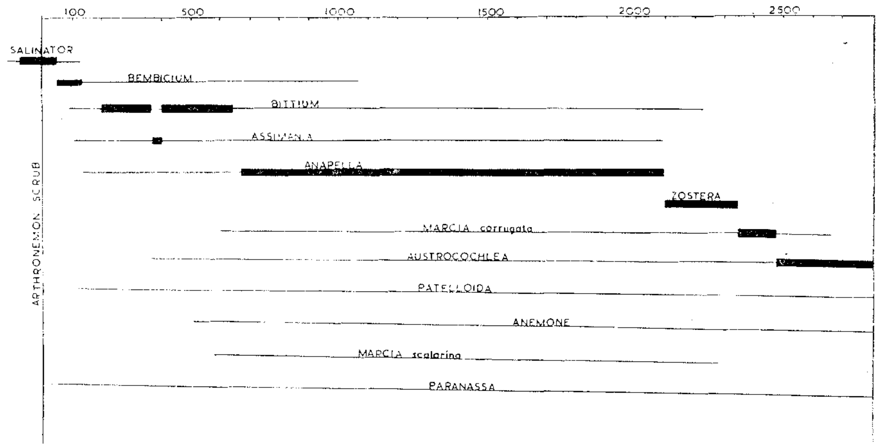

FIG. 3.—Detailed zonation at Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

The Upper Shore

The Upper Shore is populated by a growth of *Arthrocnemon arbusculum.* This plant forms a scrub-like growth up to two feet six inches in height. *Salicornia australis* Sol. which may be classed as a sub-dominant, is the chief constituent of a dense mat of procumbent plants extending from above 'high high' water mark to the lower limit of the Upper Shore. *Salicornia* extends from the driest parts of the formation to the wettest. On the seaward side in all but the wettest parts of the marsh *Samolus repens* Pers. is found with the *Salicornia, Arthrocnemon* is frequent, *Suaeda australis* (R. Br.) Moq. is common and *Wilsonia backhousii* Hook. is found in the drier parts.

Towards the landward side, as the soil becomes richer in organic matter and drier, *Arthrocnemon* and *Samolus* are still frequent, *Suaeda* remains common and *Wilsonia* becomes more frequent at the expense of *Salicornia.* Grass occurs occasionally. Finally, Cyperaceous dry-land plants appear and *Arthrocnemon* disappears.

There are very few intertidal species found in this part of the shore. In the lower and wetter parts of the formation the gastropod *Salinator solida* is very common. The species is largely confined to muddy patches and drainage channels in the marsh. In these places as many as 30 individuals per square foot have been found. A few specimens of *Bembicium melanostoma* were found and one *Paragrapsus gaimardii* (M-Ed.) was captured at the extreme seaward edge of the marsh.

Numerous dead mollusc shells and crab carapaces are to be seen hanging from the *Arthrocnemon* shrubs and lying on the *Salicornia* mat. These probably are deposited during abnormally high tides in easterly weather.

The Supra Zostera Zone

Most of the area of the transect falls into this zone. The *Zostera* forms a small bed about 700 yards from the *Arthrocnemon* scrub. The zone, as mentioned above, can be divided into a series of belts. These can be distinguished only by a close examination of the fauna.

The zone may be considered in terms of the various indicator and other species and their distribution. Text figure 3 shows the ranges of the most common species on the shore.

Salinator solida von Martens

This gastropod is found both in the Upper Shore and in the first 120 feet of the Supra *Zostera*. Throughout this range it is very common and is dominant for the first 50 feet of the lagoon shore proper.

The only other species found in the belt dominated by this species are a few *Bembicium melanostoma* and *B. nanum* (Lam.) and some small crabs *Paragrapsus gaimardii*.

Bembicium melanostoma (Gmelin)

Throughout this work this species is that identified by May (1923).

This species is present for 1060 feet of the transect. It first appears just below the *Arthrocnemon* scrub and follows the *Salinator* belt, being dominant for 95 feet below the latter belt but the species still occurs further down the shore and does not become rare until the last 400 feet of its range. Other species found in the upper part of the belt dominated by *Bembicium melanostoma* are the crab *Paragrapsus gaimardii*, *Salinator solida* and one individual of *Austrocochlea obtusa* (Dillwyn).

In the lower part of the belt are *Bittium lawleyanum* Crosse, *Assimania brazieri* (Ten.-Woods), *Mactra rufescens* Lam. (one individual only), and one individual of *Anapella cycladea*. *Assimania* becomes very common in the last 40 feet of the *Bembicium* belt. Here also the limpet *Patelloida subundulata* (Angas) is found adhering to solid objects, usually shells. May (1923) considers that this species may be a variant of *P. conoidea* Quoy & Gaim. The latter species is found on wave exposed coasts and also occurs in small numbers in the entrance to the lagoon.

The density of the population of *Bembicium melanostoma* is very varied. Between 20 and 40 feet from the *Arthrocnemon* scrub four random counts showed that there were 2, 2, 1 and 0 individuals per square foot respectively. Local concentrations of as many as 8 per square foot were recorded. At 70 feet from the top of this belt several random counts showed that there were four individuals per square foot.

The gastropod *Paranassa pauperata* (Lam.) was first noted at low water in the last 20 feet of the *Bembicium* belt. At 'high high' water this species was observed in all but the top 20 feet of this belt. Johnston and Mawson (1946) note that *Paracanassa pauperata* buries itself in the sand and readily comes to the surface when food is available. It seems probable that the Tasmanian carnivores bury themselves shortly after the tide has exposed them and reappear when the tide has covered the sand. They will appear if food is left on the surface of the shore and trampling of the sand also brings them to the surface.

Digging into the substratum as far as the shelly bed failed to reveal any burrowing molluscs. Worms (? *Leptonereis* sp.) were encountered but were not common.

Immediately following the *Bembicium* belt is a mixed strip containing *Bittium lawleyanum* and *Assimania brazieri* of which the former ultimately becomes dominant.

Bittium lawleyanum Crosse

This species has already appeared in the *Bembicium* belt and becomes dominant at a distance of 180 feet from the *Arthrocnemon* scrub. It remains dominant, with one small break, for 440 feet. Eighty feet after the commencement of this belt a small strip 20 feet wide is dominated by *Assimania brazieri*. *Bittium* is found as far down as the Infra *Zostera* zone at a distance of 2400 feet from the *Arthrocnemon* scrub.

The species also found in this belt can be divided into two ecological groups, those from the belts above and those from the belts below that dominated by *Bittium*. The former group contains such animals as *Assimania brazieri, Patelloida subundulata, Austrocochlea obtusa, Paranassa pauperata* and *Paragrapsus gaimardii*. Species found only below the *Bittium* belt but which appear in that belt are *Anapella cycladea, Polinices conicus* (Lam.), *Marcia scalarina* (Lam.), *Marcia corrugata* and *Cominella lineolata* (Lam.). *Anapella cycladea* was recorded as being found in the *Bembicium* belt but as only one specimen was found the species is noted here as occurring below the *Bittium* belt.

An anemone, *Anthopleura aureo-radiata* (Stuck.), appears 460 feet from the *Arthrocnemon* scrub. Only the tentacles and oral surface of the anemone appear above the sand. The aboral surface adheres to the shells of burrowing lamellibranchs. In the *Bittium* belt the shore is fairly level and there is usually sufficient water retained between ridges in the sand for the anemones to remain partly expanded throughout the intertidal period.

At a distance of 420 feet from the *Arthrocnemon* scrub an interesting algal growth appears. The algae concerned are Cyanophyceae, mostly *Oscillatoria* sp. These algae are filamentous and form small mats which become closely congested with sand grains and mud. The mats are ovoid in shape and measure up to two inches across the long axis and about a quarter of an inch in thickness. They lie scattered over the shore, and are scarce at first but further down the shore they become more numerous. Further notes on the mats are given below. The small gastropod *Assimania brazieri* was noted as not occurring on the mats in this belt but further down the shore in the *Anapella* belt the species occurs on the algae.

