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AN INTRODUCTION TO THE NATURAL HISTORY OF THE  
HEATHCOTE ESTUARY AND NEW BRIGHTON BEACH ,  
CANTEBURY -- NEW ZEALAND.  
A STUDY IN LITTORAL ECOLOGY.

*Code Word : Andante.*

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## Synopsis.

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## I. General

### A. Introduction:

Ever since Marine Ecology began to take its place as a section of Biological Research, divergent views have been held as to the limits of marine and supra-marine regions; particularly is this so with regard to the fixation of the boundary between littoral and sub-littoral regions. Thus Murray(1898) defines littoral as down to 20 fathoms, while Flattely and Walton(1922) in their division of plant zones, consider this lower boundary to be at low-water mark. Sernander(1927) applies the degree and nature of exposure as a principle of division. On his principle the boundary between littoral and sub-littoral would coincide with the lower limit of intermittent exposure.

As the upper limit he had taken the normal high water line, but this plan had been modified by Kylin(1918) who took, as his upper limit for the littoral zone, his "Physiological High-water Line". This line, determined by three factors, normal high water level, wave motion and solar illumination, constitutes the upper limit of algal growth. Sjostedt(1928) objects to the term "Physiological High-water Line", and substitutes his term "Lotus-line", with exactly the same meaning. In his case it was equivalent to the lower limit of the Verrucaria-maura Association. Here the same author discusses the matter of division and proposes a system of division of the coastal region which would appear to be

quite satisfactory from a botanical point of view.

In this work it will be noticed that I have not classified the smaller groups under ecological terms. This is because I have been unable to reconcile my own conceptions of the standing of the various groups, with those set out in the various text books. Thus Pearse (1927a) divides association on Piles, Wharves and Ships into:

Stratum 1. Surface Animals.

Stratum 2. Boring Animals.

while in the Association of Mud Beaches, he groups them as,

Stratum 1. Animals of Drift Line.

Stratum 2. Animals of Intertidal Zone. (*Exposed Mud Flats*).

Stratum 3. Animals *of Among or under Plants*

*Stratum 4 Animals of Lagoons*

Stratum 5. Animals of Shore-water.

It seems to me that he has confused two methods of classification. In the one case we have surface as distinct from sub-surface. In the other case tide level is the criterion. It seems to me that tide level is just as important on piles as on muddy or rocky beaches, while the distinction between surface and sub-surface forms is quite as definite on muddy beaches as on piles.

As I have found similar difficulties with other classifications, and not wishing to obscure facts by a nomenclature which seems to mean something different to each writer, I have endeavoured to confine myself to such ecological terms as seem to have a fairly well established and constant meaning.

In New Zealand, Littoral Ecology is practically untouched. A paper by Oliver(1923) on "The Marine Littoral Plant and Animal Communities in New Zealand", while a very interesting general survey, bears the stamp of an attempt to cover several thousand miles of coast line in a few months work. The "History of the Portobello Marine Fish-Hatchery and Biological Station" by Thomson(1921) is chiefly an account of attempts to introduce various marine food animals into our waters; and these accounts, not from want of care but from lack of knowledge of our coastal conditions, and the natural difficulties involved in such a change, read like an obituary column. The account also contains a few notes on the fauna, and a list of some species found. Last year work was commenced on a biological survey of the Auckland Harbour, but nothing has as yet been published, though I hope it will result in some useful information, especially with regard to the breeding habits of littoral mollusca.

Aside from the work mentioned, there are a few scattered, incomplete and often inaccurate notes on the habits of some marine forms; but as a general rule, the approximate locality in which a species occurs is the only ecological fact known about it.

Animal Ecology in this country must be difficult till more specialists in particular lines have arisen. At present an ecologist must do the majority of the identification himself, and this is made more difficult in that much of the necessary literature is unobtainable, while very few groups



have been revised within the last 30 years. In every class of invertebrates there are probably many new species, while "lumping" has been over common in the past.

In this paper a definite attempt has been made to outline the chief ecological characters of two typical types of New Zealand beach. Work was concentrated on the shifting or microlithic beaches, and the stable or macrolithic beaches are here but summarised in so far as essential to the unity of the area. It was not expected, considering the magnitude of the task, the time at my disposal, the distance from the laboratory and the almost entire lack of apparatus, such as boat, nets, and much chemical gear, that the more intimate details of the region would be determined. The lack of data as to the quantities of phosphates, nitrates, sulphides, carbon dioxide and the hydrogen ion concentration, due to the necessary gear being unobtainable, I regard as one of the most serious defects of this work; but it is hoped that the results here recorded will be of service in opening up the particular lines of study in this area.

## B. Methods of Work

### 1. Determination of Physical and Chemical

#### Environmental Factors:

As much data as time and the conditions of work would allow was collected on this side of the question. As the nature of a given locality is a function of its past, a brief geological sketch of the origin of each locality has been collected

The water was examined for chlorine by the usual volumetric method, using silver nitrate with potassium chromate as indicator. In test experiments an accuracy of .01 grams of chlorine per litre was obtained, and I consider the results throughout as correct to at least .02 grams of chlorine per litre.

Densities were determined by the density bottle method, the usual precautions being taken.

Oxygen content was determined by an adaption of Dr. Thresh's method. It depends on the liberation of iodine from potassium iodide and sodium nitrite by sulphuric acid in presence of dissolved oxygen, in an atmosphere of coal gas. From my experiments I do not consider this method as accurate as that depending on the oxidation of ferrous iron; but it is quicker and sufficiently accurate for the purpose.

#### 2. Organic Environment:

To familiarise myself with the animals of the locality, some months were spent in collecting from the surface, under stones, and sieving mud. The material was taken back

to the laboratory for identification. Practically all the identification I did myself , but 4 worms (one a new species) were determined for me by Dr. Benham (Dunedin) , while an amphipod was referred to the family Phoxocephalidae for me by Dr. Chilton (Christchurch).<sup>\*</sup> As I considered that for the work to be of any value , the identification must be accurate, I have had my identifications of worms and crustacea checked by the above two workers. The mollusca were compared by me with specimens in the Canterbury Museum , identified by Suter. In the faunistic lists I have endeavoured to use the most correct names, except in the case of the mollusca. Here I considered it better to retain Suter's nomenclature as it is best known and established. I am quite satisfied that in many cases Suter's nomenclature is faulty, but any person wishing to consider this question should consult the papers in the New Zealand Institute Transactions by Iredale and Finlay.

An attempt has been made to reduce distribution in tide level to a numerical form, not because it was considered that the problem was solved by so doing, but that it was found to be by far the simplest and most precise method of demonstrating the actual state of affairs. Throughout, the graphic method has been used as much as possible , because it was felt that hundreds of figures would be of little interest to anyone except the worker, whereas when graphed the results of months of work can be taken in at a glance.

*\* Bale (Australia) examined a hydroid for me, as I considered it an undescribed species. Bale is of the same opinion.*

## C. Conditions affecting New Zealand generally:

### 1. Position:

New Zealand, extending for nearly a thousand miles south of latitude 34 South, offers a variety of conditions from almost tropical in the far north to sub-antarctic in the extreme south. The islands are of various origins and, being 1100 miles from the nearest large body of land, have a typical insular or oceanic climate.

### 2. Ocean Currents:

The generally accepted views (Oliver 1923) are as follows:

The coasts are washed by two main ocean currents.

The Antarctic Drift Current is confined to the south end of the Island, reaching up as far north as Jackson's Bay on the west and Banks Peninsula on the east. From Jackson's Bay the current flows southward, through Foveaux Strait, and up the east coast as far as Banks Peninsula where it is deflected eastward to the Chatham Islands. To this deflection is perhaps due the identical element in the Chatham Island and Banks Peninsula fauna, especially noticeable in the mollusca.

The other current is a branch of the Notonectic Current (Hedley 1915) which after following down the east coast of Australia, is deflected eastward on coming into contact with the Antarctic Drift Current, about the latitude of Tasmania. After crossing the Tasman Sea, it impinges on the west coast of New Zealand, and is again deflected, now northwards,

and passes round the northern part of New Zealand, continuing in an easterly and south easterly direction. Winds no doubt cause diversion in the surface water, and to this may be attributed the presence of logs from New Zealand rivers at the Kermadec Islands. A part of the eastward coast current , after passing through Cook Strait, continues in a southerly direction to about the latitude of Banks Peninsula, where it is again deflected , now in a south easterly direction.

From information received from Captain Bullons, Professor Speight, and my own observations , I believe the current system to be far more complicated. In Figure 1. I have shown the current system recognised by Marshall.

### 3. Tides:

Though the climatic conditions of these islands are largely determined by such large currents , local surface currents are more or less dependent on tides. Owing to the absence of any large land masses in the South Pacific, the tidal wave has a comparatively free course. It appears to strike New Zealand from the south west, and from there works up both coasts of the North and South Islands.

At full and change of the moon , the tidal wave reaches the south west extremity of the South Island at about 12 a.m.. Two hours sees it through Foveaux Strait, and in another couple of hours it has reached Lyttelton and even Wellington. Here it splits, one branch going up the east coast, towards Napier, while the other one passes through Cook Strait. The northerly branch passes up on round the East Cape, to the North Cape, and then descends along the west coast. At Cape Egmont it meets

the Cook Strait branch about ten hours after its first incidence on our coasts. (see Figure 1.).

The amplitude of the tide varies greatly from place to place according to the configuration of the land. Where there is an open coast with no disturbing factors, the spring tide rise is about 4 feet; while at Auckland and Nelson, situated at the apex of a funnel-shaped bay, the water banks up to 12 feet or more.

The highest spring tides sometimes follow the full moon and sometimes the new moon (Oliver 1923) ; but the periodic difference between the height of night and day tides, recorded by Hedley (1915) in Australia seems never to have been noticed here.

#### 4. Climate:

The range of length of day for Auckland and

Dunedin is:-	Auckland.	Dunedin.
Longest day	14 hours 40 minutes.	15 hours 46 minutes
Shortest day	9 hours 38 minutes	8 hours 39 minutes

Most other parts of New Zealand come in between these extremes. It will be seen that the difference between daylight and dark for any particular season is not very great.

New Zealand is very favourably situated for sunshine and the average daily period of bright sun for the whole year is about 6 hours.

The series of water and air temperatures for Auckland and Dunedin, recorded by Oliver (1923 p. 500-501) , gives a fair idea of the coastal range in temperature for the country. It is true that certain shallow waters vary much more than these limits, but for the average set of coastal conditions they

sufficiently accurate. These results show a fair relation between air and sea temperatures, though it will be noticed, especially from the graph:-

- a. That air changes precede sea changes.
- b. That the amplitude of air changes is greater than the amplitude of the corresponding sea changes.

#### D. Conditions affecting Canterbury.

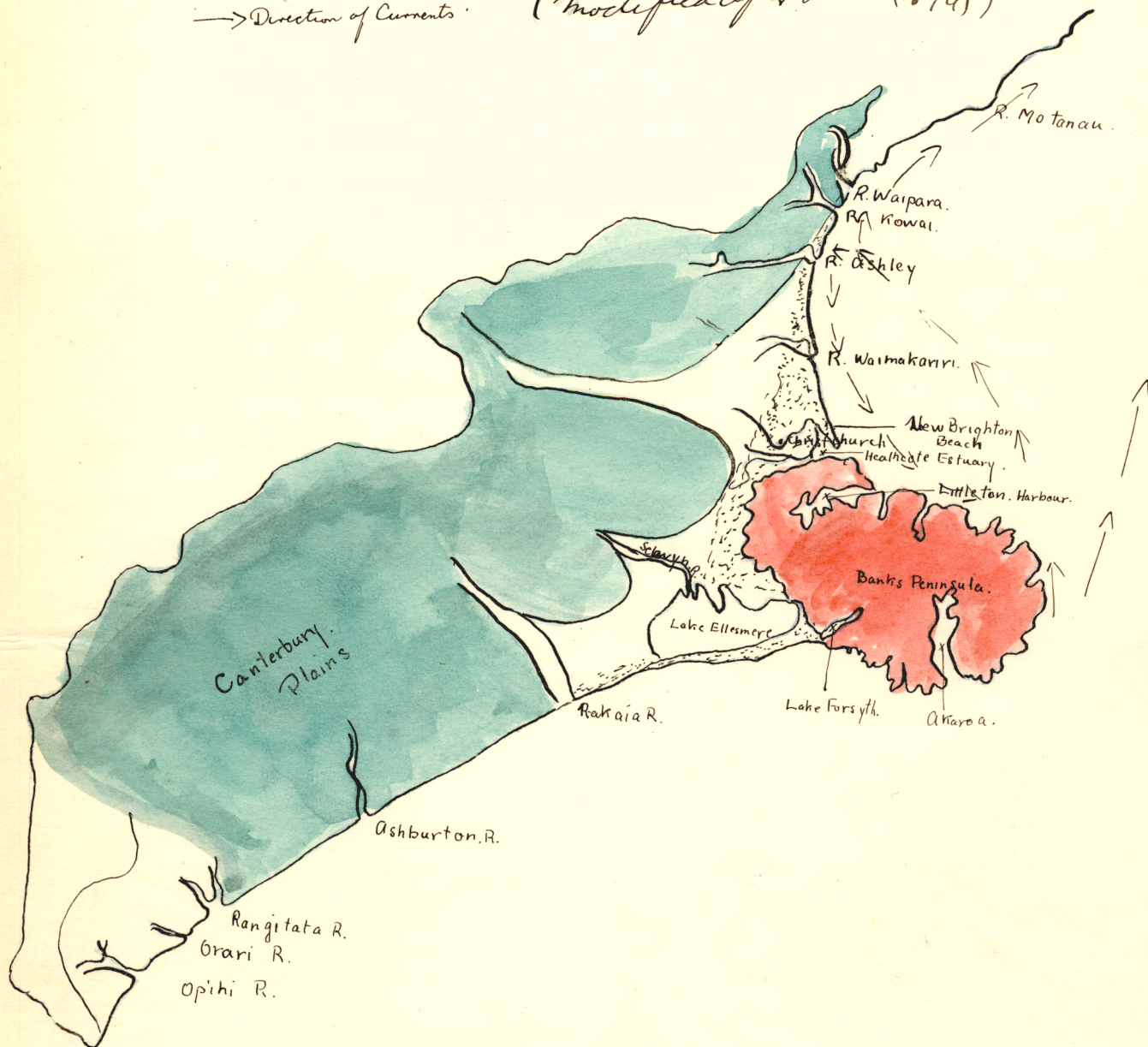
As the areas considered here are on the outskirts of the Canterbury Plains, an idea of the nature and origin of them seems necessary for the full understanding of these areas. These plains extend for about 110 miles along the east coast of the South Island. They owe their origin to the great deposits of gravel poured out of the mountain area during the advance, maximum and decline, of the glaciation during the Pliocene Period and later. At that time the action of erosive agents was more intense, and the quantity of material shed from the mountain area correspondingly greater than that carried now.

Von Haast (1879) states: " Since my report on the Canterbury Plains, published in 1864, all the levels, surveys, and engineering works, together with well sinkings, have amply confirmed my views that the Canterbury Plains are of fluviatile origin; that with the exception of some moranic accumulations in the upper parts, and the drift sands around Banks Peninsula, and the partial lacustrine deposits filling the former extension of Lake Ellesmere, the whole of the plains were formed by the deposits of large rivers issuing



- Basalt & Dolomite etc.
- Post-Pliocene Alluvium
- Recent Alluvium
- Littoral Deposit
- Direction of Currents

Map to Illustrate Geological  
Character of Canterbury Plains & Banks Peninsula  
(modified after Haast (1879))





from the front end of large glaciers."

A rough geological sketch of the area , largely after Haast, is given in Figure 2.

The greatest width is 40 miles and there is a steady rise from the sea to the Southern Alps. It is due to this range that the North West Wind, which sweeps across the Tasman Sea and strikes the West Coast as a wet wind, passes over the Canterbury Plains as a hot dry one. This wind is rather notorious on the plains for its suffocating heat and parching effect, and undoubtedly helps to characterise the flora of the plains. It certainly decreases the rain fall , Christchurch showing but 25.3 inches annually. The climate of Canterbury is almost continental; but as the sea is approached , a distinctly milder set of conditions is met with.

The areas considered here are the Heathcote Estuary and the Brighton Beach, both situated immediately to the north of Banks Peninsula.

## II. The Shore Line Formation.

### IIa. Microlithic Substratum or Shifting Beach Sub-formation.

#### A. Type of Sandy Beach --Brighton Beach.

##### a. Locality:

The Brighton Beach stretches for about 8 miles immediately north of Banks Peninsula. It starts in a sand spit immediately north of the mouth of the Heathcote Estuary, and is practically uniform to the mouth of the Waimakariri River. The line of the beach is not much west of north. Most of the observations were made on the  $3\frac{1}{2}$  miles from the Brighton Pier to the mouth of the Heathcote Estuary. The position is indicated in Figure 2.

##### b. Conditions Offshore:

The Admiralty chart of these waters, based on Captain Stopes survey of 1850, shows that the sea bottom off the coast has a very gradual slope. Thus off the Waimakariri the 5 fathom line is one mile out, while the 8 fathom line is two miles offshore, the 10 fathom line 4 miles, the 12 fathom line 6 miles. The slope off New Brighton proper is slightly steeper, the 9 fathom line coming much closer inshore towards the south.

Sand is recorded at a distance of 2 miles out from the Waimakariri in a depth of 8 fathoms, while mud and fine shell material appear to be widely distributed further out. There are few records off New Brighton, but these seem to point to similar conditions there.