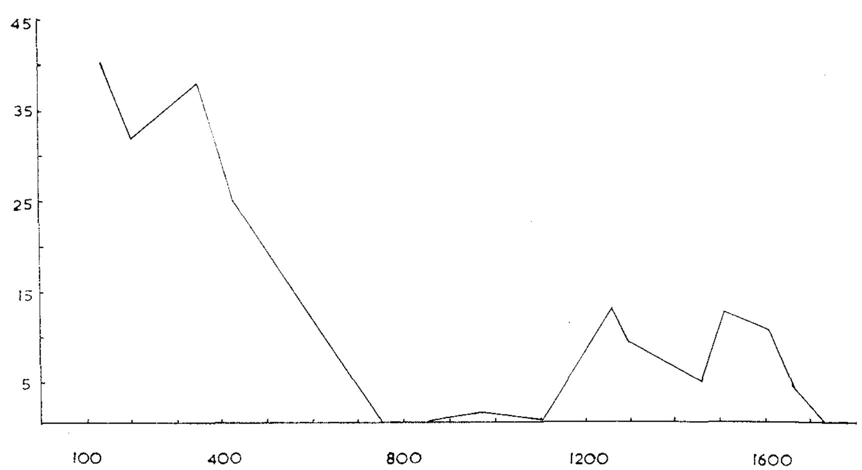

FIG. 4.—Density of population per square foot of *Bittium* on the shore of Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

At the lower end of the *Bittium* belt one of the few barnacles encountered on the transect was found living on the shell of a *Bembicium melanostoma*. The barnacle was an *Elminius modestus* Darwin.

The density of the population of *Bittium* is very variable throughout the zone (Text fig. 4). At the beginning of the dominance of this species there were in two counts 35 and 45 individuals per square foot with 30 and 30 individuals of *Assimania brazieri* respectively. At the end of the dominance of *Bittium* there were 25 individuals per square foot. The species, although present over most of the shore, falls off in numbers beyond its area of dominance and counts taken further down the shore showed a very variable population.

Anapella cycladea (Lam.)

This species first appears at the end of the *Bembicium* belt and becomes dominant 680 feet from the *Arthrocnemon* scrub. It remains the dominant species as far as the *Zostera* bed a further 1420 feet away. The lamellibranch sometimes occurs at the surface of the sand but usually is found burrowing in the thin sandy belt above the black organic mud. All counts of this and other burrowing species were made in a one foot square to the depth of the shell bed.

Species noted for the first time in this belt are *Friginatica beddomei* (Johnston), a burrowing worm which leaves obvious casts (? Fam. Maldanidae) and *Salinator fragilis* (Lam.). The worm casts become more plentiful in the lower parts of the belt.

As noted above, *Assimania brazieri* was found living on the algal mats in this belt. In the lower parts of the belt, up to 400 feet before the *Zostera*, this species was noted as being found in puddles of water and not on the, by then, scarce algal mats.

Other previously noted species found in this belt are *Marcia corrugata*, *Marcia scalarina*, *Bittium lawleyanum*, *Paragrapsus gaimardii*, *Mactra rufescens*, *Paranassa pauperata*, *Cominella lineolata*, *Patelloida subundulata*, *Austrocochlea obtusa*, *Elminius modestus* and *Oscillatoria* sp.

A telegraph pole 80 feet from the beginning of this belt had a cluster of barnacles on its sun-sheltered side. The barnacles reached a height of nine inches above the sand (Plate II). The barnacles were mostly *Elminius modestus*.

A feature of this zone is the remarkable uniformity of the fauna inhabiting it. In a distance of 1420 feet only three species, listed above, are found which do not occur in previous belts. Of these species only the burrowing worm is common, the other two being represented by scattered individuals.

The density of the population of *Anapella* is summarized in Figure 5. The species is most numerous between 700 and 1000 feet after the beginning of the belt. The species density varies between 15 and 30 individuals per square foot over most of its range. The maximum density encountered was 32 per square foot.

The Zostera Zone

The belt dominated by *Zostera nana* follows sharply after the *Anapella* belt. The *Zostera*, forming a firmly aggregated mass, prevents the passage of the burrowing lamellibranchs.

The *Zostera* bed is raised about one or two inches above the general level of the surrounding lagoon shore. This has the effect at low tide of enclosing on the inshore side of the *Zostera* a pond of considerable area but very shallow depth. The presence of this water does not appear to alter the constitution of the fauna of the immersed portion.

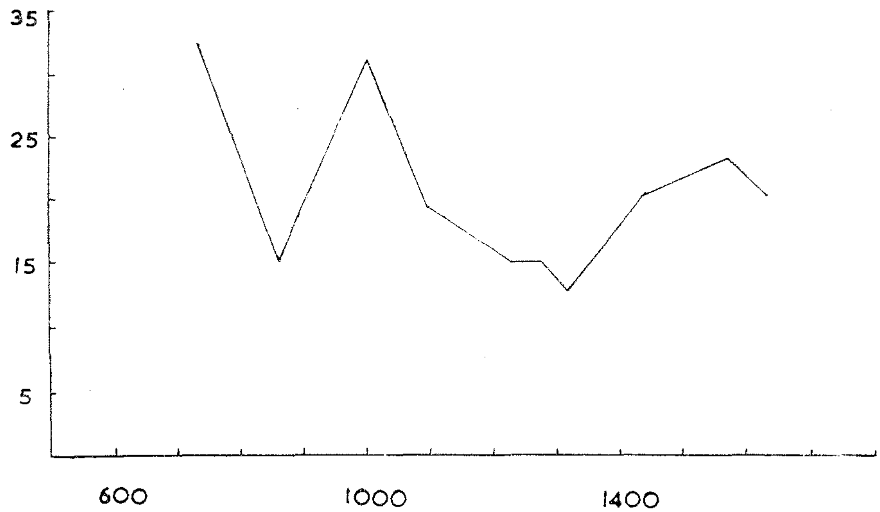

FIG. 5.—Density of population per square foot of *Anapella* on the shore of Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

The sea grass does not form a fully developed Zosteretum as the characteristic fauna of such a habitat is absent. Species are found which appear for the first time, namely *Brachyodontes rostratus* (Dunker), *Venerupsis diemenensis* Quoy & Gaim., *Lucinida assimilis* (Angas), *Pyrazus australis, Fasciolaria australasia* Perry, *Ostrea virescens* Angas, two species of Nemertines and small individuals of *Leander intermedius* Stimpson.

Of the above species only the Nemertines and *Pyrazus australis* are not found in other places in the lagoon. The shrimp is found in the pool behind the *Zostera* bed. This latter species is seasonal in its occurrence, being only found in the late summer.

Other species found in the *Zostera* bed are *Salinator fragilis, Patelloida subundulata, Bittium lawleyanum, Cominella lineolata, Marcia scalarina* and *M. corrugata, Paragrapsus gaimardii* and *Elminius modestus* attached to *Brachyodontes rostratus.*

It is evident from the extent of large 'peaty' deposits that the *Zostera* beds were, until recently, of greater area than at present. In particular, the beds must have extended further out into the lagoon and to the east of their present limits. The fauna living on these old beds is poor but does not contain any of the forms noted above as being confined to the *Zostera* beds. *Paragrapsus* makes large burrows in this 'peaty' material.

Marcia corrugata (Lam.)

This species becomes dominant immediately after the *Zostera* belt, i.e., on the old *Zostera* beds and the sandy mud further out. There are no species appearing for the first time in this belt.

Other species found are *Elminius modestus* and *Chthamalus antennatus, Patelloida subundulata, Paranassa pauperata, Cominella lineolata, Bittium lawleyanum, Austrocochlea obtusa, Venerupsis diemenensis* and *Brachyodontes rostratus.* There are no burrows of *Paragrapsus gaimardii* beyond the first 30 feet of this belt.

Austrocochlea obtusa (Dillwyn)

This gastropod is distributed throughout most of the shore. One individual was found in the *Bembicium* belt and a few in the *Anapella* belt. Searching did not reveal a large number of specimens and it is thought that these few individuals may have been accidentally distributed. In this connection it is worth noting that many shells of various species are found littering the shore of the lagoon, and care has to be exercised that shells identified are inhabited. Numerous shells were found but do not appear in these lists as they were not inhabited. Stephenson (1939) makes similar observations about the distribution of South African molluscs.

Austrocochlea obtusa suddenly appears in large numbers 2470 feet from the *Arthrocnemon* scrub. It becomes dominant almost immediately. The *Austrocochlea* belt is about 320 feet in width, extending as far as the Lagoon Bottom.

Other species found are *Ostrea virescens* (not plentiful), *Venerupsis diemenensis, Marcia corrugata*. The latter species is in large numbers and in places ranks as a co-dominant. *Anapella cycladea, Lucinida assimilis, Mytilus planulatus* Lam., *Brachyodontes rostratus, Patelloida subundulata, Paranassa pauperata* and *Cominella lineolata* are also found. Only one specimen of *Anapella cycladea* was recorded in the course of several visits and the presence of this species must be regarded as doubtful. *Paragrapsus gaimardii* is found living in the byssus threads and below the colonies of mussels. *Elminius modestus* and *Chthamalus antennatus* are found attached to mussels and isopods and amphipods are very numerous swimming in the water retained on the shore.

Notes on Other Species

(*a*) *Patelloida subundulata* (Angas)

This small limpet has a very considerable dessication toleration, being found in the *Bembicium* belt and extending as far down the shore as the lower tidal limits. During the summer the individuals in the *Bembicium* belt are exposed to the air and sun for most of the period of daylight. The dessication effect of the sun is supplemented by the possibly greater effect of the wind which is nearly always blowing across the lagoon.

The limpets living at the top of the shore are very easily removed from their substratum. The foot in many instances showed signs of drying and the animal was not in a very healthy state. At a distance of 260 feet from the *Arthrocnemon* scrub it was noticed that the limpets had a more firm grip on their substratum.

The limpets use any solid object as a substratum. Small pebbles, which are few in number, and shells, either living or dead, are used. If shells are used a preference seems to exist for those which are occupied by an animal. In the Upper Shore this is usually *Bembicium melanostoma*. In the lower shore regions many *Anapella*, living just below the surface, have one valve projecting above the sand with a *Patelloida* living on it. In the lower tidal areas there is not much preference shown for habitat except that *Paranassa pauperata* is never occupied by limpets. *Bittium lawleyanum* and *Assimania brazieri* are not used as a substratum due to their small size.

Paragrapsus gaimardii (Milne Edwards)

This crab is common throughout the whole of the area examined. The crabs spend the intertidal period in either permanent or temporary burrows in the sand. The larger crabs make large permanent burrows but the smaller individuals seem to be content to bury themselves at any convenient place. When covered by the tide these crabs scuttle about on the bottom seeking food and, on alarm, they either bury themselves or assume a fighting pose.

There exists a very definite size distribution of this species on the shore. Small individuals are found at both the upper and lower tidal levels. The largest crabs, of up to 5·5 cm. in carapace width, are found immediately below the *Zostera* bed. Large crabs may be seen scuttling about the Lagoon Bottom in non-tidal waters. These crabs sometimes invade tidal waters in large numbers for sunbathing.

At low tide, usually on days with hot sun, these crabs are to be seen sunbathing at various places on the shore. The edge of the sea may be crowded with crabs from non-tidal waters. The crabs stand on the extreme tips of their claws with the body raised high off the ground.

Philyra laevis Bell

I have not mentioned this crab in the text above as there is some doubt as to its behaviour. At high water these crabs can be found at the highest levels reached by the tide, but digging at low tide produced only one specimen and it is concluded that it is a Lagoon Bottom dweller. It invades the tidal areas with the flow tide and retreats again on the ebb. It is most commonly found in the drainage channels which contain permanent water. In the channel to the east of this transect these crabs can usually be found buried with only their eyes and claws projecting from the sand. They can move fairly rapidly and cover considerable distances in search of food.

The species is both a predator and a carrion feeder. It will feed greedily on a *Paragrapsus* which has been trampled underfoot, using both chelae in what can only be described as an orgy of feeding.

Paranassa pauperata (Lam.)

As noted above, this species is found over nearly all of the area of the transect. Its role is that of the carnivorous predator and carrion feeder. At low water the species is inclined to bury itself in sand especially if it lives in the higher tidal levels. In those parts of the shore where water lies in hollows the species does not seek protection by burying. At high water or where there is more or less permanent water it roams across the sand seeking out lamellibranchs or dead crabs. These form its main food supply.

The hunting is conducted by a strong sense of smell. During a period with a moderate wind a lamellibranch *(Marcia scalarina)* was opened and placed on the sand. Within very few minutes the gastropods were approaching from all sides. Those upwind (and therefore on the weather side of the surface water drift) were attracted within a foot or so of the prey but from as much as four or five feet downwind animals were proceeding towards the food. The course pursued is zig-zag as if the animal were using an average intensity of smell as a course. When close to the prey the gastropod moves straight towards it. Within five minutes, five animals were feeding on the lamellibranch, four were coming downwind and five more were coming upwind to the food. In one and a half hours time the mollusc was devoured and the gastropods dispersed.

Spisula trigonella (Lam.)

This species occurs sporadically throughout most of the Supra *Zostera* zone. It is never plentiful and is found burrowing in the subsurface layers.

Assimania brazieri (Ten. Woods)

This small gastropod first appears on the shore in the lower *Bembicium* belt and extends as far as the *Zostera* bed. The species does not live on the *Zostera* nor on the shore below the sea grass. At about 700 feet from the *Arthrocnemon* scrub the species is frequently found in large numbers (as many as 10 individuals per square foot) on the algal mats described below. At lower levels where the algal mats are not so common the species occurs on the surface of the sand usually in places where it is covered by water. Figure 6 shows the density of the *Assimania* population at certain places on the shore. The species becomes locally dominant in small areas and numbers as many as 30 individuals per square foot. These small patches, with one exception, have not been included in the zonation outlined above as they are purely local in occurrence.

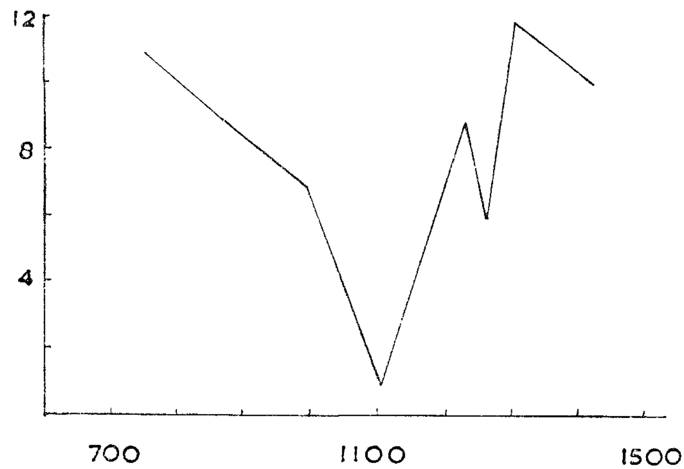

FIG. 6.—Density of population per square foot of *Assimania* on the shore of Pipe Clay Lagoon. Distances in hundreds of feet from the *Arthrocnemon* scrub.

Algal mats

At approximately 420 feet from the *Arthrocnemon* scrub small mats or pads of sand were noted on the shore (Plate II). These pads extended as far as 200 feet from the *Zostera* belt. At this place they were replaced by worm casts. The sandy mats and worm casts are not usually co-existant.