The deepening offshore is so gradual that material brought

down by the currents from the Waimakariri will appreciably advance the shore line, and will alter the grade of the rivers upstream to a slight extent. There is ample evidence that such an effect has taken place.

c. Currents:

The general currents affecting New Zealand were mentioned in an earlier section. It was there pointed out that the Banks Peninsula is regarded as the meeting ground of two main currents, the Notonectic and the Antarctic. The Notonectic is a warm current when it strikes the west coast of the South Island, and to this fact may be attributed the presence of Snapper (*Pagrosomus auratus*) in higher latitudes on the west than on the east coast. The same factor may explain the larger size of the whitebait (young of *Galaxias attenuatus*) from the former locality. In all probability the west coast water temperature, from Jackson's Bay north, is warmer than corresponding positions on the east coast. But the current system off the Brighton Beach is by no means simple and is largely affected by the tides. The available information is extraordinarily scanty.

Neither the Marine Department nor the Lyttelton Harbour Board were able to give me any information; and their chief authority seemed to be a 60 year old chart which is anything but complete.

Dr. Dendy was of the opinion that there were two main currents off the coast. He states (1897):- "Mr. R. M. Lang informs me, and what he says harmonises well with my own

observations, that there are two well marked currents off the coast at New Brighton. The one is more inland , coming from the mouth of the Waimakariri River, tending south along the shore , and bringing with it enormous quantities of drift wood when the river is in flood; the other, a more important current, tending northwards for a long distance up the coast. It is probably this latter which , in heavy weather , brings to the beach from the rocky coast of Banks Peninsula, and the mouth of the Lyttelton Harbour, the vast quantities of giant seaweeds, *Macrocystis* and *D'Urvillea*."

In an engineering report on the Waimakariri , Sir A. Gibbs (1928) states:- " In the case of the Waimakariri, however, the discharge is into Pegasus Bay, a backwater, as it were, of the Pacific Ocean, which is formed by the projection of Banks Peninsula. This bay has a shallow depth for a long way out from the shore, and the main ocean currents, travelling northwards, are deflected past it, and only an eddy of the main current, having a southward tendency, acts at the mouth of the river. The result is that the sand and other fine material, brought down by the river , is not swept away, and removed, but is deposited in the river bar and along the shore , thus building out the shore line and flattening the gradient of the river near its mouth."

It will be seen that this may be but an extension of the suggestion put forward by Dendy and Lang. In support of this eddy theory it may be mentioned that the Brighton Beach has certainly grown out considerably within the last 40 years,

though this may , of cours , be attributed to the tide set.

Code and Mathews(1911) in another engineering report on the Heathcote Estuary Canal Scheme, state:-" It is however apparent that the mouth of the River Avon has, in the course of time, been pushed to the southward, until the rocky ground prevented any further movement in that direction. This is evident from the sand spit extending southwards from New Brighton to the river mouth. Further northwards , near Kaiapoi a similar spit extends southwards of the Waimakariri, giving evidence of the same action" (i.e. the action of an inshore current)

Of the drift bottles liberated at Dunedin, practically all those recovered were from localities considerably to the north of the point of liberation. Those found furthest from "home" were recovered at Rangitata River( about 100 miles south of Banks Peninsula), Kaiapoi Beach(near the mouth of the Waimakariri) , Sumner , Lyall Bay(Wellington) and one from Maunganui(Chatham Isds.).

Examination of the beaches north of Brighton leads to the c conclusion that the current which sweeps past Banks Peninsula strikes the coast again at about 3 miles south of the Waipara.

It will be seen that these observations do not agree altogether satisfactoraly with the generally accepted course of the main currents of New Zealand. Further observation is necessary before even the most general scheme of currents can be satisfactoraly drawn up; But from the data here summarised , and from my own observations on drift material, and the actual movement of water, I am of opinion that:-

1. There are two main currents off the Brighton Beach.

a. One inshore moving down past Sumner from about three miles south of the mouth of the Waipara River.

b. One further offshore, moving up from Banks Peninsula and further south, perhaps a branch of the Antarctic current, which travels in a northerly direction till it strikes the coast south of the Waipara, where it divides, giving off a northerly branch which continues up the coast as far as Cook Strait, and a southerly branch which ultimately gives rise to branch a. above.

It is possible that a third branch to the Chatham Islands may arise from the same point.

2. The ultimate result is a backwater in Pegasus Bay, with a gently sloping bed of fine deposit.

3. The course of the currents at any particular time are largely effected by the tidal currents.

d. Tides:

The tidal wave reaches the Brighton coast at about the same time as at Lyttelton. The spring tide range is normally about 6 feet, and washes a width of about 95 yards. This width may, however be greatly varied by winds as a north easterly wind will raise it another foot, while a similar wind from the south will lower it about the same amount.

Captain Featherstone, for many years Harbour Master at Kaiapoi states (private communication) that the flood tide off the mouth of the Waimakariri, sets northward at about 2 miles per hour, and the ebb tide to the south at  $2\frac{1}{2}$  miles per hour. There is thus a balance in favour of the drift to the south;

and this is more important in that floods in the river are usually accompanied by northerly winds which cause an increased set to the south. It is to this balance in favour of the southern set that that Professor Speight attributes the rapid advance of the Brighton foreshore.

It would seem that at New Brighton at least, the flood tide does not affect the shore current greatly., but the constant balance in favour of the southern movement, is in support of the theory of the existance of a southern, inshore current off the Brighton Beach.

If this area of ocean is to be regarded as a backwater. it will obviously have an important bearing on the kind and quantity of plankton brought to the beach.

e. Prevailing Winds at New Brighton:

i. East from the sea-- Moist and has a modifying effect on the temperature.

ii. North West from over the Plains-- Hot and Dry

iii. South West --- Cold often with rain. It is the usual cause of storms on this piece of coast.

## f. Substratum:

The beach consists of fine quartz sand. At low water the slope is about one degree, but it gradually increases to three at 8 hours exposure, seven at high water mark, and continues to increase as it rises into the dunes.

The size of particles, is, on the average, at low water level .35 to .40 mm. diameter but varies considerably. The particles are all rather rugged and angular in appearance, and their clear colour seems to point to very little impurity in the silica.

At high water mark the particles show greater variation in size and shape, varying from .5 to .15 mm. in the same sample. Contrary to what might be expected, they are even more angular than those at low water. A general view of the beach is given in Plate 1.

## g. Temperature:

Under the conditions under which the work was done, it was impossible to obtain continuous readings of temperature. The following readings must, therefore, be regarded as only approximately correct.

Air Temperature: (all temperatures are in degrees C.)

	Spring	Summer	Autumn	Winter	Annual
Mean	10.6	14.5	11.1	7.8	11.1
Maximum	13.9	20.0	15.0	15.0	
Minimum	9.5	11.1	6.6	5.5	

These represent day temperatures only. I have a few readings for night temperatures, the lowest being -3 degrees C.



## Water Temperature:

Spring	Summer	Autumn	Winter
8.5	9.5	8.0	7.0

\*

## Sand Temperature:

The sand temperature is a function of its position in the tidal belt, the state of the tide, and the temperature of the water and air respectively. The temperature falls as one descends below the surface as is shown in the following tables.

## Summer

Air Temperature 19.7 Water Temperature 11.2  
Tide full out.

Hours exposure per complete Tide	Surface	10 cms. down.	20 cms. down.	30 cms. down.	40cms. down.
Low Water.	11.4	11.1	-	-	-
2½	13.1	11.6	-	-	-
5	14.4	11.6	11.1	-	-
7½	14.7	11.4	10.3	9.6	-
9	16.9	11.5	9.9	8.7	-
12½	23.2	13.3	9.9	8.4	8.4

## Winter

Air Temperature 16.2 Water Temperature 11.1 \*

Tide full out.

Hours exposure per complete tide.	Surface	10 cms. down.	20 cms. down.	30 cms. down.	40cms. down.
Low Water.	11.3	11.0	-	-	-
2½	12.4	11.3	-	-	-
5	13.3	11.2	10.2	-	-
7½	13.5	10.0	9.2	9.0	-
9	15.3	10.1	8.7	8.6	-
12½	16.3	9.7	8.7	8.6	8.6

The effect of the sea in reducing the temperature gradient with depth is very noticeable in the lower levels.

\* The difference of these results is perhaps to be explained on the fact that the water temperature in the former case was taken away from the sand, while in the latter case it was not. The water, out from the beach in the latter case was 8.9°C. which agrees better with the other readings.

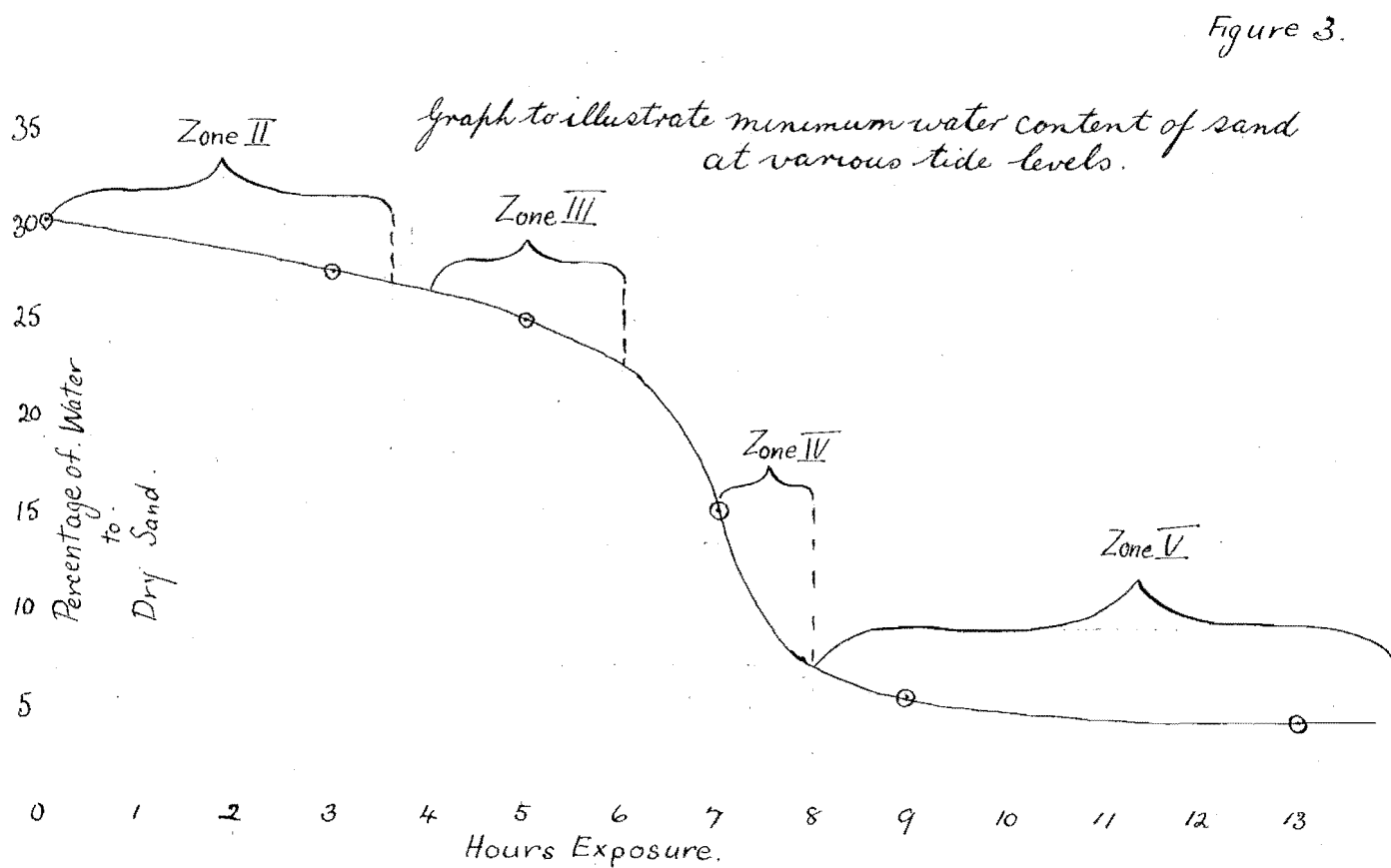
## h. Water Content of the sand.

The following table gives the minimum water content of the sand for the first four inches for various tide levels:

Air Temperature. 17.1. Hot Sun. Time 12 a.m.

Hours Exposure per Complete Tide	Percentage of water to dry sand
Completely Exposed.	4.576%
9	5.646%
7	15.2 %
5	25.02 %
3	27.9 %
Low Water	30.1 %

The graph, Figure 3, was made from these results.



# 1. Chemical Characters of the Water.

## Suspended Matter:

Normally the water is exceedingly clear and, except for a few sand particles raised by the surf, contains no solids in suspension. At times of storm large objects are present, such as seaweed, but little if any mud.

## Smell:

Aside from the so called sea smell the water is odourless.--- a good sign of freshness and purity. Tests for sulphur compounds and nitrogenous impurities yielded only negative results.

## Aeration:

A sample of water taken from the surf was full of bubbles of gas. Even when the bubbles were allowed to escape an analysis gave the oxygen content as: 10.2 milligrams per litre at 13.5 degrees C. It follows that the water is ordinarily over saturated with air and particularly oxygen. This is, of course , to be attributed to the efficient stirring action of the waves.

## Chlorine content:

The chloride , when estimated as grams of chlorine per litre of solution, gave the following figures.

Low Water	18.67 grams.	High Water	18.8 grams of Cl per litre.
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## Density:

Low Water	1.244 ( 15.5/4)
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## j. Protection:

The beach is practically without protection from the sea. Certainly the Banks Peninsula helps to deflect currents

and some wind, but this effect is not sufficient to temper the violence of the surf to any extent. At the back the beach rises up to low sand dunes, built by the action of the north east wind. These may shield the beach from the north west wind, but only to a limited extent.

## 2. Floristic Composition:

There is practically no true flora in this area. Between tides there is no visible plant life, except a huge pile of drift seaweeds and kelp, which apparently come from Banks Peninsula. In this pile a large number of species of Algae are represented. The most common genera met with are:

*Hormosira*, *Carpophyllum*, *Marginaria*, *Cystophora*, *Macrocytis*, *Ulva*, *Porphyra*, *Cladhymenica*, *Nelophallum*, *Sarcodia*, *Gigantina*, *Pachymena*, *Ptilota*, and *D'Urvillea*. My knowledge of botany is too elementary to determine the various species in this group.

Above the belt of drift kelp there is a vacant space of sand, rising up to low sand hills supporting a growth *Scirpus frondosus*, and the introduced grass, *Ammophila arenaria*.

No doubt the absence of flora can be attributed to the lack of stable substratum, organic material, and nutritive salts in the sand. The Plant Ecology of these dunes is discussed by Peg(1913).

## 3. Faunistic Composition:

## a. Catalogue of Species.

## Annelida Polychaeta.

## Family Nephthydidae.

*Nephthys macrura* Schmarda. -----

Hutton 1879

Quite common burrowing in the sand up to 4 hours exposure.

In my collections from New Brighton, I have a fragment of another polychaete, but it must be rather uncommon.

## Mollusca

## Pelecypoda.

## Family Mesodesmatidae.

*Mesodesma subtriangulatum* Gray. -----

Suter 1913 p.957.

Common in sand from about 7 to 2 hours exposure. Popularly known as the "Brighton Pipi".

## Family Mactridae.

*Mactra discors* Gray. -----

Suter 1913 p.964.

Apparently quite common below low water.

*Spisula aequilateralis* Deshayes. ----

Suter 1913 p.969.

Apparently quite common below low water mark.

*Zenatia acinaces* Quoy and Gaimard.---

Suter 1913 p.971.

Occurs from low water to about 20 fathoms.

*Resania lanceolata* Gray. ----

Suter 1913 p.973.

Occurs in about 5 fathoms.

## Family Veneridae.

## Family Veneridae.

*Dosinia anus* Philippi. -----

Suter 1913 p.978.

Common below low tide.

## Family Psammobiidae

*Soletellina nitida* Gray. -- ---

Suter 1913 p.1005.

From well below low water to about 5 fathoms. Apparently quite plentiful.

## Family Saxicaridae.

*Panopea zelandica* Quoy and Gaimard.

Suter 1913 p.1013.

From low water mark to about 5 fathoms. Very deep in the sand.

## Echinodermata

## Echinoidea

## Family Scutellidae.

*Arachnoides zelandiae*. Gray. ----- Farquar 1898 p. 321.

Below low water mark.

## Holothurioidae

## Family Dendrochirotae

*Cucumaria ocnoides*. Dendy.

Dendy 1898a. p.36.

Below low water . Fairly common.

## Crustacea

## Amphipoda.

## Family Orchestidae

*Talorchestia quoyana* (Milne-Edwards) Chilton 1916 p.294.

Common all along the Brighton Beach at and above the kelp line  
--- from 7½ hours exposure to high water spring tide.

*Talorchestia telluris* (Bate) Chilton 1916 p.299.

A few specimens from sheltered places near the mouth of  
the Waimakariri. Does not seem to frequent the pure ocean  
beach.

## Family Phoxocephalidae.

Specimens referred to this family by Dr. Chilton, from 4 hours  
exposure down to low water.

## Isopoda.

## Family Cymothoidae.

*Pseudaega punctata*. Thomson. Thomson 1884 p.234.

In sand from four hours exposure down to low water.

## Family Phaeromidae.

*Scutuloides maculata*. Chilton. Chilton 1883 p.70.

Reported from Brighton Beach by Bennett but not found  
by me.

## Family Scyphacidae

*Actaecia euchroa* Dana. Chilton 1901 p.130.

Plentiful in and on sand at bottom and just below the  
drift kelp line.