On examination these mats were found to consist of numerous strands of blue-green algae, a species of *Oscillatoria* forming the largest proportion of the algae. Mixed with the algae were sand grains.

The pads ranged in size from about half an inch diameter to nearly two inches. The smallest were found at the upper limits of the range of the pads and the largest were found just above the lower limit. The largest pads were not more than a quarter of an inch in thickness. The colour of the mats was slightly darker than that of the shore. The mats numbered about six per square foot.

The mats do not seem to offer a food supply to many animal species. The only species which has been noted to occur on the mats is the tiny gastropod *Assimania brazieri*, but even this appears to be local in character.

There is field evidence pointing to a considerable seasonal variation in the abundance of the mats. In late summer (March) the mats were noted as far down the shore as the *Zostera* belt but in winter they ended sharply at the commencement of the worm tubes. In the spring the distribution is similar to that in the winter with the exception that the upper limit is higher on the shore. There is not a great seasonal difference in the size of the mats, the pads in the summer being only slightly larger than those in the winter. The number of mats per unit area varies greatly, being very high (more than 20 individuals per square foot) in the spring.

Lying on the floor of the lagoon are clusters of several algae which appear to float about at high tide and lie on the shore when the water has receded. The most common of these is *Enteromorpha compressa* (L.) Grev. The other species are Rhodophyceae. All these species, especially the Rhodophyceae, are in the nature of drift and it is difficult to find the part they play in the intertidal region.

Section B

The Entrance To The Lagoon

As has been noted above that the northern and southern sides of the entrance channel show two sharply contrasting types of shore. From X to Y (Text fig. 2) the northern shore consists of a thin layer of greyish sand overlying black organic mud which in turn lies on a shell bed. Beyond Y the shore is composed of fine ocean beach sand which is backed by low dunes. This sand continues along the rest of the northern shore.

The fauna of the northern shore is similar to that described on Transect 12, and only the differences will be considered here. A feature which is characteristic of this shore is the presence of the crab *Mictyris platycheles* Milne Edwards which is dominant over most of the shore below the *Bembicium* belt and above the *Marcia* belt. The crab is found over the shore between X and Y but some individuals occur on the ocean beach. Also found on this part of shore are *Anapella cycladea, Marcia scalarina* and *M. corrugata.* The first of these species is not as common as in the more muddy parts of the lagoon. *Bittium lawleyanum* is not found on the shore, nor is *Assimania brazieri.* The anemone *Anthopleura aureo-radiata* is also absent. Occasional individuals of the lamellibranch *Antigona gallinula* (Lam.) are encountered. *Spisula trigonella* is rare and *Zostera* is absent. The absence of the latter plant is one of the most obvious features of the shore. Due to the lack of shells over most of the shore there are no limpets. The colonies of *Pyura* and the mussels with their *Galeolaria* adherents are also absent. The crabs *Philyra laevis* and *Paragrapsus gaimardii* are both numerous, the former being found at high water. The gastropods *Cominella lineolata* and *Paranassa pauperata* are both plentiful in the sand in this region.

In general, it might be said that the fauna of this section of the shore is in part transitory between that of the ocean beach and the muddy lagoon. There are few surf beach species but there has been a definite elimination in the number of lagoon species. The crab *Mictyris* forms an ecological feature which is not encountered in the lagoon proper. The behaviour of this crab is discussed below.

Mictyris platycheles H. Milne Edwards

This species is very common in vertical burrows over large areas of the sandy shore at both the northern and southern sides of the entrance to the lagoon. The species has a definite preference for a certain type of sand, being found only where that substratum occurs.

(a) On the Northern Side of the Lagoon Entrance

The spit at the lagoon end of the ocean beach is of sand of the same consistency as that of the wave exposed beach but it is populated by a small number of *Mictyris*. The wave exposure found on the lagoon side of the spit is even less than that found within the lagoon and the reason for the poverty of numbers of this species must be found in the substratum. Similarly, to the west of X (Text fig. 2) there are no crabs to be found.

The substratum at the sandy spit consists of a fine white sand typical of surf beaches. There is no substratum of black mud below it. At X there are numbers of dead lamellibranch shells lying thickly on top of and buried in the sand strip which is thin with a thin black mud below it. Between these two places the sand is about 1 inch thick with 3 inches of black mud separating it from the shell bed. Over all this latter area of the shore *Mictyris* is very common. The surface sand is greyish brown in colour, soft and suitable for easy burrowing. The ocean sand is probably too hard to allow easy burrowing and the shells in the more muddy places also offer an obstruction to this habit.

The crabs periodically, at some time when the sand is uncovered by low water, come out of their burrows and move across the sand in large numbers. The general line of movement is parallel to the shoreline. The time of migration is irregular but always occurs at some part of the intertidal period although all of this period is not thus occupied. It is possible that each individual spends only a short time on the surface. There are so many crabs that only a percentage is present at any one time and the number on the surface of the sand is more or less maintained by an unconscious replacement of the satiated individuals which burrow into the sand and await the next tide. McNeill (1926) gives a full description of the genus and described the habits of this species as being similar to those of *M. longicarpus* Latreille. The latter species feeds in horizontal galleries below the surface before coming out on to the top of the sand. Once on the surface the species scrapes the sand and sieves the material for food. In *M. platycheles* as seen at Pipe Clay Lagoon, there is no formation of subsurface galleries. The crab bores its way straight to the surface leaving a round hole such as would be left by a walking stick.

The crab feeds as it moves across the surface of the shore. The chelae are used to scrape sand into the mouth. The movements of the legs of the crab form little balls of sand about one-eighth of an inch in diameter and these are closely spread on the shore. The gut of many crabs examined was full of black mud with little or no sand. This indicates that some subsurface feeding must take place.

The burrows are formed in a similar fashion to that described by McNeill (*loc. cit.*). The crab rotates in a clockwise direction, at the same time lowering one side, usually the left, by scooping with the legs of that side. The crab forms two types of burrow. One is a shallow excavation just below the surface and is made for protection during a migration. On the passing of the danger this burrow is soon quitted. A more permanent burrow is formed for inhabitation during the tidal period. This burrow extends vertically down into the black mud, usually terminating at the top of the shell bed. The crab lives in a slightly enlarged circular chamber at the bottom of the shaft. On the surface the burrow leaves a rosette of disturbed sand so that the surface of the shore is pitted with exit holes and liberally strewn with rosettes and small pellets of sand. The subsurface feeding must take place in this burrow.

The crabs make two sounds on the shore. During migration a noise is made which resembles the patter of large and heavy raindrops on a sandy surface. When buried and possibly feeding a bubbling sound can be heard which resembles that made by a swiftly flowing stream.

The crabs inhabit a broad belt of sand 10 feet below the level of a low 'high high' tide to a level approximately that of 'high low' water. The total width of this belt of the shore is 130 feet and the distance along the shore which is inhabited by the crabs is about ½ a mile. Text fig. 7 shows the density of the species at different levels on the shore. The density was obtained by digging down a foot square of sand as far as the shell bed. It is noticeable that the species becomes numerous quite suddenly and the lower limit of the species is even more sharp. Based on an average density of 7 crabs per square foot there is a population of some 2½ million crabs on this stretch of the lagoon.

Other species found on the same part of the shore as the crab are *Marcia scalarina*, *Antigona gallinula*, *Spisula trigonella*, *Paragrapsus gaimardii*, *Cominella lineolata* and *Paranassa pauperata*.

In view of the scarcity of records of this species from Tasmania it is worth noting that it also occurs at Seven Mile Beach, Kingston, Blackman's Bay and Orford. McNeill states that the northern coast of Tasmania is the centre of distribution of the species and quotes Smith (1909) as recording the same species from Bridport.