20.  
*Macrura.*

*Family Callianassidae.*

*Callianassa filholi* A. Milne- Edwards. Filhol 1874 p. 429.

Occasionally burrowing in the sand at low water.

*Myriapoda.*

*Order Chilopoda.*

An unidentified member of this group is quite common on dead birds etc. in the drift kelp line.

*Arachnida.*

*Araneida*

*Family Theridiidae.*

*Latrodectus hasselti* Thorell. Cambridge 1902 p.255/

The Katipo spider. Occasionally found in drift kelp, but usually above the drift line.

*Insecta.*

*Diptera.*

*Family Phycodromyiidae.*

*Coelopa littoralis* Hutton Hutton 1900 p.80.

Common on kelp all through the summer months.

*Family Milichidae.*

*(Agromyza) fulvifrons* Hutton. Hutton 1900 p.93.

(Mr. Tonnoir informs me that it does not really belong to this genus-- his revision of the group is in course of publication in the Records of the Canterbury Museum.)

Common in kelp all through the summer .



## Coleoptera.

## Brachelytra.

*Staphylinus oculatus* Fabricius.

Broun 1893p.107

No. 119.

Occurs in the drift line in the summer among decaying matter.

## Aves.

## Family Spheniscidae

*Eudyptula minor minor* (Forster) Mathews and Iredale 1913 p.222.  
(Blue Penguin)

Occasionally cast up as drift.

## Family Diomedidae.

*Diomedea epomorphora epomorphora*

Lesson Mathews and Iredale 1913 p.239.

(Royal Albatross)

Occasionally driven onto the beach.

## Family Laridae.

*Sterna striata striata* Gmelin Mathews and Iredale 1913 p.244.  
(New Zealand White-fronted Tern.)

Common flying over the beach.

*Brachigavia melanorhyncha* Buller. Mathews and Iredale. 1913 p.247.  
(Black-billed Gull)

With the next species , the commonest bird on the beach.

*Larus dominicanus antipodus*(Bruch). Mathews and Iredale 1913 p.248  
(New Zealand Black-backed Gull)

With the previous species the commonest bird on the beach.

## b. Communities of the Beach.

As might be expected from the arduous nature of the environment, and the absence of an established flora, the beach is poor both in species and in individuals. Of the five zones into which I have divided the beach, only three are at all thickly populated. The zoning is very sharp and clear cut (see summary graph--Figure 6), with three quite definite vacant spaces. In this locality, division by hours of exposure, height above low water, or minimum moisture content of the sand, leads to practically the same result; and in this comparatively simple environment, each of these methods of division is fairly satisfactory. The characters of the five zones may be set out as follows:-

(Numbers in square brackets indicate average density of population per square metre, at position of optimum for the species).

Zone	Hours Exposure	Water Content of Sand	Characteristic Animals
I	None	Over 30 %	<i>Nephtys macrura</i> <i>Macra discors</i> <i>Spisula aequilateralis</i> <i>Zenatia acinaces</i> <i>Resania lanceolata</i> <i>Dosinia anus</i> <i>Panopea zealandica</i> <i>Arachnoides zelandiae</i> <i>Cucumaria acnoides</i>
II	0 to 3½	30.2 to 27.4 %	Amphipod of Family <i>Phoxocephalidae</i> [4] <i>Pseudaea punctata</i> [5] <i>Nephtys macrura</i> [9] <i>Callinassa filholi</i> [2 or less]
III	4 to 6	26.6 to 22.4 %	<i>Mesodesma subtriangulatum</i> [2300] <i>Nephtys macrura</i> [4] Hydroid (New Species). <i>Pseudaea punctata</i> [rare].
IV	7 to 8	15 to 7.6 %	<i>Acteocina euchroa</i> [59] An unidentified <i>Polychaete</i> . [V. rare].
V	8 to complete	7.6 to 4.6 %	<i>Talorchestia quoyana</i> [276 but varies greatly] <i>Talorchestia telluris</i> (local). Chilopod: <i>Latrodectus hasselti</i> <i>Coelopa littoralis</i> <i>Agromyza fulvifrons</i> <i>Staphylinus oculatus</i>

} Scattered.

ii.

## Zone I.

Low water down to about 5 fathoms.

Just at and below low water , moving about partly under the sand, is the cake urchin *Aracnoides zelandiae*, while the scaly pink holothurian, *Cucumaria ocnoides* lies burried about here and lower down. To this region too, may be referred *Mactra discors*, *Spisula aequilateralis*, and *Dossinia anus*.

Still further out to sea , and probably at a depth of several fathoms, there must be a great sand bank inhabited by a very rich population, but owing to the fact that it is rarely stirred by the tides and currents, and that its inhabitants are buried 10 to 12 inches deep, they are rarely seen caste up on the shore. Occasionally dead valves of the members of this association, *Panopea zelandica*, and *Resania lanceolata*, are met with among the drift rubbish. At very rare occasions, however, this bank is disturbed, and then huge piles of relatively rare molluscs are cast up on the shore. An example of such a case was recorded by Dr. Dendy (1897) .He attributes the routing out of these firmly anchored denizens of the deep, to a mixing of the two currents, thus causing a vortex which would stir up the sand and perhaps unearth the organisms concerned. Perhaps heavy rains, swelling the Waimakariri, freshened the water over the beds and partly killed the animals, this condition coinciding with the ebb tide ,causing the vortex mentioned. A somewhat similar occurrence in Sidney is attributed by Hedley(1915) to this freshening effect, while in Japan the freshening was supposed first to kill the seaweed, and subsequently the dead weed poisoned the water.

Until systematic observations are made for a number of years, the full explanation of this phenomenon cannot be given, and this tends to show how little is really known of even the most important factors controlling the life of the sub-littoral zone.

Characteristic growth type---adapted for retention of position in the sand.

iii.

Zone II.

Low water to three and a half hours exposure.

This zone has a very poor fauna. The small amphipod of the family Phoxocephalidae, shows no apparent adaption for life in this locality, but the isopod, *Pseudaega punctata*, is an extraordinarily rapid burrower, shooting the sand out between its uropods in a continuous stream.

The most numerous species in this zone is the polychaete, *Nephtys macrura*. This worm burrows rapidly and continually everts its pharynx, perhaps in search of prey or to assist in burrowing. It is an unusually strong swimmer and its pale grey colour renders it inconspicuous in the sand. The crustacean, *Callinassa filholi*, another rapid burrower, preys on *Nephtys*.

Characteristic growth type----adapted for swimming and burrowing.

iv.

Zone III.

Four to six hours exposure.

*Nephtys macrura* and *Pseudaea punctata*, are quite scarce here; they really belong to zone II. The dominant form is the "Brighton Pipi", *Mesodesma subtriangulatum*. This pelecypod is very definitely adapted to its mode of life. In its habitat it is exposed to the full force of the waves, to the rush of retreating water, to short but acute periods of desiccation. The smooth shell with elevated umbo, is wedge-shaped, and well suited for quick downward burrowing, which process is accomplished by the large foot. In damp sand, a pipi measuring 65m.m. in length, was observed to draw itself completely under the sand in 45 seconds from the time the first move was made. The elongated siphons, far longer than those of its shelter-seeking relative, *M. australe*, allow it to remain at 1 to 2 inches below the surface of the sand. Plate 2 shows the animal in position. The surface position adopted by *M. australe* would be untenable here. When the tide is over the pipi bed, the mollusc pushes the long siphon up through the sand, and spreads out the ciliated disc to the water. On the retreat of the tide the siphons are withdrawn into the shell (Plate 4.)

The animal does not live successfully in sheltered places, and in such localities it is succeeded, first by *M. australe*, and then by *Chione stutchburyi*.

Rather a strange method of gaining access to the pipi is reported. The gulls (Black-backed and Black-billed) are said to carry the shell high in the air and then drop it. I have twice seen gulls drop pipies in this manner, and in both cases the shell broke, but the bird made no attempt to eat.

The apparently haphazard distribution of *Mesodesma* on the beach is very misleading. It is really confined to a rather narrow belt of the tidal zone as is seen in Figure 5. Only the so called first fear pipies, the  $O^+$  group, were considered. The inhabitants eat the pipi and if the larger ones had been considered the results might have been disturbed. As a matter of fact the few figures I have point to a sharpening of zoning with growth.

I do not know the time of spawning but would expect it to be not later than October or November. In Figure 4, I have shown the size against numbers for two comparable localities for March and April. It will be seen that the curves show two definite pairs of peaks, A.B., A'.B'.. The fact that the peak move on would seem to show that they are not due to errors of sampling, but would correspond to two spawning maxima, perhaps two months apart. Half way between is another but much smaller spawning period. From these curves it can be seen that the pipi increases by 60 to 70% of its length in the four months, March to July.

Examination of the shell of the pipi shows that it is definitely banded with dark rings, which I think can be correlated with the end of a season's growth. (Plate 3.) Thus the pipies I have called 'this year's growth' show no dark bands. Examination of shells gave the following results:

Length of first ring	16 to 23m.m.
Length second -first ring	14m.m.
Length third -second ring	8m.m.
Length fourth- third ring.	7m.m.
Length fifth -fourth ring	7m.m.
Length sixth -fifth ring	6m.m.
Length seventh -sixth ring	5m.m.

From these figures it will be seen that , if the rings are to be regarded as yearly bands, then the adult pipi of about 60m.m. length is in its seventh year, and some individuals can continue on into their eighth year; but the seven ringed individuals are rare. From observations on the shell and the above measurements, it would seem that the larger shells are just about to lay down another dark layer. But these results are not sufficient to establish the growth rate or that these bands are annual ones. One obvious difficulty is the necessity explaining how this year's pipi would double its size in the next few months, as it would seem to have to do if it is to catch up to the first ring measurements. Again there is a strange shortage of "years" 1 to 3 and less so of 4 and 5. Thus a 1/4 square metre gave, on 20/7/29,

Number of Rings	Number of Individuals
1	2
2	0
3	0
4	22
5	19
6	97
7	-



In the sand except immediately after a storm, about 99.9% of the pipies will be found to be definitely orientated with relation to the tide, the umboes pointing seawards. In one day over a thousand individuals were turned round, but on the following day the percentage of individuals so turned was normal. With the smaller animals the tide rip is sufficient to upset the orientation, but the animal makes every attempt to regain this position.

The pipi has three obvious enemies.

1. Birds.
2. Human beings who use them as food.
3. A sole.

I have not seen complete specimens of this fish, so that I am unable to refer it to its species. The gut from about December (or earlier) to March, is filled with small pipies, up to five m.m. in length. To this fish I attribute a good deal of the heavy early mortality in the pipi. But as this animal does not appear to touch individuals over about 6 m.m., and a comparison of the curves in figure 5 will show that the mortality rate increases with fall in tide level, when the majority of the individuals are past the 6m.m. size, there are probably other fishes preying on the pipi.

Growing on the upper end of the pipies from the larger ones down to those with at least one ring, is a sertularian, (which is new to me and has been sent to Bale for identification\*) This animal is not found on first year forms and only sparingly on groups 2 to 4. Beyond that the roughened end of the shell seems, judging by the large growth, to offer a very favourable situation. The food relations of this sertularian, living

\* Bale writes me, "The species is new to me, & I cannot be certain as to the identity even of the genus . . . . . but the species belongs to the Atractylidae"

completely below the surface of the sand, should prove very interesting. Here in the midst of the microlithic substratum, an animal which requires a macrolithic one, has found such a habitat. While the separation of animals into micro and macrolithic forms seems to me to be fundamental, this example shows how difficult it is to draw any hard and fast lines in the classification of habitats.

Typical growth form---- Adaption for retention and recovery of place in the sand, against tidal movement.

v.

Zone IV.

7 to 8 hours exposure.

Except for an uncommon and unidentified polychaete, the small isopod, *Actaecia euchroa*, seems to be the only regular inhabitant of this zone. This animal which is about 1/6 inch. long, is beautifully marked on the dorsal surface with dark grey and green, so that it forms an almost perfect match with the sand. It can move exceedingly quickly and scurries about on the beach as it is laid bare by the retreating tide; but if disturbed it immediately rills up into a ball which is so like a sand blob, that unless an observer has seen the animal moving, he would almost certainly pass it by.

It makes holes about one to two inches deep, which have a frill of loose sand round the top, and outwardly look like the splash of a rain drop or a piece of spray. (Plate 5)

On the approach of the tide or the onset of rain, the animal

returns to its burrow and remains there till the tide has retreated or the rain has stopped long enough to allow the surface of the sand to dry somewhat.

It was suggested by Dr. Chilton that the animal was nocturnal in habits, but my observations at night do not support this idea. The animal seems to be positively phototropic.

vi.

#### Zone V.

8 hours to full exposure.

About 3/4 tide lies the long line of drift kelp already described,. Added to this medley is a pile of drift wood and rubbish, dead birds, barnacles, and in the holdfasts of the large kelp, *D'Urvillea antarctica*, many varieties of chitons, gastropods, Polyzoa, Sertularia, and the wealth of plant and animal remains always found in and around the roots of seaweed.

Among this mixture of drift, burrowing beneath it in the sand, is a large amphipod, *Talorchestia quoyana*, which is by far the most numerous inhabitant of this region. It feeds on the drift kelp, almost exclusively *D'Urvillea* and *Macrocystis*. Its burrows are almost always just below high water mark. The animal can withstand complete and frequent wettings of the surf, but is almost completely terrestrial and runs and leaps with great agility. Correlated with this mode of life, the hind legs are prodigiously developed and

much stronger than in purely aquatic forms.

The great widening of the body is probably to be explained in that stability is required in extra-aqueous progression as the typical *Gammaria* form was evolved in water and was unsuited to terrestrial conditions.

Its colour, a mottled grey with black brown patches, is well calculated to match a patch of dirty sand or sand speckled seaweed. It is worthy of note, that, if knocked off into the sand, it lies on its side which is entirely grey and a perfect match for the sand; and if dug out it will lie very still for some time, and can easily be overlooked. It, too, is a highly specialised organism, and cannot survive a change in its economy; thus attempts to introduce <sup>it</sup> out of reach of the spray, even in as damp a locality, and where its food was provided, proved futile. It is apparently intolerant of fresh water and is seldom seen out of cover during rain. On the advance of the tide, it seeks shelter in its burrows and remains there during the period of submergence.

*T. telluris* has been placed in this group, but it seems to prefer the proximity of fresh water. Thus it is found up at the mouth of the Waimakariri River and at the entrance of the Avon River into the Heathcote Estuary.

Another organism found in this zone is a chilopod (sent to Archey for identification). It lives on dead birds and is found in and among the feathers. It is cryptozoic in general habit

, moving away from the light immediately it is brought from cover; but it prefers a faint light to complete darkness (Lab. results).

A number of Diptera are common here, especially in the summer months. The chief of these are *Coelopa littoralis* and (*Agromyza*) *flavifrons*. Both these animals are well suited to their surroundings. The blackish brown body of *Coelopa* closely matches the dark brown kelp stems on which it rests, while the slate colour of *Agromyza* is close to that of the sand. The only specimens of the latter which I have taken are females. Both of these have long narrow wings suitable for strong flying. I am at present rearing out two species of dipterous <sup>larva</sup> taken from rotting kelp; and at least one of these is distinct from the above two species.\*

The New Zealand poisonous spider, the Katipo (*Latrodectes hasselti*) is sometimes found here though it really belongs further back among the dunes. It has a prominent scarlet band on the back of the abdomen which might be taken as an example of "warning" colouration. The female spider spins a cocoon for her purplish eggs about the middle of November. This cocoon is suspended among the rubbish above high water mark. Other observers note that use is made of old tins and bottles for the reception of the cocoon. I have never been fortunate enough to see these cocoons hatch out, but Robson (1879) states that the young appear as transparent individuals in the beginning of February.

*One of these proved to be Coelopa littoralis. The larvae ate greedily in decaying kelp & was very definitely negatively phototropic till the time for pupation approached. It then climbed out of the mud.*  
*Larval period 2 - 3 weeks (avg temp 12°C) pupal period 1 - 3 weeks.*

In spring and summer, the cryptozoic beetle, *Staphylinus occulatus* ? , is quite common under the kelp, burrowing through the refuse; while dipterous larvae are plentiful in the decaying shelfish and kelp.

Of the remaining forms found among the drift kelp few if any have any important effect on the economy of the locality.

I have called this association the drift kelp association as all the forms found here are directly dependent on the drift kelp and the refuse which accompanies it , for food and shelter. The quantity of drift kelp is vary variable. Sometimes there is an enormous pile, 20 yards in width , and almost continuous for the whole length of the beach. At such times the amphipod becomes more common and, if it is summer, the flies, beetles and centipedes are more plentiful. At other times , when certain winds and states of the tides coincide, the beach may be swept clear; or a long continued spell of calm weather may leave but dried up fragments of kelp. At such times all the fauna except the amphipod, disappears, and even this amphipod burrows deep back into the sand, and is much less obvious. (Plate 6 and 7.)

From a zoological point of view, the dominant forms is the large sand hopper, *Talorchestia quoyana*.

Characteristic growth type--- Burrowing and cryptozoic \*adapions. Swimming of little importance.

*"Adapions" used almost in the same sense as "Adaptations".*

## c. Experiments on the Fauna and Laboratory Work.

A summary of the experiments carried out on some of the dominant forms is given below.

*Mesodesma subtriangulatum*.

This species was transplanted to different localities with the following results.

1. When placed in sand at the end of the spit, subject to a slight lessening of surf and salinity, a colony of 26 all died within a fortnight.

2. When placed inside the Estuary, with no surf and much decreased salinity, in places already occupied by *M. australe*,

In Estuary sand (10% mud)

15 placed.

10 days later 9 dead.

18 days later all disappeared.

In Estuarine Mud.

18 placed.

open valves found in 9 days; no trace of live shells.

Sheltered sand beach.

23 placed

all disappeared in 5 days-- probably dug by a fishing party.

*Talorchestia quoyana*.

Transplanted into the Estuary with kelp supplied.

Just inside the Estuary.

34 placed

2 found three days later.

none found 7 days later.

Half way inside the Estuary.

43 placed.

none found 8 days later.

At entrance of the Heathcote River.

55 placed.

one found 6 days later.

The above experiments were repeated without supplying kelp, but in no case were any hoppers found after two days.

Consideration of results for *T. quoyana*.

The above results are not as satisfactory as could be desired for the following reasons:

The animal, by its great ability to hide, might be present and never be found, in spite of the careful search made.

The kelp would get slimy and stale in a short time in the fresher water of the Estuary.

It was impossible to visit the experiments every day, and a certain amount of interference by fishermen and others may have taken place.

But the general trend of the experiments seems to point to the facts that:-

a. The animal cannot live permanently out of reach of the spray.

b. The animal cannot tolerate more than a very limited freshening of the water.

It is worthy of note that in this species, the males go through a form similar to that of the female. Perhaps the males are at one stage hermaphrodite or even definitely female. With this change is associated a change in the first and second gnathopods. This change in what is a specific character, gave considerable trouble during identification.

It has been suggested that this animal is nocturnal in habits because it is so seldom seen in the bright light. Several attempts to keep it in captivity having failed, I



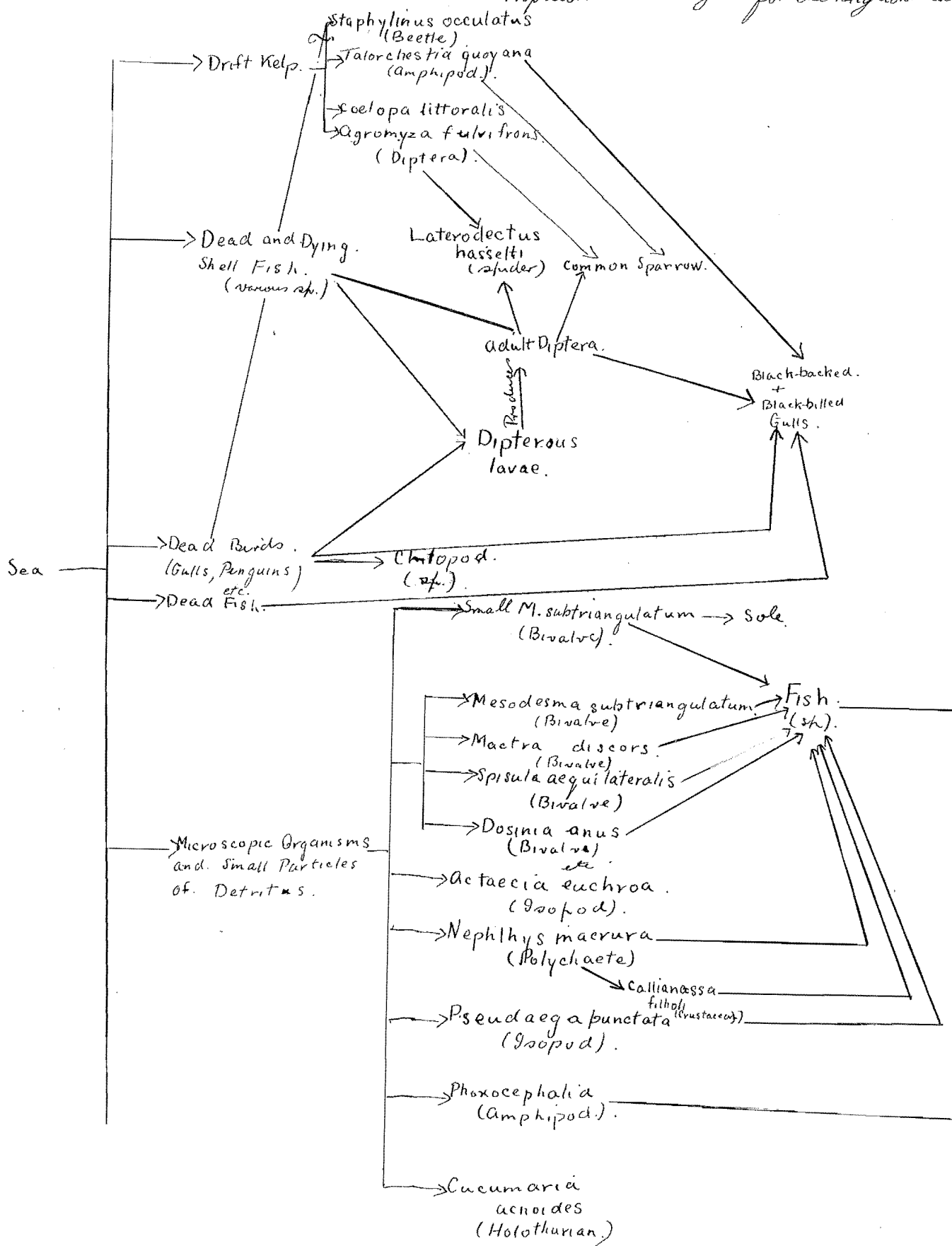
watched the animal on the beach for several nights. It did not seem any more active or obvious at night than at day time. When disturbed, it fled from an electric torch, but whether this was negative phototropism, or desire to regain cover, I cannot say.

d. Birds of the Brighton Beach.

The birds do not belong to any particularly zone, but range like scavengers, over the whole area. The Terns do not seem to frequent the beach very much. Very likely the small crustaceans for which they dive in the estuary and in less broken water, cannot be obtained here. The Black-backed and Black-billed Gulls are extremely constant and numerous members of the fauna. Something has already been said of the methods employed by the former to open shells of *M. subtriangulatum*. However it is accomplished, it is certain that this bird can break into all the bivalves of the beach. Broken and torn *Macra* and *Dosinia* are quite common, with scratching and marks to show where the gull has been pulling the shell about. It is quite a common sight to see this bird at work, finishing off one of these large bivalves. (Plate 9.)

In stormy weather these animals usually retreat inland, where they will eat worms or grain---- in fact anything.  
(Plate 11.)

## Propositional Food Cycle for the Brighton Beach.



f. The Brighton Beach Community.  
 ----Discussion of Results.

From the above it will be seen that there are 5 zones on the beach. The dominant forms of all the zones are highly adapted for burrowing, while even the minors are mostly modified to the same end. But if the various zones are considered, it will be seen that there is a gradual but definite elimination of swimming forms(e.g.Nephthys, or compare Pseudaega punctata which swims well with Actaecia euchroa.).

Burrowing becomes less and less a method of obtaining food, and more and more a method of avoiding desiccation and attacks by enemies. What from a human point of view would be called "Protective Colouration" is more highly developed as the upper zones are reached. Again compare Actaecia and Pseudaega, or the Phoxocephalid with Talorchestia.

Again there is a definite dividing line between the animals which feed only when the tide is over them (Zones I -III), and those which feed only when they are uncovered(Zones IV - V). It will be seen that this division coincides with a division into an area which is more than half its time submerged, and an area which is more than half its time exposed. A glance at the minimum water content graph(Figure 3.) will show that the same line of division coincides with a rapid drop from nearly saturated sand to rather dry sand.

g. Comparison with similar areas in other places.

On exposed sandy beaches throughout New Zealand, similar communities are met with, though in some parts of the West Coast

*M. ventricosa* is reported as having replaced *M. subtriangulatum*.

It might here be of value to mention two other types of microlithic ocean beach with which I am acquainted.

To the south of Banks Peninsula is a long ocean beach composed of small rounded stones of from 4 to .8 m.m. diameter. There the shingle is so motile and the surf so strong that no pipi beds have been established. At high water there is little or no kelp, due to the fact that all the currents tend to the north, and would carry all kelp from the rocky Banks Peninsula, away from the beach. The result is that the sand hopper association at high water is missing. (Plate 12)

Still another type of microlithic ocean beach is represented at Akaroa. The beach is composed of rounded pebbles, of from one to four inches in diameter. The rattle of these stones under the influence of even the mildest surf, is sufficient to explain the absence of the low water pelecypod association. At high water there is a little kelp but the large amphipod, *T. quoyana*, is absent. Perhaps the size of the stones is unsuitable, as this animal never seems to inhabit anything but fine sand. (Plate 13 and 14).

Thus it is evident that the location of the Brighton Beach, in a backwater of the Pacific Ocean, which has probably led to the fine nature of the beach, and which results in a constant and sufficient supply of drift kelp from Banks Peninsula, has determined its physical nature and thus the nature of its fauna.

From New South Wales, Hedley (1915) reports a strikingly similar formation. Here *Donax deltoides* replaces *M. subtriangulatum*. It is extraordinary how similar the habits of these two forms

are; and Hedley's description of the shape, habits, and situation of his form, could be applied to the local species without being incorrect in the smallest detail.

Under kelp he describes the sand hoppers, *Talorchestia quadrimana* and *Orchestia maclayana*, which seems to agree identically with our sand hopper association. Hedley(1915), in this connection, states;- "In all countries and various climates the ocean beach preserves the same external appearance. If by some cosmic change, the climate of Sydney became warmer, then in response, a thicket of *Rhizophora* would spring up on the *Zostereta* of Middle Harbour, and a reef of coral would build on the *Hermosireta* of the Heads. But the sandy beach, though sheltering another series of species, and perhaps serving as a turtle incubator, would still remain unchanged. externally."

#### h. Summary.

The ocean beach is a region of few, highly specialised forms. Its chief character is its moving and unstable form, which prevents the establishment of a flora, except back in the dune area. Consequently all forms are dependent on the sea for their livelihood; and dependent on their burrowing ability for protection, there being no sheltering rock, or vegetation as is found in many localities.

The constancy of this sub-formation in all climates, in varying degrees of sunshine, salinity, etc., leads to the conclusion that the deciding factors in establishing it are:

1. Finely divided substratum.
2. Ocean surf, bringing a plentiful supply of plankton.
3. An adjacent rocky coast where kelp can grow, with a current from it to the beach.

And provided these are present, this formation will appear regardless of almost all other considerations.

B. Type of Muddy Estuary-----The Heathcote Estuary.

1. Physical Factors.

a. Situation and Formation.

The area known as the Heathcote Estuary is situated immediately north and north west of Banks Peninsula. According to von Haast (1879) its existence may be explained as follows:-

" The Banks Peninsula itself, a big mountainous region of volcanic origin, was in the post-pliocene era, separated from the plains by a narrow arm of the sea. Soon however, the ocean swell travelling northwards, carrying the products of disintegration of the post- pliocene deposits, and assisted by the material from the rivers, was directed by the two prevailing winds to form a dam from the mouth of the Rakaia to the isolated volcanic system.(Banks Peninsula). Year by year the dam grew till it formed a definite isthmus which was really a shingle spit. Behind this spit, and sheltered from most disturbances, now lay a long arm of the sea with an entrance to the north of Banks Peninsula. Into this the Selwyn, Waimakariri, and probably the Rakaia, fell. Gradually the shingle and sand , brought down by the northern rivers, the Waipera and the Ashley, travelling with a northerly swell, built a bar across the bay, thus forming a large lagoon, of which Lake Ellesmere is the only remnant."

The other part of the once large arm of the sea dwindled, in size till the small area known as the Heathcote Estuary is the only remnant.

At the same time the tidal action off the coast at New Brighton was extending a sand bar across the entrance of this area so that now it has an area of but  $2\frac{1}{2}$  square miles.

The Heathcote Estuary , as at present existent, has the shape of an equilateral triangle , with sides approximately 2 miles long. Into it run the two rivers, Avon and Heathcote, both to some extent at least, of artesian origin. They flow through remarkably flat country for many miles ,with the sinuous course of rivers running very near grade. Each of these rivers flows in at an angle of the triangle , while the opening to the sea is at the other angle. This opening is about 250 feet wide at low water, but a large rock, Shag Rock, reduces the free passage to about 180 feet with a depth of 20 to 25 feet. (Plates 15-16).

There are many artesian "leaks" in the Estuary, but in addition it receives the water from 150 square miles(J. Little 1911) ; the same authority quotes the amount of water flowing out of the Estuary at ordinary tides as 9500,000 tons.

The map shows the general shape of the area. The seaward side, from the outlet to the mouth of the Avon, is but little west of north in direction. It changes from almost wholly sand at the outlet, to rather soft mud at the Avon. Plant growth , too, changes from the ordinary sand dune grasses, *Scirpus frondosus* and *Ammonophila arenaria*, at the mouth of the Estuary, to rush topped banks, with plant *Suaeda maritima* creeping on the ground. At the Avon the rushes are an almost pure formation of *Juncus maritimus*, and *Leptocarpus simplex*.



The side running from the Avon to the Heathcote, is north-north <sup>East to South-South West</sup> ~~of east~~ in direction. It is more uniform in composition, consisting of a stiff clay sand bank, rising two or three feet from the level below. The bank is topped in most places, by a flat level area, supporting the usual salt reed swamp, interspersed with occasional stunted manuka trees, gorse, and the box wood tree (Plagianthus divaricatus) .

The side from the Heathcote to the outlet is rather <sup>approximately</sup> ~~north~~ <sup>East to West</sup> ~~of south~~, in direction,. It shows great variation. For the first 1/5, it is rather like the previous section; then its natural aspect is altered by a stone wall with rocky patches below. This gives way to a tram cause-way which cuts off an area of 115 acres of mud flat. This area is still in free communication with the rest of the Estuary, by two openings in the cause-way. The banks of the area are typical of Salt-Reed Association, but here the box-tree is more common.

At the other end of the cause-way, a rocky outcrop, an extension of the Redcliffes volcanic mass, juts out into the Estuary at a place I have called "Rock House Point." From there on for some distance the bank is an artificial stone wall, which at Monks Bay, changes to a stone wall with a sandy beach in front of it. From there the banks are covered with rocks, put down when the road and tram-way were built. The next change is at Whag Rock .

This rocky area, jutting out into the seaward opening of the Estuary, is a continuation of a volcanic

spur. From there the coast is rocky round to Sumner.

Just past Shag Rock, however, another cause-way has been built, and mud has so accumulated that it was considered with the rest of the Estuary.

Within the limits described is the Estuary itself. It is a flat area, cut up by water channels. Almost the whole area is uncovered during tides, except these water channels, and over half of it is above half tide.

Near the mouth of the Estuary, especially on the Brighton side, in isolated banks, a considerable admixture of sand is found. For some distance inside the spit, the substratum is entirely fine sand, while further in the proportion of sand decreases. At Monks Bay the proportion of sand is quite considerable, and at the higher levels at other places. Further in the Estuary, and always near the water channels, the mud is soft and heavy, ---- grey on top with black, evil smelling substance beneath. When the Avon and Heathcote Rivers are reached, the sand has practically disappeared, there being nothing but heavy mud at low water, merging into clay at high tide mark.

A few pieces of rock here and there, a few piles, odd pieces of wood, and tins, are the only exceptions to almost complete microlithic substratum.

#### b. Climate.

##### Temperature:

##### Air:

The temperature range at the mouth of the Estuary is about that already recorded for the Brighton Beach. As the upper end of the Estuary is approached, the conditions approximate

to those of Christchurch and become more extreme.

#### Water.

The water temperature shows even greater departure from the conditions at Brighton. In summer the upper end of the Estuary is almost invariably several degrees higher than the lower end, while in winter the reverse is the case. It must be realised, too, that the kind of day, state of the tide, and other factors, influence the result. An approximate idea can be gained from the following readings at Heathcote Bridge.

	Jn.	Fb.	Mh.	Ap.	My.	Jn.	Jy.	Ag.	Sp.	Oc.	Nv.	Dec.	
Air.	18.2	19.9	18.8	14.3	12.7	9.2	10.4	8.7	9.9	12.8	16.3	17.9	
Water	17.7	18.1	17.8	14.2	12.1	10.0	10.4	8.4	10.1	12.4	15.9	17.5	

But it must be borne in mind that these readings were all taken in the day time, and that in the winter nights the air temperature falls as low as 2 or 3 degrees below zero, and the water to 4 or 5 degrees C.

The temperature of the mud shows a gradient similar to that found for the sand at Brighton Beach.