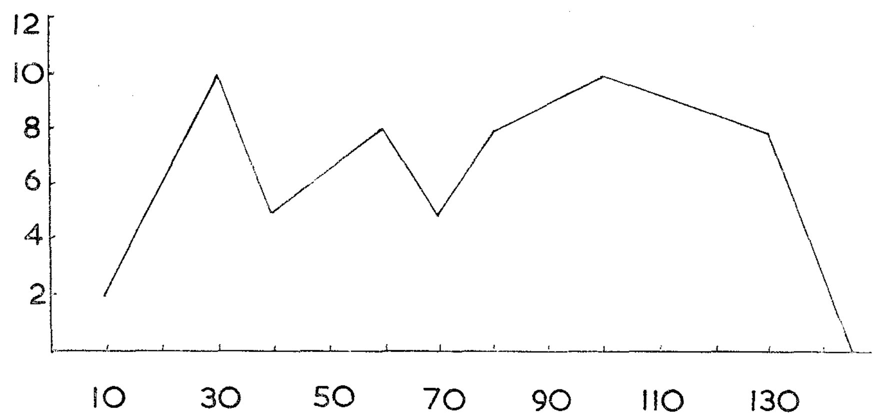

FIG. 7.—Density of population per square foot of *Mictyris* on the shore of Pipe Clay Lagoon. Distances in feet from the level of 'low high' water.

(b) On the Southern Side of the Lagoon Entrance

With the exception of one small area, the crab is not as numerous on this side of the entrance channel as on the northern side. The distribution of the species closely follows the distribution of sand of a similar constitution to that in which the crab is found on the northern side of the channel. The shore from H to I (Text fig. 2) at a distance of 20 feet from the foot of the low cliffs is densely populated by the crabs. The lower limit of this species is 'low low' water. Based on an average density of 6 crabs per square foot, there must be nearly one million crabs on this stretch of shore. The crabs here, as at other parts of the lagoon, avoid water and do not enter the sea. If water has to be crossed they do so rapidly and without stopping. Areas of the shore which are covered with small stones are also avoided. The dislike of stony ground is probably because the crabs find it difficult to feed on rough ground.

On rounding the point at I the foreshore is rocky for about half of its width. The other, lower half, is occupied by *Mictyris*. It was noted that neither *Philyra* nor *Paragrapsus* seemed to make any attempt to feed on the crabs. The predatory species may become satiated with *Mictyris* at an early time in the intertidal period. At J the soldier crabs die out due to the substratum becoming too muddy. At L the mud gives way very sharply to a patch of sand. On this latter substratum *Mictyris* is extremely numerous, crabs being packed together in a compact mass.

Between L and M the species is only found in very restricted areas of sand. Beyond M the shore is very muddy or stony and the species is not encountered.

The southern shore of the lagoon entrance is very different from the northern. Between I and J the substratum is a yellow-grey sand. Beyond J the sand is replaced by a mud which in turn is replaced by sand at K. At L there is a rich mud patch with sand beside it. Currents deposit a large amount of organic material on this mud patch. At M the shore consists of mud with stones and outcrops of mudstone. This type of shore continues as far as N where there is a shingle beach. Beyond the beach as far as the open sea there are large boulders embedded in mud. Along the shore from L to the sea there are low cliffs of mudstone. The lagoon bottom from J to the sea is of mud.

The fauna and flora of the shore is dominated by the presence or absence of mud. Stones, rocky outcrops and boulders are all covered by a coating of fine silt. Roving species leave very obvious tracks on this incrustation. The presence of such large quantities of mud undoubtedly restricts the distribution of open sea species and so the fauna is composed largely of lagoon forms but with a few open coast species present on the extreme seaward end of the entrance.

Wherever the substratum is suitable the soldier crab *Mictyris platycheles* is found. All the more muddy parts of the shore are populated by *Paragrapsus gaimardii.* At M the surface of the rocks is devoid of macroscopic life, but below stones there are numerous *Paragrapsus*, *Sypharochiton pellis-serpentis* (Quoy & Gaim.), *Plaxiphora costata* (Blainville), *Amaurochiton glaucus* (Gray), *Amphitrite* sp., *Botrylloides* sp., two species of ascidian, *Coscinasterias calamaria* (Gray), *Petrolisthes* sp., and the alga *Codium tomentosum.* On rocks higher up the shore are the barnacles *Elminius modestus* and *Chthamalus antennatus* with the worm *Galeolaria caespitosa* forming considerable growths between the barnacles and the mud covered stones. The holothurian *Stichopus mollis* (Hutton) is found in numbers around 'low low' water mark. This species is only encountered in the summer. Burrowing lamellibranchs are absent from this mud which is very soft. No burrowing forms, other than worms were noted. *Mytilus planulatus* is found on boulders at and above Mean Sea Level. Those individuals living lowest on the shore are infected by the pea crab, *Fabia hickmani* Guiler. The 'patelliform' *Patelloida subundulata, Siphonaria diemenensis* Quoy & Gaim. and *S. zonata* Ten.-Woods are all common, the latter in places numbering 12 per square foot. *Austrocochlea obtusa* (Dillwyn) occurs but it is not very common.

Only one oyster, *Ostrea virescens* was found. The whole of the mud and most of the rocks and stones were covered by a thick growth of small Cyanophyceae. These algae undoubtedly form an important part of the food supply of the browsing herbivores.

The shingle bed at N is situated at a place where the current is strongest and where there is scouring action on the bend of the channel. There are no sedentary animals found on the shingle and predatory or browsing species also appear to be absent. Even *Paragrapsus* is not present.

On the large stones at the entrance to the channel the most common organism is the anemone, *Actinia tenebrosa* (Farq.), which has been considered by Blackburn (1937) to be very similar to, if not identical with, the European and African *A. equina.* This anemone also occurs on the rocks at J. In both localities it frequents the sun sheltered side of rocks. The zonation here is different from that in the lagoon and is a modified form of the rocky coast zonation which can be seen on the Frederick Henry Bay coast. The zoning is . . . *Melaraphe unifasciata* (Gray), *Elminius modestus, E. modestus* with *Chthamalus antennatus, Actinia tenebrosa, Pteria pulchella* Reeve with *Enteromorpha* and *Chordaria cladosiphon* Kutz. The Infralittoral is occupied by various Rhodophyceae which are covered by *Pteria.*

The presence of *Melaraphe* and *Actinia* is undoubtedly an invasion from the rocky coast. The lamellibranch, *Pteria pulchella,* is very numerous in the entrance to the channel forming dense clusters on rocks, algae and waterlogged wood. Some large masses of these molluses are found unattached but are of sufficient size to resist normal wave action. After a gale millions of these bivalves are found washed ashore on the ocean beach. The presence of *Pteria* in the entrance channel is an invasion from the Infralittoral of a sandy beach.

The seaward end of the entrance channel thus shows two separate invasions. In the tidal areas are found species which have wandered in from the rocky coast and in the Infralittoral are species which normally are found in the Infralittoral of a sandy beach.

In the lagoon proper many species are found which also occur on rocky coasts. The most important of these are the mussel *Mytilus planulatus,* the barnacles *Elminius modestus* and *Chthamalus antennatus,* the ascidian *Pyura praeputialis* and the serpulid *Galeolaria caespitosa.*

These species furnish a valuable set of indicators to correlate the faunistic levels within the lagoon with those in other habitats. In some instances it is not possible to use some of the lagoon species on account of their specialized habitat. As an example, the barnacles living on the telegraph pole on the line of the transect are confined to the sun sheltered side of the pole and they do not give a true correspondence of the exposure at that level and at an equivalent level on a rocky coast. The correlation of lagoon faunal levels with those on rocky coasts is treated in the discussion.

At high tide several predatory species invade the lower parts of the tidal region. Foremost among these are fish. No attempt has been made to capture the pelagic fish but some of the bottom feeding species are known. The most common of these, judging from impressions left in the sand, are flounders, probably *Ammotretis* sps. These fish leave impressions in the sand as far up the shore as the lower limit of the *Anapella* belt. Other larger somewhat diamond shaped hollows are made by the less common rays.