Air temperature (in shade) 11.4

Water temperature 10.4

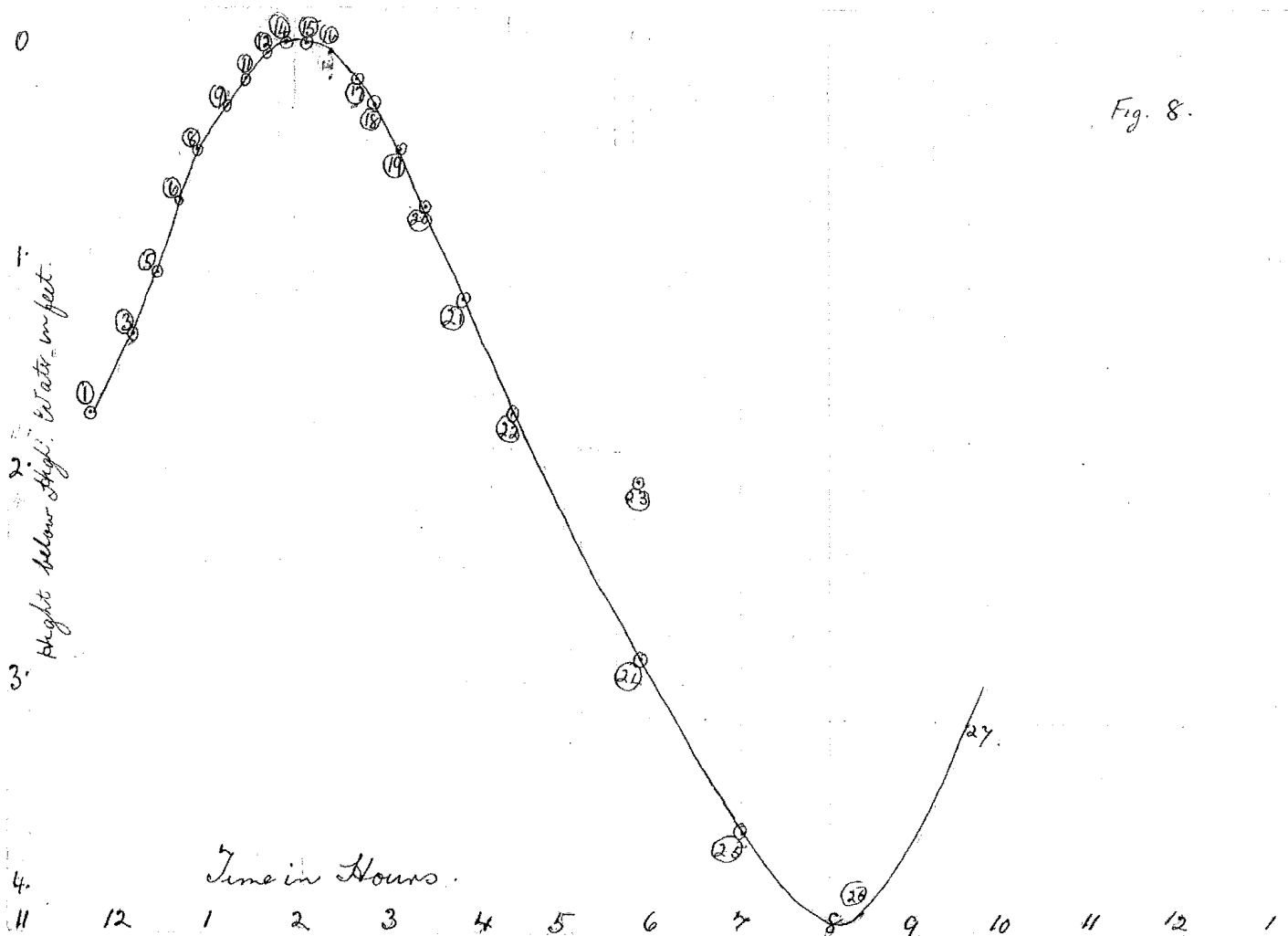
Hours exposure.	Surface.	10cms. down	20cms. down	30cms. down	40cms. down
2hrs.	10.3	10.3	10.0	9.5	10.0*
4hrs.	10.2	10.1	9.8	9.7	9.5
8hrs.	10.2	10.0	9.6	9.4	9.2

\*The rise in this value is due to the seepage of water.

For the rest of the climatic factors, the readings given for Christchurch (N.Z. Year Book 1915) are very approximately correct.

## c. Currents and Tides.

The only currents in the Estuary are the river and tidal currents, and the swirls and eddies produced by them. The tide rises to between 4 and 6 feet in the Estuary, and is about  $\frac{1}{2}$  to one hour later than at Lyttelton. A change in wind, however, has a pronounced effect. An easterly wind, either a north easterly or a south easterly, tends to bring the tide in a little earlier, raise it to a greater height, and keep it in a little later. A westerly wind has almost the opposite effect. Usually the tidal movement in the Estuary follows the simple harmonic expression given by Bruce (1928). This is illustrated in the following graph (Figure 8) of time against tide height, taken at the Mount Pleasant Pier.



## d. Composition of the Water.

The chloride content , estimated as grams of chlorine per litre, the oxygen estimated as milligrams per litre, and the density, were estimated for different samples , taken at different places and states of the tide. The localities where these samples were taken are indicated in figure 9. The actual results of the analyses is given below and the results of the chlorine estimation , shown in figure 10. Though it was not expected that these would provide any definite relationship, it was felt that they were necessary if these results were to be of any use for further work or for comparison with other localities.

Locality. Referred to fig. 9 first fig. horizon. tal see vert. -cal.	Sample mbr.	56 and 57.	Cl in grams per litre.	Density 15/5/4	Oxygen content in milligrams per litre.
		State of Tide etc.			
9.5/11.5	1	Tide High. Bright Sun. Surface	16.8	1.0219	4.26
10/12	2	$\frac{1}{2}$ Tide. Coming in. Surface	.259		
11/16	3	Low Water. Surface	.114		
10.5/11.2	4	Low Water. Coming in. Surface	.179	1.0015	
8/7	6	High Water. Bright sun. Surface	18.53	1.0243	10.2
13/6	7	" " " " "	18.53	1.0242	
11/9	8	" " " " "	18.53	1.0242	
15/2	9	High Water. Going out. "	18.7	1.0244	
13/16	10	Low Water. (Brighton Beach)"	18.68	1.0244	
10.8/14.2	11	Low Water. Tide going out "	.307		
11.2/12.5	12	Collected off mud flats. "	8.23		
		Tide going out.			
11/5	13	Tide low. Coming in. "	11.53	1.017	
10.8/13	14	Tide high. Hot day. "	12.6		
6.8/6.2	15	Tide nearly high. Going out"	17.15	1.0224	7.6
14.6/1.6	16	Tide high. Going out. "	18.46	1.0240	
13.8/4	17	Tide high. Bright sun. "	18.9	1.0247	
6.8/6.2	18	Tide $\frac{1}{3}$ in, and coming in "	9.96		
10.2/10.5	19	In Zostera pool. Low Water			3.96
		Surface	13.65		
11/5	20	$\frac{1}{2}$ Tide. Coming in. "	12.82		
5/4.7	21	$\frac{1}{3}$ Tide. Coming in. "	7.15	1.009	
11.5/10.2	22	High Tide. Bright sun. "	18.7	1.0243	
11/5	23	Nearly high. Going out. "	18.0		
13/4.8	24	Nearly high. Bright sun. "	18.53		
5/4.7	25	Very nearly low water.			
		Tide going out. "	.99		
14.5/2.6	26	High Water. Bright Sun. "	18.53		
5/4.7	27	High Water. Going out. "	13.33	1.018	9.07
15.4/2.4	28	Low Water. Coming in. "	14.78	1.0186	
14/1.7	29	Tide third in. Coming in "	13.74	1.0181	
10/5.8	30	High Tide. Bright sun. "	18.54	1.0245	
6.8/6.2	31	Tide nearly high. Going out. 4 ft below surface. 2ft off bottom.	17.2	1.0224	5.63
11/9	32	Tide nearly high. Bright sun. 5ft down.	18.6	1.0243	
5/4.7	33	Low Water. Squeezed out of mud.	13.6	1.0200	
15/2	34	High water going out. 4 ft down.	18.7	1.0243	
9.5/11.5	35	Tide high. Bright Sun. 5 ft down.	17.0	1.0229	

As well as the "spot" samples from all over the Estuary, four stations were established, at Heathcote Bridge, Mt. Pleasant Pier, Rock House Point, and Shag Rock. Here samples were taken at frequent intervals, over the whole of a tide. From these results, which are summarised below, the graphs on Figure 11. were constructed, which allowed me to build up a fairly accurate picture of the salinity changes in the Estuary. The four stations are marked XI, X2, X3, and X4, on Figure 12.

#### Station XI

Heathcote Bridge

X2.ctd.

Time after Low Water	Salinity
-2 hrs.	5.573
-1hr. 30min.	4.394
-1 15	3.394
-1 0	2.625
- 45	2.129
- 30	1.775
0	.6528
15	.5322
30	.4825
45	.3193
1 15	.4613
2 15	5.783
3 35	9.792
6 20	13.550
6 35	14.060
6 50	14.060
7 5	13.700
7 20	13.700
7 35	13.450
7 50	13.420

Station X2.  
Mt. Pleasant Pier.

-8 30	13.580
-8 0	15.720
-8 0	16.220
-7 45	16.440
-7 30	15.080
-7 30	16.290
-7 15	15.850

Time after Low Water	Salinity.
-7hrs. mins.	16.17.
-7	14.57.
-6 45	15.37.
-6 30	16.23.
-6 30	14.44.
-6 15	16.79.
-6 0	17.15.
-5 45	17.76
-5 30	17.79
-5 15	17.68
-5 0	17.68
-4 45	16.62
-4 15	15.54
-4 45	15.37
-2 45	14.19
-2 15	13.22
-1 35	8.932
-1 0	6.002
- 50	5.002
- 5	2.697
10	1.854
25	1.647
40	1.597
55	2.271
1 10	3.903
1 40	4.506
2 10	5.855
2 40	10.150

ROCK HOUSE POINTSHAG ROCK

Time after L.W.			Time after L.W.		
No.	L.W. Hr. Mins.	Salinity	No.	L.W. Hr. Mins.	Salinity
		12.7			
	40	13.3	81	10 mins	15.62
65	1.10	15.12	82	0	14.07
66	1.25	14.76	83	15 "	12.90
67	1.40	14.89	84	30 "	12.97
68	1.55	14.80	85	45 "	12.93
69	2.10	15.63	86	1.15	14.15
70	2.25	16.31	87	1.45	13.69
71	2.55	16.20	88	2.15	14.72
72	3.25	15.89	89	2.20	19.86
73	3.55	16.42	90	2.45	17.97
74	4.25	17.94	91	3.15	18.68
75	4.55	18.70	92	3.45	?
76	5.25	18.72	93	4.15	19.36
77	5.55	18.93	94	4.45	18.78
78	6.10	19.26	95	5	19.28
79	6.25	19.26	96	5.15	18.26
80	6.40	19.13	97	5.30	19.22
			98	5.45	18.92
				6	18.86
			100	6.15	19.16
			101	6.30	19.26
			102	6.45	18.85
			103	7	18.89

Taken from  
Rock Pool



### Discussion of Results.

It will be noted that the readings vary considerably for different states of the tide, depth and locality.

### Chloride Value.

In many cases where fresh water enters salt water, a definite stratification of the water has been noted. Among the workers who have noted this effect may be mentioned Huntsman (1918) and Cowles (1923). In the case under consideration such a stratification was not observed (cf. results No. 31, 32, 34, 35) the salinity varying little with depth for the same state of the tide etc. Probably this is to be explained in terms of the shallowness of the area, and the large proportion of tidal movement.

At full tide the salinity varies from 12-14 units of chlorine near the entrance of the rivers to about 18-19 in the lower parts of the Estuary.

At low tide when the water is confined to the water channels, <sup>(of the Heathcote & Avon Rivers)</sup> the salinity varies from almost fresh at the mouth (.114 to .9 units of Chlorine) to 14 - 15 units at the mouth of the Estuary.

A fact worthy of note is that water taken from the mud itself has a salinity distinctly higher than the water at low tide. An interesting fact brought out by the tidal salinity curves (fig 11) is that the maximum and minimum salinities at any point are reached after high and low water respectively. The salinity change is most rapid at about half tide. It will be seen that animals living at high water at Heathcote Bridge need be no better able to withstand freshening of water than those at low water at

Shag Rock.

### Density.

The density, except in case No. 4 seems to follow the salinity. The irregularity in this case may quite likely be due to suspended matter in the water.

### Oxygen Values.

As there are but seven values for Oxygen, no detailed conclusions would be justified. But these results point to a very definite and considerable decrease in the proportion of dissolved oxygen as we proceed up the Estuary (Fig 13). Proximity of mud seems to decrease the oxygen content as the differences between results 18 and 31 might be supposed to show. But the decrease from 10 to 4 mmgs. is a rather large decrease and seems to show conclusively that surface water is not necessarily saturated.

## 2. Floristic Composition.

The Estuary shows remarkably little flora. Except for a little Ulva in sheltered rock pools and on muddy sand banks a little Zostera, the salt reed formation, and one or two small plants, it is bare mud. The flora will be considered with each area.

## 3. Faunistic Composition.

### a. Catalogue of Faunistic Species.

The following is a list of species of animals found in Heathcote Estuary with which is included the list from the New Brighton Piles. No attempt has been made to identify the numerous species of protozoa and small crustacea which have been found. Except for these, the list probably includes all the common forms,

though in some cases the animals have not been identified and are referred to their group only.

PORIFERA

Calcarea

One species from below rocks inside Shag Rock - unidentified.

COELENTERATA

Hydrozoa

Several forms on rocks and shells, notably a sertularian on pipi and mussel shells at Brighton beach.

ANTHOZOA

Family Phyllactidae

1. *Oulactis plicatus* Hutton 1879 p. 311. In rock pools at Shag Rock and between rocks at low water covered with pieces of shell.

Family Bunodidae

2. *Bunodes aureoradiata* Stuckey. (Stuckey 1908 p. 367)

In mud on any solid object from Monks' Bay to Mount Pleasant. Range from 6 hours exposure to low water. Also on other species of Anthozoa.

ECHINODERMATA

Asteroidea

Family Asterinidae

3. *Asterina regularis* Verrill (Bennett 1927 p. 135)

Common at Shag rock and in as far as Monks' Bay. Range to half hour exposure or more.

PLATYHELMINTHESTricladia4. *Leptoplana australis*.

Common under stones and in deep moist crevices at Shag Rock and inside as far as the long tramway embankment. Range to 2 hours exposure.

Nemertinea

Apparently five species - none of which have been identified.

1. Large black nemertine under stones just inside Shag Rock, also on Brighton Piles.

2. Pink nemertine. Very common under stones at Shag Rock and some distance inside the Estuary. (Perhaps *Amphiporus heterophthalma* Schmarda).

3. Thick black nemertine under stones in mud at Monks Bay (Perhaps

4. Grey striped nemertine, not unlike *Lineus marinus*, in mud at Mount Pleasant.

5. Dirty coloured, large form - Mount Pleasant in mud.

ANNELIDA POLYCHAETAFamily Aphroditidae

5. *Lepidonotus polychroma* Schmarda. (Benham 1909 p. 72)

Very plentiful under stones up to 1 hour exposure at Shag Rock and outside. Scarce inside the Estuary but occurs as far up as Rock House Point.

Family Phyllodocidae

## 6. Porroa

(Eulalia) microphylla Schmarda. (Ehlers 1904 p. 16 and 1907 p. 6).

Very plentiful on mussel beds at and outside Shag Rock. On New Brighton Piles. Does not occur in the Estuary further up than Monks Bay. Range up to 6 hours exposure.

Family Nereidae (Lycoridae)

## 7. Nereis australis Schmarda. (Benham 1909 p. 73)

Moderately common in the lower parts of the Estuary chiefly under stones and sometimes in loose membranous tubes. Range up to  $\frac{1}{2}$  hours exposure.

## 8. Nereis vallata Grube. (Benham 1909 p. 73)

Common under stones and burrowing in the mud. Most plentiful well up the Estuary and takes the place of Chione stutchburyi near the Heathcote Bridge. Range low water to 3 hours exposure.

## Nereis amblyodonta Schmarda. (Benham 1909 p. 74)

Occurs to 6 hours exposure at Shag Rock and outside; inside the Estuary as far as Rock House Point. Range low water to 6 hours exposure.

## Nereis kerguelenensis

Recorded by Oliver (Oliver 1923 p. 541) but not found by me.

Family Nephthydidae

## 9. Nephthys macrura Schmarda. (Hutton 1879 p. 321).

This species has an unusually large range. It is quite

common in the sand at New Brighton where it is almost the only polychaete. It occurs in the Estuary up as far as half way between the Heathcote Bridge and Mount Pleasant. Ranges up to 5 hours exposure in mud and 4 in sand.

Family Glyceridae

10. *Glycera origera* Schmarda. (Benham 1909 p. 79).

Quite common from Shag Rock to half way between Mount Pleasant and Heathcote Bridge. The range as I have observed it is from low water to 3 - 4 hours exposure. Benham records it down to 35 fathoms.

Family Eunicidae

11. *Lumbriconereis sphaerocephala* Schmarda. (Benham 1919 p. 79).

Occurs freely over the Estuary especially in stiff mud.

Family Arichiidae

*Scoloplos cylindrifer* Ehlers.

Fairly common in muddy parts of Estuary.

*Aricia papillosa*.

Recorded from here by Oliver (1923 p. 541) but not so far seen by me.

*Scolecoides benhami* Ehlers. (Ehler 1907 5 No. 4 p. 14.)

Common at Mount Pleasant, at about 8 hours exposure.

Family Spionidae

12. *Spio*. Benham says "An undescribed species I believe. It differs from *S. aequalis* Ehlers in its much larger tentacles on the prostomium."

Common at Mount Pleasant, at about 7 hours exposure.

Family Terebellidae

13. *Thelepus plagiostoma* Schmarda. (Ehlers 1904 p. 50)

In tubes under stones at low water at Monks' Bay but not common.

Family Arenicolidae

14. *Arenicola assimilis* var. *affinis* Ashworth. (Ashworth 1903 p. 737).

Common in stiff sandy mud near Mount Pleasant. Range from 6 to 4 hours exposure.

Family Serpulidae

15. *Vermilia carinifera* Gray. (Hutton 1879 p. 326)

On rocks as far in the Estuary as Rock House Point. At Shag Rock forms large masses. Range from low water to 6 hours exposure.

16. *Spirorbis zelandica* Gray. (Hutton 1879 p. 327).

On mussels at low water at Shag Rock.

Family Hermellidae

17. *Pallasia quadricornis* Schmarda. (Hutton 1879 p. 324).

Tubes common all over lower part of flats. Only one animal taken at low water, Mount Pleasant.