The large gastropod, *Fasciolaria australasia* Perry, is rarely found in the Infra *Zostera* zone. The starfish, *Coscinasterias calamaria,* and the holothurian, *Stichopus mollis,* both are frequent invaders.

All these species will be restricted in their choice of food by their limited vertical range.

Discussion

(1) Comparative Notes on the Distribution of Certain Species.

The *Arthrocnemon* scrub is found along all of the western shore of the northern bay of the lagoon. The northern shore of the same bay has a poorly developed scrub. At A the dominant is *Salicornia,* the *Arthrocnemon* plants being reduced in numbers. The *Arthrocnemon* and *Salicornia* marsh is not as well developed in other parts of the lagoon. At C, the marsh is not well developed. In some places there is no marsh at the top of the shore and at D and E it is replaced by a bed of shells and shell fragments.

The lower part of the *Arthrocnemon* scrub is populated by the gastropod, *Salinator solida*. The distribution of this species is controlled to some extent by the amount of water in the marsh. Where there is no marsh, as at D, and therefore little or no seepage on the shore the species is absent. The belt is partly replaced by *Bembicium* but is generally bare of molluscan life. If there is little seepage, as at O, there are only a few of the molluscs on the shore and in the marsh. The marsh at O is the driest in the lagoon. At the marsh at A where there is considerable seepage, the gastropod is very numerous, an average of several counts being 20 per square foot. *Salinator* partially covers itself when exposed to the air by rotating itself clockwise in the sand. The individuals living in the marsh, being independent of the tides do not practise this burying habit.

The *Bembicium* belt is present throughout the lagoon. The belt is usually well developed, but at A, due to a large amount of seepage from the marsh, it is narrow and is soon replaced by *Assimania*. At one place (F) both *Bembicium* and *Assimania* are considerably reduced in numbers due to a concentration of dead *Anapella* shells. The species never attempts to bury itself at low water.

Bittium lawleyanum is distributed throughout the lagoon except in the entrance channels. It does not differ in its tidal distribution from that noted above. In the small bay B, the lamellibranchs *Anapella cycladea* and *Marcia scalarina* are both very numerous. The latter numbers 35 individuals per square foot. In the more sandy parts of the lagoon these species are not as numerous as at Transect 12. It is to be noted that in some small areas *Marcia scalarina* assumes dominance in the lower part of the *Anapella belt*. This is the case in the bay B where there are 35 *Marcia* per square foot, there being only 10 *Anapella* in the same area.

The barnacles found in the lagoon are of two species, *Elminius modestus* and *Chthamalus antennatus*. The former is by far the more common species, being found wherever a suitable substratum offers itself for colonization. Thus, it is encountered on wood, telegraph poles (Plate II), stones and mollusc shells. At the spit at B on the western shore of the lagoon deep water is found close inshore and a rocky substratum is exposed. *Elminius modestus* is found on the rocks and also forms very thick growths on a small jetty nearby. *Chthamalus* is more common on the southern side of the entrance channel. Pope (1945) observes that the latter species likes rocky situations or mollusc shells at high shore levels with some spray. The absence of rocks and spray in the lagoon will probably restrict the distribution of this species.

Algal mats occur at the appropriate tidal levels throughout the lagoon. The mats are most numerous at B. At G, where the Clifton road branches off the lagoon road, the mats occur further up the shore than at other places. The probable reason for this is the direction of the prevailing wind. The effect of this factor will be discussed more fully in connection with the distribution of the *Zostera* beds. In the vicinity of Z_5 the mats are smaller and less numerous than over the rest of the lagoon.

The anemone, *Anthopleura aureo-radiata* (Stuck.), has all but the ring of tentacles and the oral surface buried in sand. It is found living on the shells of *Anapella cycladea* and *Marcia corrugata*. More rarely, it is found on *Marcia scalarina* and *Spisula trigonella*. The most dense population of anemones is found in the small bay B where 20 per square foot is an average figure. The food of this species is largely planktonic. It has been seen to eat worm fragments but rejected isopods.

The *Zostera* beds show a very interesting distribution. Beds are found at Z_1, Z_2, etc. in the lagoon. The beds are found very much closer inshore at the south of the lagoon than at any other place. The Z_1 is close to the point B but this is due to the depth of water off the point. At the southern end of the lagoon there is no such depth of water and the gradient of the shore is the same as at the northern side of the lagoon. The bed Z_3 occurs only 306 feet from the *Arthrocnemon*. At a tidal period when other beds, particularly Z_1, were under 1 inch of water, the Z_2 bed had 3 inches of water covering it and Z_3 was covered by 1½ inches of water. At the time of examination a strong wind was blowing from the North. It is suggested that the prevailing wind, which is in the North quarter, causes a considerable raising of tidal and faunal levels in the southern part of the lagoon. The difference in levels probably amounts to about 3 inches, which is sufficient, considering the level nature of the lagoon floor, to permit *Zostera* to grow much closer inshore at one end of the lagoon. The algal mats also occur nearer the *Arthrocnemon* scrub at the same end of the lagoon. It is significant that the plants in beds Z_5 and Z_4 are very thin and the plants are not nearly as well developed as in the other beds. The bed Z_2 is the homologue of beds Z_1 and Z_5 but the beds Z_3 and Z_4 are special developments due to the elevation of tidal levels caused by the prevailing wind.

In this connection is to be noted that the beds Z_1, Z_2 and Z_5 are followed by the *Marcia scalarina* belt, beds Z_3 and Z_4 occur within and are followed by the belt of *Anapella cycladea*.

The gastropod *Austrocochlea obtusa* is found plentifully distributed over the lower tidal areas of the lagoon shore. Three varieties of the species are found. The most common is the striped sheltered water form which is the dominant in the *Austrocochlea* belt The small estuarine form is also encountered but it is not common. Although the salinity of the lagoon is above that of sea water this does not seem to produce any notable variations in this variety of the mollusc. The large, ribbed white variety, formerly *A. constricta,* is encountered on the lower parts of the shore. It is usually a feature of wave exposed places. I have found this variety in other wave sheltered places such as Dodge's Ferry. Of the three varieties of *Austrocochlea obtusa* in the lagoon, only the sheltered water form may be considered as being in its characteristic habitat. I am indebted to Miss H. McPherson of the National Museum of Victoria for identification of this species and for drawing my attention to the ecological varieties of the species.

The worm *Galeolaria caespitosa* is found living on shells of mollusca and on stones in the Infra *Zostera* belt. Small pieces of massed colonies of tubes of the worm occur on the sand. These masses are not attached to the substratum and have been broken off thick incrustations. The length of time that the tubes have been detached is a matter of some speculation. Some of the worms in the detached pieces were alive in October, 1950. It has been noted previously (Guiler, 1951) that sometime between December, 1949 and December, 1950 the thick masses of *Galeolaria* found on various parts of the coastline of Tasmania were broken up. The cause of this is obscure. In Pipe Clay Lagoon I have not seen any masses of tubes which correspond to the 'breeding stock' which is left unharmed in other areas. Some tubes are found at J (Text fig. 2) but they do not form such large masses as those at Dodge's Ferry. Assuming that the pieces of worm tube masses found in Pipe Clay Lagoon were disturbed about the same time as at other places, it is of considerable local interest to note that at the time of writing the individuals in these masses are still alive. The wave action in the lagoon must not be sufficient to either bury or break up the worm masses once they have become detached from rocks. This appears to be a special feature of the lagoon. The assumption that the catastrophe which caused the breakage of the worm tubes was general is fairly secure as its results have been observed over about 100 miles of coast. It is doubtful if the worm masses originally came from the lagoon. There are not sufficient areas of rock suitable for intense colonization except at J which is occupied by small, old colonies which have not been broken up. The broken masses of worm tubes were probably smashed up on the wave exposed coast and were washed into the lagoon.