Sipunculoidea

18. *Dendrostoma huttoni* Benham (Benham 1905 p. 306).

Low water to 8 hours exposure in soft mud from Shag Rock to Mount Pleasant.

CRUSTACEABrachyuraFamily Cancridae

19. *Cancer-novae-Zealandiae* (Jacquinot and Lucas)  
(Chilton and Bennett 1928 p. 744).

Common outside Shag Rock. In mud in the Estuary as far as Monks Bay but not commonly in so far. Range to  $\frac{1}{2}$  hours exposure.

20. *Ovalipes bipustulatus* (Milne - Edwards ) (Chilton and Bennett 1928 p. 755).

Occasionally at Shag Rock, in deep water, attracted by meat bait.

Family Ocypodidae

21. *Hemiplan hertipes* (Jacq and Lucas) (Chilton and Bennett 1928 p. 759).

Common in muddy places from latter part of Monks Bay to past the Heathcote and nearly to the Avon Bridges. Range from  $5\frac{1}{2}$  hours exposure down.

Family Grapsidae

22. *Hemigrapsus sexdentatus* (Milne-Edwards) (Chilton and Bennett 1928 p. 764).

Common at Shag Rock and outside. Not common inside the Estuary. Avoids muddy places. Range up to 7 hours exposure in sheltered places. Usually up to 4 hours exposure.

23. *Hemigrapsus crenulatus* (Milne - Edwards) (Chilton and Bennetts 1928 p. 766).

Common from rock pools on the open coast to far up



the Avon and Heathcote. Range from below low water to 8 hours exposure, under stones.

24. *Cyclograpsus lavauxi* Milne-Edwards. (Chilton and Bennett 1928 p. 770).

Common under stones at Shag Rock. Occasionally associated with *Helice crassa* in the Estuary and forming a colony in a gravelly place near the Heathcote Bridge.

25. *Helice crassa* Dana. (Chilton and Bennett 1928 p. 772).

Common inside the Estuary from Monks Bay to far past the Avon and Heathcote Bridge. Range from 8 - 6 hours exposure on the open flat. Range up to 10 hours exposure in salt marshes.

Family Pinnotheridae

26. *Pinnotheris pisum* Linnaeus. (Chilton and Bennett 1928 p. 775).

Occurs in many large mussels (*M. edulis*, *M. canaliculus*), and apparently the same species found in the cockle and pipi.

27. *Hymenicus varius*.<sup>+</sup> Dana. (Miers 1876 p. 50)

Occurs in the dark brown weed ----- in pools and on the flat between 5 and 7 hours exposure.

28. *Hymenicus pubescens*.<sup>+</sup> Dana. (Miers 1876 p. 51).

On mud just inside Shag Rock. Range up to 4 hours exposure.  
+ This very difficult group has never been properly revised, and I am by no means satisfied with my identification. Some of my specimens are at present with Bennett (Australia) who is revising the group.

ANOMURAFamily            Paguridae

29. *Eupagurus novae-zealandiae* (Dana) (Thomson 1898 p. 173)

Common in rock pools and in sheltered places at Shag Rock. Less commonly inside the Estuary up to Rock House Point. In shells of *Turbo smaragdus*, *Monodonta aethiops*, *Struthioloria* sp? *Euthria littorinoides*, *Cominella maculata*. Range about low water.

30. *Eupagurus traversii*. Filhol. (Thomson 1898 p. 179).

Two specimens taken in rock pools at Shag Rock in shells of *Monodonta aethiops*.

Family Porcellandiae

31. *Petrolisthes elongatus* (Milne-Edwards) Thomson 1898 p. 189)

Quite the commonest decapod crustacean at Shag Rock. Under stones and in sheltered places from low water to 6 hours exposure. Occurs plentifully inside the Estuary in stony places up as far as Rock House Point, and more sparingly on to Mount Pleasant.

MACRURAFamily            Alpheidae

32. *Betaeus aequimanus* Dana (Miers 1876 p. 83)

At Shag Rock in weed. Range about low water except in very damp places.

Family Palaemonidae

33. *Palaemon affinis*. A Milne-Edwards. (Miers 1876 p. 85.)

Common from Shag Rock to Heathcote Bridge in pools and open water. Always submerged.

AMPHIPODAFamily Orchestidae

34. *Orchestia chiliensis* Milne-Edwards. (Thomson 1898 p. 199).

Quite the commonest Estuarine amphipod. In rush bases, debris under stones, in clay banks, from Rock House Point to well past the Avon and Heathcote Bridges. Range from 5 to over 10 hours exposure.

35. *Talorchestia telluris* (Spence Bate) (Chilton 1916 p. 299)

One specimen from near Pleasant Point, at about 8 hours exposure.

Family Calliopiidae

36. *Poracalliope fluriatilis* (Thomson) (Chilton 1921 p. 529).

Common in muddy pools on the weed, and taken in the tow net from lower part of the Estuary. ~~Extends~~ from almost completely salt to almost completely fresh water. Range totally immersed.

Family Gammaridae

37. *Melita inequistylis* (Dana). (Chilton 1921 p. 535)

Under stones in muddy places in the upper part of the

Estuary, above Rock House Point. Range from 5 - 8 hours exposure, but never in dry places.

In addition there are at least two species at Shag Rock which I have not identified.

### ISOPODA

#### Family Cymothoidae

38. *Livonica raynaudii* Milne Edwards (Thomson 1921 p. 114)

Found in the gills of the sand flounder (*Rhombosolea plebelia*) From March to May.

39. *Nerocila macleayii* Leach. (Chilton 1891 p. 68)

Found clinging to the fins of the following fish. Red Cod (*Physiculus bachus*) Sand Flounder (*Rhombosolea phebeia*) Yellow Belly (*Rhombosolea leporina*).

#### Family Sphaeromidae

40. *Sphaeroma quoyana* Milne-Edwards (Chilton 1919 p. 11).

Found boring in sandy clayey rocks, in pieces of wood etc., from Shag Rock to past Rock House Point. Range about and below low water but upto 3 hours exposure in one case.

41. *Isocladus spiniger* Dana (Miers 1876 p. 113)

Under rocks at Shag Rock. Range low water to 3 hours exposure.

#### Family Idoteidae

An individual of this family was taken in the tow net in the lower part of the Estuary.

#### Family Ligiidae

42. *Ligia-novae-zealandiae* Dana. (Chilton 1901 p. 107)

Common in an isolated patch near Heathcote Bridge. Under

and on stones and decayed wood. Range 6 - 10 hours exposure.

### OSTRACODA

Members of this group occur freely on the mud from Shag Rock to Heathcote Bridge.

### COPEPODA

Occur freely, both in the water and on the mud throughout the whole length of the Estuary. Apparently several different forms.

### CIRRIPIEDIA

#### Family      Depadidae

*Lepas australis* Darwin (Filhol 1874 p. 485).

On drift kelp etc, coming in from outside.

#### Family      Balanidae

43. *Elminius modestus* Darwin. (Filhol 1874 p. 489)

Common on rocks and any solid place throughout the Estuary from 6 - 9 hours exposure.

44. *Elminius plicatus* Gaimard (Filhol 1874 p. 489)

Common on rocks in exposed places at Shag Rock, but extends very little inside the Estuary. Range 5 - 8 hours exposure.

45. *Tetraclita purpurescens* Wood ----- (Filhol 1874 p. 488)

In one small group in a sheltered place on rocks just inside Shag Rock.

*Balanus decorus* Darwin (Filhol 1874 p. 486).

In bases of drift kelp.

*Chamaesipho columna* Spengler. (Filhol 1874 p. 489)

On cockles (*Chione*) and pipi (*Amphidesma*) near Rock House Point.

MOLLUSCA

Class Amphineura

Family Mopaliidae

46. *Plaxiphora caelata* Reeve. (Suter 1913 p. 19)

Under stones at and below low water. From Shag Point to Rock House Point.

Family Acanthochitidae

47. *Acanthochites porosus* Burrow. (Suter 1913 p. 27)

One specimen taken under stones below low water near Shag Rock.

Family Chitonidae

48. *Chiton pellisserpentis* Quoy and Gaimard. (Suter 1913 p. 33).

Abundant on stones from outside the Estuary to Rock House Point, and occasionally near the Heathcote Bridge. Range from low water to 4 hours exposure.

49. *Chiton quoyi* Deshayes. (Suter 1913 p. 34).

Very abundant over sand area as *C. pellisserpentis*, but always under stones. Range from below low water to 4 hours exposure.

Class Gastropoda

Family Acmaeidae

50. *Acmea fragilis* Chemnitz. (Suter 1913 p. 68)

One specimen under stone just inside Shag Rock.

*Acmea pileopsis* Q. and G. (Suter 1913 p. 71)

Occasionally on rocks inside Shag Rock.

*Acmea stella* Lesson (Suter 1913 p. 73)

One specimen on rock inside Shag Rock.

*Acmea parviconoidea* Suter (Suter 1913 p. 69)

Common on rocks at Shag Rock.

51. *Acmea helmsi* E.A. Smith (Suter 1913 p. 69)

Common on shells of *Monodonta corrosa*, *Amphibola crenata*, and any solid material in the muddy parts of the Estuary.

Family Patellidae

52. *Helcioniscus radians* Gmelin (Suter 1913 p. 81)

Common at Shag Rock and a little inside. Range 2 - 7 hours exposure.

53. *Helcioniscus ornatus* Dillwyn. (Suter 1913 p. 80)

Distribution as for *H. radians*.

Family Fissurellidae

54. *Scutus ambiguus* Chemnitz. (Suter 1913 p. 103)

On rocks below low water mark, only small ones seen. In as far as Monks Bay.

Family Trochidae

55. *Monodonta coracina* Troschel. (Suter 1913 p. 114)

On rocks at Shag Rock.

56. *Monodonta nigerrima* Gmelin. (Suter 1913 p. 114)

One dead specimen Shag Rock.

57. *Monodonta aethiops* Gmelin. (Suter 1913 p. 116)

58. *Monodonta atrovirens* Philippi. (Suter 1913. p. 117)

59. *Monodonta corrossa* A. Adams. (Suter 1913 p. 117.

Very plentiful on muddy and rocky parts of the Estuary from Monks Bay to past the Heathcote Bridge. Range  $3\frac{1}{2}$  to 8 hours exposure.

60. *Monodonta lugubris* Gmelin. (Suter 1913 p. 119)

Shag Rock and just inside, always under stones. Range

*Cantharidus tenebrosus* Huttoni E.A. Smith. (Suter 1913 p. 129)

In scattered patches over the Estuary. Most plentiful in *Zostera* beds. Range low water to 4 hours exposure.

Family Turbinidae

61. *Turbo smaragdus* Martyn. (Suter 1913 p. 162)

Shag Rock and a little inside. Range from 4 hours exposure down.

Family Litorinidae

62. *Litorina cincta*. Q. and G. (Suter 1913 p. 187)

Shag Rock and Brighton piles. Range 7 to 10 hours exposure, sometimes down to 4 hours exposure.

63. *Litorina mauritiana* Lamarck (Suter 1913 p. 188)

Shag Rock to Monks Bay on stones. Brighton Piles.

Range 8 to full exposure.

Family Risellidae

- Risellopsis varia* Hutton. (Suter 1913 p. 191)

High water on Brighton Piles.



Family Hydrobiidae

64. *Potamopyrgus antipodum* Gray. (Suter 1913 p. 231)

Upper part of the Estuary in distinctly brackish water, from Mount Pleasant, some distance up the Heathcote River. On open mud, in bases of rushes, in vegetation. Range almost the same as *O. chiliensis*.

Family Cerithiidae

- Cerithidea subcarinata* Sowerby. (Suter 1913 p. 239)

In large numbers on small clumps of the green weed. On mud in the lower part of the Estuary, especially behind the small tramway embankment.

Family Buccinidae

65. *Cominella maculosa* Martyn. (Suter 1913 p. 387)

Common in rock pools at Shag Rock.

66. *Cominella lurida* Philippi. (Suter 1913 p. 384)

Common all over the muddy part of the Estuary, from Monks Bay to past the Heathcote Bridge. Range from 8 hours exposure down.

Family Chrysodomidae

67. *Euthria littorinoides* Reeve. (Suter 1913 p. 376)

Common under stones from inside Shag Rock to Monks Bay.

Range. Low Water.

Family Thaisidae

68. *Thais scobina albomarginata* Deshayes. (Suter 1913 p. 427).

From Shag Rock to Rock House Point. Common on rocks from 4 to 10 hours exposure. Sometimes in clusters under rocks

lower down.

Family Amphibolidae

69. *Amphibola crenata* Martyn. (Suter 1913 p. 597)

Common on mud from outside Shag Rock to past the Heathcote Bridge. Range on mud from 5 to 8 hours exposure. In salt reed swamps from 7 to 10 hours exposure.

Family Siphonariidae

70. *Siphonaria abliquata* Sowerby (Suter 1913 p. 599)

Shag Rock. Range low water to 6 hours exposure.

71. *Siphonaria Zealandica* Q. and G. (Suter 1913 page 600).

Shag Rock to Rock House Point. Range low water to 4 hours exposure.

Family Onchidiidae

- Onchidella nigricans* Q and G. (Suter 1913 p. 811)

Inside Shag Rock to Monks Bay. On mud and in sheltered places from low water to 4 hours exposure.

LAMELLIBRANCHIA

Family Mytilidae

72. *Mytilus edulis* Linné. (Suter 1913 p. 862)

Common at Shag Rock and in to Monks Bay. Range 2 hours exposure down.

73. *Mytilus canaliculus* Martyn. (Suter 1913 p. 864)

Common over same locality and range as *M. edulis*.

74. *Mytilus magellanicus* Lamarck. (Suter 1913 p. 865)

Common in large banks on the rocks at Shag Rock. Occasion-

ally inside the Estuary. Range from 2 hours exposure down to low water.

75. *Modiolus ater* Zelebor. (Suter 1913 p. 866)

Common from Shag Rock to Heathcote Bridge on Piles and rocks. Range 5 to 7 hours exposure.

76. *Modiolus impacta* Hermann. (Suter 1913 p. 869)

Just inside Shag Rock. Several shells in a nest of byssus threads. At low water under stones.

77. *Modiolus barbata* Reeve (Suter 1913 p. 868)

In mass of fibres in mouth of empty shell just inside Shag Rock, at low water.

Family Tellinidae

78. *Tellina deltoidalis* Lamarch (Suter 1913 p. 948)

In the Estuary confined to the area between Rock House Point, Pleasant Point and just past Mount Pleasant. Range from 5½ hours exposure to below low water.

*Tellina Spenceri* Suter (Suter 1913 p. 953)

2 Specimens apparently referable to this species from Rock House Point.

Family Mesodesmatidae

*Mesodesma subtriangulatum* Gray (Suter 1913 p. 957)

Found at Mount Pleasant and Monks Bay. Almost certainly introduced by fishing parties.

79. *Mesodesma australe* Gmelin. (Suter 1913 p. 960)

Common inside the Estuary in sandy banks from just inside

Shag Rock, to just past Rock House Point. Range from 3 hours exposure down.

Family Mactridae

80. *Mactra ovata* Gray. (Suter 1913 p. 966)

Live shells taken in ones and twos over the upper half of the Estuary, from 7 to 1 hour exposure. All these small forms. Large beds of dead shells appear in various places.

Family Veneridae

*Chione Stutchburyi* Gray. (Suter 1913 p. 987)

Common in muddy to sandy places from outside Shag Rock to past the Heathcote Bridge. Range 5 hours exposure to below low water.

Family Pholadidae

81. *Barnea similis* Gray. (Suter 1913 p. 1017)

From Shag Rock to Monks Bay, burrowing in soft rock at low water.

PISCES

Order Selachii

*Mustelus antarcticus* Gunther.

HOLOCEPHALI

Family Chimaeridae

*Callorhynchus milii* Bory. (Phillips 1927 p. 11)

Comes into lower part of Estuary with the tide.

TELEOSTOMI

Family Galaxiidae

*Galaxias attenuatus* (Jenyns) (Phillips 1927 p. 13)

At one time this fish was common and bred in the Estuary.  
Now only scattered individuals are taken.

Family Anguillidae

*Anguilla australis* Richardson (Phillips 1927 p. 17)

Common under stones and rocks in muddy places.

Family Syngnathidae

*Syngnathus blainvillianus* Eydoux and Gervais (Phillips  
1927 p. 20).

In *Zostera* beds.

*Hippocampus abdominalis* Lesson. (Phillips 1927 p. 20)

Taken occasionally in lower part of the Estuary.

Family Gadidae

*Physiculus bachus* (Red Cod) (Block and Schn) (Phillips  
1927 p. 23).

Common in lower part of the Estuary.

Family Pleuronectidae

*Rhombosolea plebeia* (Richardson) (Phillips 1927 p. 28)

In Estuary from March to May as far up as Mount Pleasant.

*Rhombosolea leporina* Gunther. (Phillips 1927 p. 28)

Common all over Estuary all the year round.

Family           Mugilidae

*Agnostomus forsteri* (Cuv. and Val) (Phillips 1927 p. 30)

Common throughout Estuary at high water.

Family Scaridae

*Pseudolabrus celiidotus* (Forster) (Phillips 1927 p. 41)

Common from Shag Rock to Rock House Point.

Family Blenniidae

*Tripterygium varium* (Forster). (Phillips 1927 p. 50)

Near Heathcote Bridge.

AVESFamily Laridae

*Sterna striata striata* Gmelin. (Matthews and Iredale 1913 p. 244.)

Common in the Estuary.

*Bruchigavia melanorhyncha* Buller (Matthews & Iredale, 1913 p. 247)

With the next species, quite the commonest birds in the Estuary.

*Larus dominicanus antipodus* (Bruch) (Matthews & Iredale 1913 p. 248)

With the previous species quite the commonest birds in the Estuary.

Family Charadriidae

*Cirrepidesmus bicinctus* (Jardine & Selby) (Matthews and Iredale 1913 p. 252). The Banded Dotterel.

Common on mud flats as the tide goes out.

Family Carbonidae

*Phalacrocorax carbo steadi* (M & I.) (Matthews & Iredale 1913 p. 411).

Black Shag. Common all over the Estuary

*Stictocarbo punctatus* (Sparrman) (Matthews & Iredale 1913 p. 414).

Spotted Shag. Common all over the Estuary.

Family Alcedinidae

*Sauropatis sanctus forsteri* (M & I.) (Matthews & Iredale 1913 p. 429).

Common in and about the Estuary.

(b) Communities of the Estuary.

These communities may be divided into two groups, those in areas supporting plant growth and showing three strata of life, and those in areas not supporting plant growth and showing two strata of life.

(ab) Region of growth supporting vegetable growth.

(1) *Zostera* sub association.

*Zostera* grows but sparsely in the Estuary though I cannot see any reason for this. It cannot be a climatic or a temperature factor for *Zostera* grows as well in Parenga harbour, near North Cape as in Stewart Island in the far south. Nor would it seem to be soil as *Zostera* grows as well in mud sand as in pure mud. In the Estuary it does grow in sandy places but only in stunted scattered groups. In small localities however in the mud it reaches a fair state of development.

*Zostera* is noteworthy in that it is one of the new marine flowering plants. It however flowers but rarely. Thus Hedley (1915) says that he has never found *Zostera* in flower in twenty five years and I can trace no record of its flowering in New Zealand. The significance of this fact is of Botanical rather than Zoological interest.

The rhizomes of *Zostera* are matted together to form a dense tangle of threads, which serve to hold the substrate together. But the chief feature of *Zostera* is its narrow ribbon-like leaves. These are strong and tough with long fibres. This, combined with their long slender pliant nature makes them well fitted to withstand the constant ebb and flow of the tide. According to Osterfield (1908) the leaves contain air which causes them to stand up in the water.

When *Zostera* occurs in any quantity it forms such a dense growth that it would smother any intruder. Consequently it occurs as an almost pure association.

The association may be divided into three strata and one small group as:-

- a. Sub surface layer.  
Burrowing pelecypods and worms.
- b. Surface layer.  
Gastropods and a few crabs.
- c. Green Vegetative Part of the *Zostera*.  
Herbivorous gastropods.
- d. Pools in the *Zostera* bed.  
Spider crabs, shrimps etc.

a. Burrowing Pelecypods and worms.

This stratum does not differ greatly from the other pelecyp-



pods of the Estuary, except that *Hemiplax hertipes* is practically absent. It consists of the cockle (*Chione*), occasional *Tellina deltoidalis*, the worms *Scoloplos cylindrifer* and *Lumbriconereis sphaerocephala*.

b. Surface gastropods.

Confined to *Cominella lurida* and an occasional *Monodonta*. The latter are more or less rare and seem to be strays from the mud flats. *Trophon plebeus* is occasionally found here as is *Cerithidea subcarinata*. It is worthy of note that all the surface forms have long tapering shells, well calculated to admit of rapid movement through the *Zostera*. An epizoic anemone *Bunodes aureoradiata*, growing on the cockles really belongs here. It is the same one as is found commonly on the Estuary.

c. Vegetative layer.

Here on the stems occur *Monodonta atrovirens* (scarse and small) *Cantharidus tenebrosus huttoni*.

On the shells and on the stems of the weed is the small shell, *Notoacmea helmsi*.

d. Pools.

In the pools is found the ordinary shrimp, *Palaemon affinis*, but it is usually of smaller size than that found lower down the Estuary, and of a less transparent colour (possibly due to the excess of sediment in the water). The crab *Hymenicus varius* is also present. Conditions in the sea pools must be rather different from the ordinary Esturian life, but not to the extent

found in the mud pools, as there is always ample cover. A sample of water which I took from one of these pools, while cloudy and containing much organic matter was rather poor in animal life.

One of the outstanding features of the *Zostera* is that it is entirely free from *Amphibola crenata*. *Amphibola* may and does occur right up to it, but is practically never found inside this area. It may be that the dense growth of the *Zostera*, keeping light and air from the surface of the mud inhibits the growth of the distance on which the *Amphibola* apparently feeds. Or it may be that the dense mat of rhizomes makes it difficult for *Amphibola* to pass the necessary mud through its intestine. So far I have found no distance in mud from *Zostera* beds, but they could easily be missed. Another possible reason is that its rounded flattened shell, however suitable for the open mud flats is extremely ill suited for movement among the matted strands of the *Zostera*. This is emphasised by comparison with the "stream line" shells of *Cominella lurida*, *Cerithidia subcarinata*, and *Trophon plebeus*.

The *Zostera* in the Heathcote Estuary when compared with similar areas elsewhere, shows the following differences:-

- a. Small extent.
- b. Does not extend below low water mark.
- c. Poverty of association.
- d. Scarcity of burrowing crabs.

The crab *Heterograpsus crenulatus*, does not seem to live here, but rather comes here for shelter or ~~for~~ breeding purposes.

Thus, in April I found large mature individuals of both sexes. In June I failed to find mature individuals, but found very small half developed crabs which I think are young *Heterograpsus crenulatus*.

(ii) Salt reed Swamp Sub-association.

The Heathcote Estuary on the landward side passes back into a tangle of salt reeds of the species, *Leptocarpus simplex* and *Juncus maritimus*. Warming ( 1919. ) states that salt marshes "are not only floristically but also anatomically and morphologically so peculiar that they differ widely from fresh water swamps." It might be expected that the fauna would be equally distinct.

It is noteworthy that in this area, *Leptocarpus simplex* which occurs lowest down in the zone and would be most exposed to the movement of the water, has much more pliant stalks than the other form. It occurs all over the area from Pleasant Point to the Avon Bridge.

In most places the edge of the Estuary is a steep bank rising above <sup>3</sup>/<sub>4</sub> tide, which is quite riddled with the burrows of *Helice crassa*. From the bank back the area is comparatively flat. For the most part it is thickly covered with reeds, with every here and there an open space. These open spaces are inhabited by *Amphibola crenata* while the whole area is more or less burrowed by *Helice crassa*. It seems worthy of note that while *Amphibola* is here much smaller than the average adult, *Helice crassa* shows no diminution in size, but rather seems to increase in size in the

burrows far up in the swamp. Possibly the area affords a good protection from birds, or perhaps the food supply here is good.

*Heterograpsus crenulatus* can be found here in channels between the rushes and under the rushes themselves. It is usually below the average size and pale with green markings. It possibly lives on the small shell fish, *Potamopyrgus antipodum* which is so common here. The bases of the rushes collect a variety of debris and small growth which harbour several amphipods. One of these seems to agree with *Orchestia chiliensis* and is almost identical with specimens identified by Dr. Chilton as such.

The small shell, *Potamopyrgus antipodum* occurs thickly in among the bases of the rushes and a number of worms chief of which are *Scoloplos cylindriker* and *Lumbriconereis sparocephala* are also found.

To sum up, the Salt reed sub-association has three "habitats".

- a. The sub surface habitat  
Worms and crabs part of the time.
- b. Surface habitat  
Crabs, amphipods, *Potamopyrgus antipodum*.
- c. Vegetative habitat  
Green stems of reeds, various flies, spiders  
etc.

A rather interesting point is that the Inanga, *Galaxias attenuatus* is supposed to deposit its eggs on the rushes. The Maoris have a legend that, if after the Inanga have gone up the swamp, the next tide does not reach to the same level, the whitebait will be poor next season. As this fish (*Galaxias attenuatus*) is practically fished out in the Estuary, the fact that I have found no eggs does not affect the matter in either direction.

This community is practically constant throughout New Zealand. In the far north a little Mangrove is usually present, but this does not seem to affect the association materially. I have no information of similar communities elsewhere.

(iii) Green Weed (*Syphonocladialis*) Sub association.

In very local spots in the Estuary is found this green weed (*Syphonocladia*). This grows in thick mats on the mud. Below the mud is the usual grouping of *Chione* and *Worms* and in addition a few *Helice crassa*. But in the weed itself is found a turret shaped gastropod, *Cerithidea subcarinata*. The long tapering shell of this animal is admirably suited for moving rapidly about in the tangled mass, and the *zostera* is the only other place where it regularly occurs. Whether it feeds on the weed at all I cannot say but this is unlikely as it has the grooved lip to the shell which seems to be associated with carnivorous forms and it can be "caught" with a piece of old fish head.

(iv.) The Mud Pool Community.

In small pools at the base of the banks in Estuary and on the mud in the upper flats, is the black weed *Scythothamnus Australis*.

It is not very plentiful, but grows on stones, shells and pieces of wood. At first sight the pools seem absolutely devoid of inhabitants, but on careful examination they are found to contain a characteristic and sharply defined group. The weed itself is the dominant form and at the bottom are *Chione stutchburyi* and *Potamopyrgus antipodum*, though the latter occur

only where the pool is near the banks, apparently having strayed from there.

The weed shelters a small amphipod, *Paracalliope fluviatilis*, which clings among its stems. This tiny organism is mottled so that when it is at rest either on the grey sand or on the black weed it is very difficult to see. It would scarcely be noticed if it were not for its rapid movement in the water. Its whole body is well fitted for swimming and clinging to the weed. Gliding about the bottom of the pools are flounders and about one inch long which I have identified as *Rhombosolea leporina*. They too show wonderful colorative agreement with their surroundings. This probably assists them in the capture of their prey as well as protecting them from their enemies. It seems that at this stage they live on the small crustacea, *Paracalliope fluviatilis* as the following stomach content, typical of several dozen examined, would seem to show.

- 7 limbs or portions of limbs, almost certainly from *Paracalliope fluviatilis*.
- 3 large portions of the above crustacean.
- 8 small transparent valves of a shell which agree in most particulars with a very minute *Chione*.
- 1 portion of a worm.
- 2 pieces of substance from the black weed.

The animal was .9 inches in length. It would seem that this flounder spawns in the Estuary or else the young individuals retreat there at an early age, for they are quite plentiful there, though their habit of partly covering themselves with sand or mud, and their dull colour renders them inconspicuous.

Another rather peculiar member of this community is the crab. *Hymenicus varius*. It clings to the black weed and its stick-like legs are so like pieces of the weed that it is rarely found unless specially looked for in its known haunts. A little formalin, however, quickly brings it out.

In the slightly deeper pools the shrimp, *Palaemon affinis* occurs but the specimens are always small.

This pool life is a highly specialised one for the following reasons.

1. The temperature shows greater variation than in the outside water as the following temperature readings show.

<u>WINTER</u>		<u>SUMMER</u>	
<u>Pool</u>	<u>Estuary</u>	<u>Pool</u>	<u>Estuary</u>
3.1	3.2	18.1	17
4.9	5.3	15.4	14.0
3.1	4.4	15.0	14.1

2. The salinity changes greatly, at high water mark showing the salinity of the surrounding water but at low tide, especially on a hot windy day, rising considerably, due to evaporation as is seen by the following figures:-

Air temperature 16.9° C. Hot Sun. Pool exposed 7 hours.  
Chloride content 17.1 units. Chloride content at H.W. 15.2

3. Lack of protection. When the tide is out, all the inhabitants of these areas are left open to the attacks of predatory animals. In this connection it is worth emphasising the protective colouration and habits of the organisms.

(v) Black Weed (*Scythothamnus Australis*) Sub association.

The black weed already mentioned as growing on *Chione* is not confined to that shell although it is quite often found there. It shelters a relatively small group of animals and contains but few species. Thus the only animals found there are a Polyzoon, a stunted Sertularian, *Notoacmea helmsi*, an amphipod a small crab (*Hymenicus varius*), Two species of *Onchidella*, and occasional specimens of *Cantharidus tenebrosus huttoni*.

As might be expected with a collection of animals on a weed exposed to the sweep of the tide, considerable adaption towards retaining the hold of the plant is shown. To this is added a more or less perfect protective coloration and form. To what an extent this is so may be gathered from the fact that careful search in the field yielded only *Cantharidus tenebrosus huttoni*. It was only when the plants were treated with a weak solution of formalin in the laboratory that the rest of the population was revealed.

The crab, *H. varius*, is very like *H. pubescens* except that it lacks the hairy back. It has long "spidery" legs provided with stout hooked claws. Its flat body is well suited for moving about among the matted strands of the weed. The amphipod is similarly provided only in this case the flattening is lateral instead of dorso-ventral. The large flat base of the *Onchidella* forms, probably serve the same function, and their dorsal surfaces are protectively mottled. Such a group would be worth considering from the point of view of Ecological equivalence.



(bb) Area of Estuary without Covering of Plant Growth.

(1) *Mesodesma Consocias*.

In the more sandy parts of the Estuary and notably on the isolated banks in the middle of the stream, *M. australe* is very plentiful. The beds are open to the full flow of the tides which brings a good food supply. It also brings danger, for the water becomes considerably ruffled over the beds, and exposes the shells to the attacks of the gulls. These seem to be fully aware of this fact as they congregate in considerable numbers over these beds at the turn of the tide.

With regard to the action of water this animal occupies a position mid way between that of *M. subtriangulata* and *Chione* and as might be expected, the siphon, foot and shell are a compromise between these two forms.

(With this animal occurs the same worm as is found on the pipi beds on the open beach, *Nephtys macrura*.)

It occurs up to about 7 hours exposure while it descends below low water. It reaches a maximum of up to 400 large individuals per square metre, at almost 2 hours exposure. It shows growth bands which, while less definite than those of *M. subtriangulatum*, are quite obvious (Plate 18).

(ii) *Nereis vallata consocias*.

Higher up the Avon and Heathcote Rivers, the cockle disappears and its place is taken by the worm, *Nereis vallata*. This animal is quite plentiful in this part of the Estuary and makes semipermanent burrows from low water to 3 hours exposure. These

are lined with slime and branch in a complicated manner. The animals themselves are quite red in colour with well marked blood vessels. They have a density of population of about 150 per square metre.

(iii) *Cyclograpsus* community.

At the Heathcote Bridge is a small but interesting community. This locality is the remains of an old stone embankment from which a few odd pile stumps jut out. It extends from  $\frac{1}{4}$  to  $\frac{3}{4}$  tide; the substratum is a mixture of fine mud and large boulders with an admixture of fine gravel. Every tide brings up a pile of vegetable refuse. The salinity range is 4 to 14 units.

The most conspicuous member of this community is *Cyclograpsus lavauxi*. This crab never burrows properly in the sense in which *Helice crassa* does. If it is dropped on to very moist soil it will shuffle its body down a little with a forward and downward motion similar to the second motion of *Helice crassa*, but when the surface of the carapace reaches a level with the mud it stops.

In nature it is usually found under stones or against them. The curious way in which the last pair of legs has a dorsal trend is adapted to this habit of backing up against rocks. In this position the weight is carried on the second, third and fourth pair, while the fifth pair are placed against the stone to give a "push off" in either direction when required.

The red mottled colour of the carapace is a good match to the gravel among which it is usually found. Its clean legs and body perhaps explain why it is not found in the mud. It may be a

remnant of the once much greater size of the Estuary. It seems certainly to be a rock crab rather than a mud one, and is quite common on most rocky shores, particularly where there is a fair amount of small gravel.

The eggs of this animal are small, only 2 mm. in diameter. Chilton and Bennet record this animal in copula, in November 28 1927 under a pile of stones. The description states that they made a clicking noise with their mouth parts.

As some doubt has been raised as to whether New Zealand possesses two species of *Cyclograpsus* or only one, it may be of interest that I have collected over fifty individuals from a very small locality and that, though they varied through the complete range of post megalopa development, I quite easily determined them as *C. lavauxi* as distinct from *C. whitei*.

Another member of this association is an amphipod, *Orchestia chiliensis*. This animal is brown in colour and is quite plentiful under stones. It apparently lives on the vegetable refuse so plentiful here and its colour serves to protect it.

The male of this animal seems to pass through a female stage as shown by the shape of the Gnathopod. A rather curious case, perhaps a gynandromorph, was found where the second gnathopod on one side was female while that on the other side was male. As well as being able to leap, this animal can swim quite well.

*Helice crassa* is also found here.