Roving species such as the gastropod *Cominella lineolata* and *Paranassa pauperata* are found throughout the lagoon. The latter species occurs at all tidal levels but the former is only found at the lower levels of the shore. The crabs *Paragrapsus gaimardii* and *Philyra laevis* are also found at all tidal levels. The latter species is only evident at high water, only one specimen being found buried during the intertidal period.

The most common birds found feeding on the shore are oystercatchers, *Haematopus ostralegus* L., silver gulls, *Larus novaehollandiae* Stevens, black swans, *Chenopis atrata* (Latham), whitefronted herons, *Notophoyx novaehollandiae* (Latham), the Caspian tern, *Hydroprogne caspici* (Pallas), and dotterels.

(2) General

The effect of climatic factors is considerably reduced by the nature of the lagoon shore. The shore, as noted above, is fairly level and a large amount of water is retained on the sand as the tide recedes. The sand is always very moist, even at low water in summer time, and low water species such as *Austrocochlea obtusa* are found as far up the shore as high water level. The high density of population in the belts immediately above the *Zostera* is undoubtedly assisted by the high moisture content offering extended feeding time and protection from dessication. In the bay at B there were 35 *Marcia scalarina*, 10 *Anapella* and 20 anemones per square foot. The *Zostera* bed being raised an inch or so above the level of the shore causes water to be imprisoned behind the bed at low tide. This lake increases the amount of water retained on the shore.

The warm temperatures of shore waters of the lagoon during the summer is probably of considerable importance in keeping the lagoon bottom dwelling forms from migrating freely into the lower tidal levels. In winter, temperature does not operate as a controlling factor for Infralittoral forms due to the off-shore migration of most mobile forms during that period of the year.

The fauna of the lagoon can be compared with that of rocky coasts and the correlation of faunal levels is shown in Table I. The relations of the faunal levels in different habitats will be discussed more fully in a future paper and this Table must be regarded as an interim report on the subject.

The relationship between the Upper Shore and the Supralittoral Fringe and the Supralittoral is fairly close, the *Arthrocnemon* belt corresponding to the *Melaraphe* belt of a wave exposed coast. The upper limit of the Supralittoral fringe on exposed coasts is usually fairly well defined but in the lagoon the only obvious difference is the elimination of the gastropod *Salinator solida*. The range of this mollusc may be extended by the presence of water in the marsh. The *Arthrocnemon* scrub, or *Salicornia* mat, corresponds in most part to the Supralittoral. The upper limit is not clear as the plants merge into the terrestrial maritime plants.

The lower part of the *Arthrocnemon* scrub corresponds to the saltings described by Curtis and Somerville (1947) at Boomer Marsh. In comparison with the latter area it can be noted that *Arthrocnemon* is not as plentiful at Boomer as at Pipe Clay Lagoon. Curtis and Somerville further note that the alga, *Hormosira banksii*, is found living on mussels which are buried in the mud in the Infra *Zostera* zone. This alga does not occur at Pipe Clay Lagoon.

TABLE I.

The zonation at Pipe Clay Lagoon compared with that on other types of coast in South Tasmania

	Lagoon		Semi-exposed Coast	Exposed Coast	Sheltered Bay	% Exposure
Supra Littoral	*Arthrocnemon*	UPPER SHORE	Lichens	Lichens	? Bare	100
Supra Littoral Fringe	*Arthrocnemon* + *Salinator*		*Melaraphe*	*Melaraphe*	*Melaraphe*	70-100
Mid Littoral	*Bembicium*	SUPRA ZOSTERA	*Bembicium* (local)	Absent	? local	60-90
	Bittium		Barnacle	Barnacle	Barnacle + *Austrocochlea*	27-88
	Anapella		*Galeolaria*	*Catophragmus*	*Galeolaria*	18-71
	Zostera	ZOSTERA	*Patelloid* (*Brachyodontes*)	*Patelloid*	*Hormosira* &/or *Mytilus*	7-60
	Marcia		*Patelloid* *Mytilus*	*Corallina*	*Corallina*	0-26
Infra Littoral Fringe	*Austrocochlea*	INFRA ZOSTERA	*Laurencia* & *Lessonia*	*Sarcophycus*	*Cystophora*	0-2
Infra Littoral	*Pyura*	LAGOON BOTTOM	?	*Macrocystis*	*Cystophora*	0

The Mid Littoral of Stephenson & Stephenson (1949) appears to correspond to the Supra *Zostera*, *Zostera* and part of the Infra *Zostera* zones. On semi-exposed coasts the *Bembicium*, barnacle, Patelloid and *Mytilus* belts form the Mid Littoral.

The *Bembicium* belt is very well developed in the lagoon and occurs all round the upper Supra *Zostera* zone. The belt may partly replace the *Salinator* belt where there is little or no seepage from the land above the shore. On semi-exposed coasts the belt is developed locally in places where wave action is not strong. The belt is absent on wave exposed coasts. It is absent from sheltered bays. In view of its presence in the lagoon and on semi-exposed coasts it might reasonably be expected that the species would occur in sheltered bays. The ecology of sheltered bays has not been investigated fully but the species is definitely absent from Coles Bay (Guiler, 1951).

The barnacle *Elminius modestus* does not form a belt in the lagoon but is found on stones, telegraph poles and other such objects. By making use of the range of this species it is possible to determine that all the *Bittium* and most of the *Anapella* belts can be placed in a strip corresponding to that occupied by barnacles on exposed or semi-exposed coasts. The lower *Anapella* belt is equivalent to the *Galeolaria* belt of semi-exposed coasts and the *Catophragmus* belt of exposed coasts. The Patelloid belt of exposed coasts is approximately equivalent to the extreme lower end of the *Anapella* belt. The small limpet, *Patelloida subundulata*, is found as far up the shore of the lagoon as the *Bembicium* belt but the range of this species is not equivalent to that of any species found on an exposed coast.

The tube worm *Galeolaria caespitosa* is found at different levels in various places in the lagoon. At the southern side of the entrance channel the species is found above mussels on the shore. On the transect it would appear that the equivalent level is somewhere in the lower part of the *Anapella* belt. No tubes are found there but this may be due to the very severe limitation of suitable habitats for *Galeolaria*. The *Anapella* belt is very broad and probably several of the belts found on rocky coasts are represented by the one large belt in the lagoon.

The *Zostera*, neglecting beds Z_3 and Z_4, appears to correspond in tidal levels to the mussel *Brachyodontes rostratus*, which is found living in the *Zostera* beds. The mussel has been noted to form an incomplete band on semi-exposed coasts in the *Patelloid* belt. (Guiler, 1950). The level of 'dodge' tides at Blackman's Bay is at or about the middle of the *Galeolaria* belt. At similar tides at Pipe Clay Lagoon the *Zostera* can just be seen as a dark line on the surface of the water. The *Zostera* bed projects about 1 inch above the general level of the lagoon shore and allowing for this fact it is considered that the *Zostera* is at an equivalent level to that occupied by *Brachyodontes rostratus*. In sheltered bays *Zostera* usually occurs at a much lower level, often below tide marks. The reason for this is not yet clear.

The *Marcia corrugata* belt corresponds to the *Mytilus planulatus* belt of semi-exposed shores and the *Corallina* belt of exposed shores. The belt may be exposed at 'low high' tide.

The *Austrocochlea* belt is only fully exposed at 'low low' tides. In winter the tide rarely recedes far enough to allow examination of this belt. It is thus the lagoon representative of the Infra Littoral fringe.

The ascidian *Pyura praeputialis* is found on the Lagoon Bottom. Some groups of individuals may be exposed at an abnormally low tide but a normal 'low low' tide does not expose this species.

The salient feature of the comparison of the zoning on coasts with some degree of wave exposure with that in the lagoon is the number of belts on the former coasts which are represented by *Anapella* in the lagoon. As noted above, these correlations will be fully discussed in a future paper.

The food of the ecologically important organisms in the lagoon has been noted. The notes are based on observations of food catching, gut examinations and the known food habits of the animals or allied species. A possible food chain is given (Text fig. 8).

Within the lagoon there are three faunal types of sand. The ocean beach with a poor fauna, a *Mictyris* sand and a *Paragrapsus* mud. After a few visits to the lagoon it is possible to differentiate with considerable accuracy between these types, and consequently to predict the fauna living in the sand.

All the molluscs named in this work were checked against specimens in the May collection in the Tasmanian Museum.

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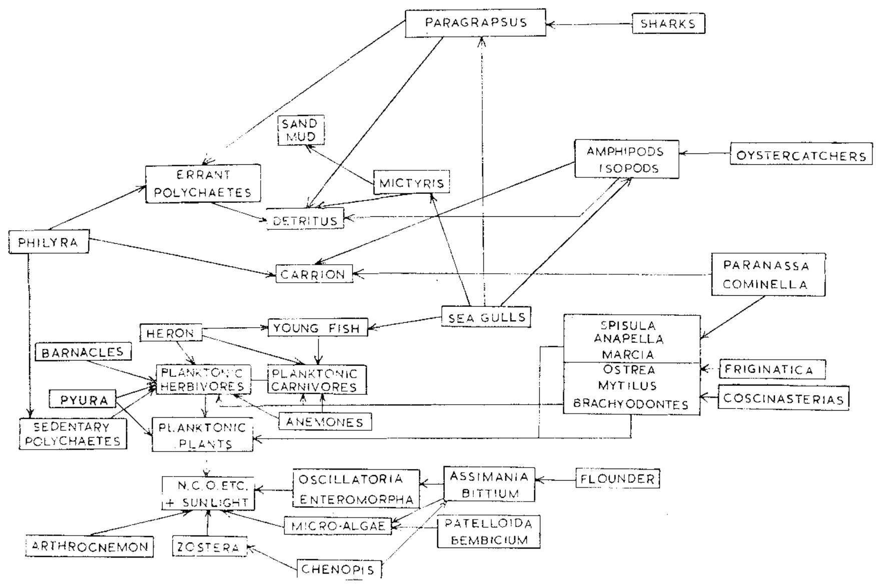

FIG. 8.—Suggested food-chain for intertidal organisms in Pipe Clay Lagoon.

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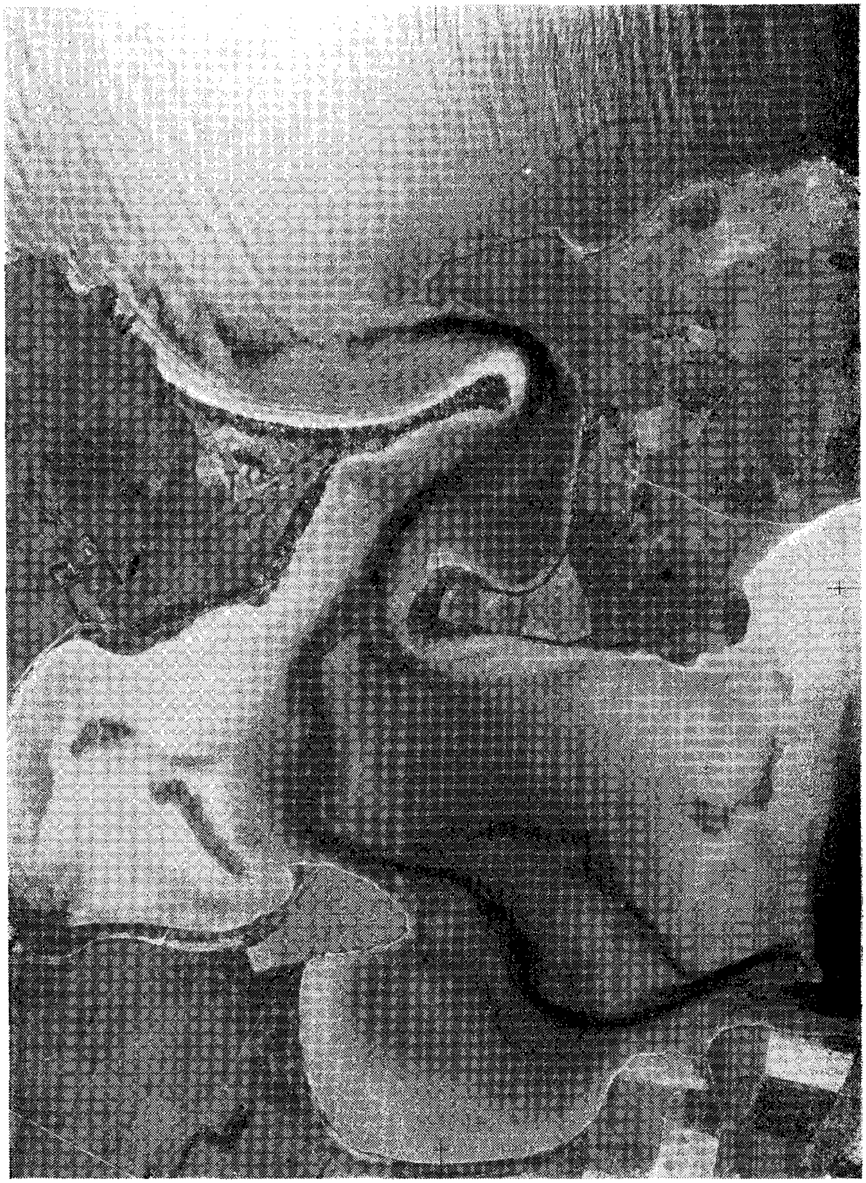

FIG. 1.—Aerial photograph of the northern bay and centre of Pipe Clay Lagoon. Published by courtesy of the Tasmanian Government Lands and Surveys Department.

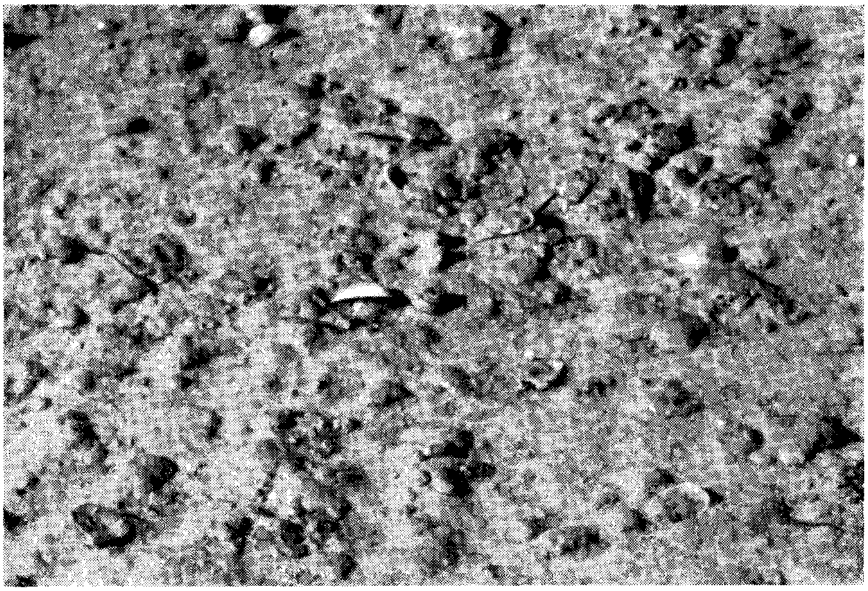

FIG. 1.—Algal mats on the shore at Pipe Clay Lagoon (October).
[*Photo. T. McMahon.*

FIG. 2.—Barnacles on the sun-sheltered side of a telegraph pole at Pipe Clay Lagoon.
[*Photo. T. McMahon.*