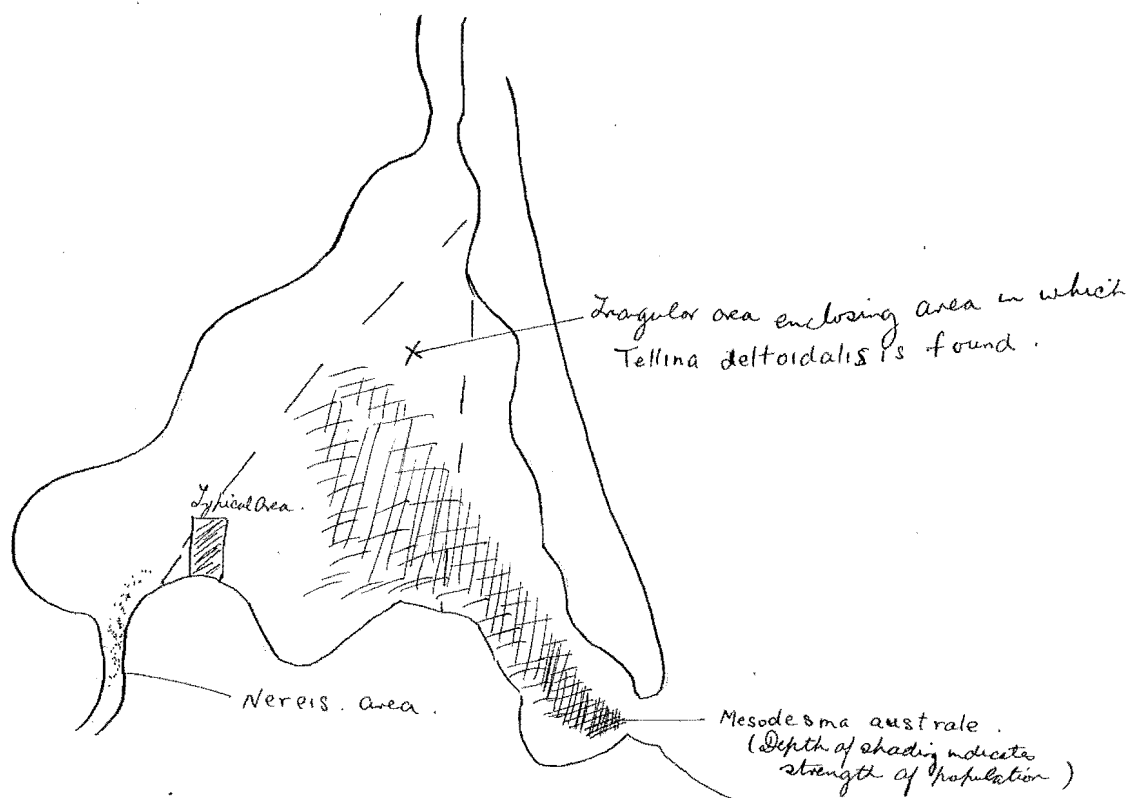
The Isopod, *Ligia novae-zealandiae*, is found here among the rocks, scattered over the shingle, and in the rotten piles.

It, too, is protectively coloured.

In the mud, the same two worms, *Scoloplos cylindriker* and *Lumbriconereis sphaerocephala* are found.

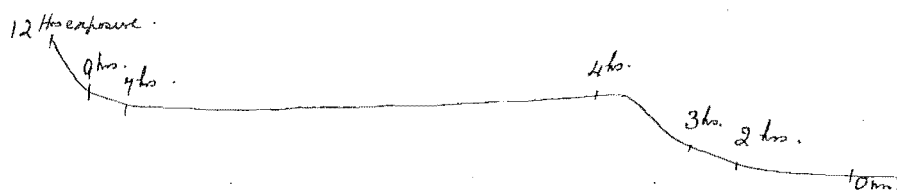
(iv) Typical Area.

For more intensive study an area at Mount Pleasant was selected.



### Physical Characters

This area extends from the edge of the Estuary, across a wide mud flat down to the water channel. The first part is shingly with a slope of some  $12^{\circ}$ . This soon gives way to the mud surface with a slope of  $2^{\circ}$  marking the region of 9 hours exposure. By the time the 7 hour exposure region is reached the slope is 50 - 58 minutes, and this continues, more or less regularly, down to the region of 3 hours 40 minutes exposure, where the bank drops suddenly down to the water channel at a slope of about  $10^{\circ}$ , but flattens down at 1 hour exposure to about  $2^{\circ}$  and continues to flatten, so that the bed of the water channel is almost horizontal as :-



At the line of separation of the two slopes, at about 4  $\frac{3}{4}$  3 hours exposure, is a great deposit of shells in the mud, which helps materially in keeping the rest of the flat constant in slope. The flat is composed of about equal parts of sand and mud, and is not very soft to walk on. It shows the usual grey colour, just below the surface, and in the higher levels is very hard and "gritty" at a depth of a few inches.

The change of salinity in the water over the area is given in the summary graph, where minimum salinities are plotted against hours of exposure.

### Fauna

At high water is the Amphipod, *Orchestia chiliensis*, living on the drift and refuse, collecting among and on the stones.

Below and reaching a maximum at about  $9\frac{1}{2}$  hours exposure, is the worm, *Spio* (n. sp.) This worm reaches a density of about 300 per square metre. It lives in semipermanent burrows, which, while running largely separately, anastomose in places. The burrows themselves are lined with a rust coloured material which seems to hold the walls in place. This animal makes burrows about 2 - 3 feet deep. It avoids the softer mud, and is thickest in the solid, blue compressed sand. It migrates downwards as the tide retreats and rises as the tide comes in. Thus in a square foot dug to a depth of one foot at various stages of the tide the following results were obtained:-

State of Tide	Right Out	Right in	Coming in but not quite up to area.
Number of worms found	6	23	11

It was necessary to dig rapidly as the animals are very sensitive to vibration and will go "to earth" at the least disturbance of the substratum. This worm is very similar in habits to *Scolecopides benhami* except that the latter does not seem to be confined to such solid areas. These worms extend down to about 6 hours exposure. In the Estuary they seem to

occur wherever the conditions are muddy and there is a stiffening of sand.

As the tide goes out the Banded Dotterels (*Arrepidasmus bicinctus*) can often be seen in flocks of ten or twelve slowly making their way over the mud flats just as it is exposed. They peck down at intervals and very likely seize these worms. This would account for the sensitiveness of the latter to any disturbance at the surface.

The holes of some of the worms are shown in Plate 20.

At about 8 hour exposure, a crab, *Helice crassa*, becomes quite common, and extends down to about 5 hours exposure. It occurs all over the Estuary in places where the substratum is reasonably solid and not too sandy, within this range, (Plate 21 and 22), but its greatest work is seen in the banks which line the Estuary, and in the salt reed swamps beyond. The latter belongs to a different association but the former may be considered here.

At low tide these sandy clay banks appear riddled with holes (Plate 24.) In places the honeycombing is so complete that the bank has fallen away, while in one place a stone wall has been built out to protect it from the ravages of this animal. But in spite of the glaring evidence of their handiwork there is scarcely a crab to be seen; in fact, unless one approaches very carefully he will find the bank bare. Even when a piece of bank is torn down few will be found, though the bank is riddled from top to bottom.

The animal appears to retire to the lower levels as the water flows out. Many of the burrows intercommunicate so that when one hole is being explored the occupant moves on but does not fly out into the open except as a last resort.

The actual burrows themselves contain an assortment of rubbish, straws and even feathers. Much of this rubbish is undoubtedly carried in by the tide, but I have seen crabs in the act of carrying straws into the warrens. Quite often the deepest part of the warren slopes down, so holding from half to two and a half inches of water, at low tide. Another peculiar thing about these warrens is that at the end of a large hole in which is a large female, there is sometimes a small hole in which is a small male. This I have found sixteen times so that it would seem to be more than mere coincidence. It probably has something to do with the breeding habits.

The scarcity of these crabs about the warrens suggested that they were nocturnal in habit. To test this a number of observations were carried out in the field and in the laboratory. In the former case it was found that after a long watch, in some cases about two hours, but usually about fifteen minutes, some crabs appeared, very stealthily. Particularly was this so when the weather was warm and sunny. Their mode of coming out seemed rather peculiar. First one or two small animals would creep out in little bursts of speed, with pauses between. Quite a time after, one or two mature individuals appeared half out of the burrows and remained there, motionless. Then they would



disappear into the burrows only to reappear to be followed by several others. It would seem that the older ones have "learned by experience" or perhaps that the more cautious ones have survived. It would seem, then that crabs come out of these warrens during the day, but are exceedingly timid and have fair powers of vision.

For closer observation some were kept in a glass vessel, half filled with salt water which was changed fairly often. It was found best to keep the water in a separate vessel sunk into the mud, and to saturate the mud with salt water.

For the first day they refused to burrow at all. Next morning they had made a fair beginning. The two most likely explanations were that:-

They only work at night, or

They only work when there is no movement around them. After several hours watching they had made only small shallow burrows, just to a level with the top of the carapace. By pulling down the blind the room was made dark and in a few minutes the whole "family" were moving slowly about, and were soon at work hollowing out their pits. By means of an electric torch I was able to watch most of the processes by which the pits are dug. The procedure varies considerably according to the hardness of the ground, the depth to which the pit has sunk and several other factors.

To begin with the last two joints of the third, fourth and fifth walking legs are thrust into the mud and held rigidly

there for a few moments. Then by a combined shoving of the first and second legs of one side and a pulling of the legs on the opposite side the crab pulls away a piece of mud. This process is repeated two or three times. Next the animal sinks down in the depression it has made, and pushes against the anterior side of this depression with the outer side of the hand. It then pulls itself forward, depresses the posterior part of the carapace, and pushes back. By repetition of this process, the crab sinks in the mud till it is just visible. Then it repeats the first motion with the third fourth and fifth pairs of legs. Now the crab concentrates on work on either the right or left side, and as soon as it begins to get below the surface it uses a slow, paring motion with the lower hand. It must be realised that all these motions are extremely slow. The rapid scuttle for safety is one of the few times when this animal moves quickly. The flat broad palm is an excellent grubber. For a time the pieces of mud so loosened, are removed in much the same manner as that described for step one; but once the holes become deeper it is necessary to push it up ahead. This is done by the uppermost hand assisted by the second and sometimes by the third pair of legs. Each little piece of mud is laboriously pushed up the tube and rolled clear of the mouth. Just to see what the animal would do, the observation tank was tilted so that each piece as it was pushed out rolled back again. This happened four times, (about fifty minutes). Then it deliberately set about pushing back its mound of earth. If a small stone

be rolled into the burrow it will be repeatedly removed. If water is added, the process is accelerated. Now the mud is brought up adhering to the first leg by which it was excavated; and it is scraped off at the surface by the other limbs.

Most of the burrows have a narrow neck about half an inch from the surface after which they widen out. The mouth of a burrow is shown in Plate 21.

It is not known whether each crab has its own burrow. I am inclined to think not. By marking crabs I found:-

(1) When alarmed they fled to the nearest burrow, regardless of whose it was, and sometimes tried to force their way into a burrow which was much too small.

(2) When not alarmed they usually return to the same burrow but often two use the same burrow.

I am by no means certain of the food of these animals. Thus a piece of carrot put in was thoroughly attacked for a time. In this case the tip of the chelipede was run over the tip of the carrot and applied to the mouth at frequent intervals. When a piece of *Chione stutchburyi* was put in, the process was rather different. The soft part was seized between the two hands and slowly torn into shreds. The shred was then raised to the mouth with the left hand, and the third maxillipedes pressed lightly against it, perhaps for taste but more likely to brush off sand particles.

After a time the shred was pulled out of the mouth and then again raised, and the process repeated. To view the process I

used a small mirror as otherwise it was impossible to see the under side of the crab. They are reported as eating flies but I have no record of this. So far I have been unable to identify any of the material from the digestive tract, though care was taken to see if any remnants of flies legs or wings were present. The material seemed to be a mixture of vegetable and animal matter.

When watched in the field they will be seen to pick up microscopic objects from the mud with the hand, and apply it to the mouth. Examination of the gut showed very numerous small round bodies, perhaps unicellular algae, which were too constantly present to be the result of chance. These animals feed while the tide is out, and retreat to their burrows on the return of the tide. On a hot sunny day, if all is still, the little specks of light, which are the shining backs of these animals, can be seen hurrying busily about.

An interesting adaptation of the third maxillipede is shown in this crab. The terminal joint of this appendage is long and has a number of extremely long hairs. When this crab is out of the water it will be observed to swing these third maxillipedes back and out, turn the outer three joints out and then reverse the whole process. At the same time the eyes are lowered so that the terminal hairs sweep the eyes, with a brush like motion. These motions are not regular but are repeated at irregular intervals. Sometimes both sides move

together; quite often separately. Very occasionally the motion is carried out under water but it is then never so complete nor is the eye depressed to meet it. My first idea was that it was a cleaning process, and to try this out some mud was put on the eyes, but there was no response. Then I observed the same crab -

1. In water  
very rare and incomplete response.
2. In damp tubes.  
not very frequent motions
3. In hot dry tubes  
much more frequent motions.

It seems that the chief function of this motion is the moistening of the eye which would become dry out of the water. A crab from which these terminal parts were removed and which was kept in a dry tube for some time appeared to have its power of sight impaired.

The power of vision of these animals is good. They are sensitive to a shadow or large object at any distance inside 16 feet. But they did not show any sign of seeing a small object, such as a pencil at a greater distance than two or three inches.

If this crab is disturbed by a large shadow at some distance it will scuttle for its hole; but if suddenly disturbed away from its hole, by a closed object, it either remains rigidly still, or crouches down, showing only the slaty grey back and upper portions of the legs which match the mud perfectly. In their natural surroundings they move more or less together, one moment all is still, next moment they are all on the move; next moment

all is still again. This may be quite an efficient protection, for the simultaneous movement tends to distract the attention of the observer from any particular individual, so allowing it to sink into stillness and the mud without the observer being sure exactly where it has gone. That considerable protection is needed is shown by the fact that the birds of the Estuary, both the gulls and the kingfisher (*Sauropates sanctus forsteri*) prey on it regularly.

The remains of this crab from a Kingfisher are shown in Plate 23.

This crab affords rather a good example of Ecological succession. As it begins to mine into a bank it at first makes it more and more suitable for its own use. Soon however, the bank begins to crumble away and leave but the broken ends of galleries jutting out from the beach. Such a state of affairs is illustrated in Plates 24 and 25. It is then abandoned by the crab. If the jagged surface is polished down by the sea and sand brought in, it will again form a home for *Helice*, now burrowing in the flat where once it burrowed into the bank.

The megalopa stage of this crab is common on the upper part of the flat at the end of February and the beginning of March. By the end of March the small, transparent forms have largely given place to minute pigmented crabs, each with a tiny hole of its own. (See Plate 22).

At about  $7\frac{3}{4}$  hours exposure *Amphibola crenata* starts to

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appear, and increases rapidly so that it has reached its maximum at  $7\frac{1}{2}$  hours exposure (Plate 26). From there on its numbers drop rapidly, till it practically disappears at about  $3\frac{1}{2}$  hours exposure. The rapidity with which its numbers rise and fall is shown in the following figures:-

Metres down from Peg.	Number of Amphibola per 20 square metres.
1	0
2	0
3	0
4	0
5	0
6	3
7	14
8	19
9	16
10	18
11	22
12	21
13	23
14	14
15	47
16	129
17	222
18	360
19	368
20	369
21	447
22	354
23	382
24	326
25	295
26	269
27	213
28	203
29	176
30	147

N.B. To obtain usable readings, it was found that 20 square metres in a line at right angles to the slope of the beach, was the minimum.

Thus for a few square metres the results ran:-

Metres Across

	Place	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
res	10	3	5	1	0	0	5	4	5	7	2	1	2	2	6	1	1	0	0	0	0
1	11	11	3	10	13	12	9	7	12	11	12	4	3	7	4	1	0	0	0	0	0
a	12	14	11	6	9	20	11	18	20	18	15	21	17	12	12	11	7	0	0	0	0
	13	3	3	2	1	10	16	22	32	35	26	14	17	27	23	20	22	21	30	21	15

Even with this area, it was found necessary to correct the figures by sampling at different times in the same area. The complete set of figures for all the gastropods for each square metre of this 20 x 200 metre patch was taken, in an effort to correlate the irregular distribution with some factor, but so far these results have been unproductive. A rather interesting case is that of a sandy spot on the other side of the Estuary, Here the usual point of maximum distribution of *Amphibola* is bare of this animal, which appears in scattered groups at the bottom of its usual range - *Monodonta corrossa*, in the same locality reaches the greatest density I have yet recorded - 1668 per square metre.

*Amphibola* seems to have a large salinity range, thriving in water with a chlorine content of 10 to 19 units wherever there



flat muddy slopes above half tide, 10 units of chlorine appear to be its usual lower limit.

The anatomy and general habits of this animal are quite fully discussed by Farnie (1919). There she records finding only mud with diatoms in the gut, which agrees with my own observation. The commonest diatom was *Mavicula*. As diatoms do not appear to be common in the mud, it is not surprising that enormous quantities of mud are passed through the gut. I have measured seven yards of mud, ejected during a single tide.

The following table summarises a series of results of experiments carried out with the idea of determining whether the common predatory animals would eat *Amphibola* when the shell was broken. In each case the *Amphibola* was left where the animal would find it, and careful watch kept. With the crabs it was not so difficult, as it was usually but a matter of keeping quiet and still. But with the birds I found it practically useless to keep closer than about two hundred yards. With each *Amphibola* a pipi shell was left and by this means it could be seen whether contamination or natural suspicion caused rejection and whether the animal was ready to eat; for if one were taken and the other left it seemed natural to suppose that this showed preference for one and dislike for the other. At the same time it gave some indication of the attitude of the animals towards pipi food.

Animal	No. of Ex- periments.	Amphibola Taken.	Rejected	Pipi Taken	rej.	No. Result.
<u>CRABS</u>						
Helice crassa	26		9	2	7	8
Cyclograpsus lavauxi	8	1	3	2	2	4
Hemiplax hertipes	12	2	5	3	4	5
Heterograpsus crenulatus	14	3	3	4	2	8
<u>BIRDS</u>						
Black-backed Gull	6	-	4	3	1	2
Black-beaked Gull	7	1	3	4	-	3
Sea Swallow	3	-	2	1	1	1
<u>Total</u>	76	7	29	19	17	31

In the majority of cases the number of experiments was not enough to give more than a rough idea, It will be observed that over half of the tests (31 out of 76) returned no result. That is to say that, during the time of observation, the animal would not approach the test sample. The proportion of these has no significance.

Of the 36 cases where a result was observed, it will be seen that for Amphibola, 6 crabs took it but 20 rejected it, and for birds the ratio is one to five and the one case recorded as "taken" was merely pecked at, perhaps out of curiosity, rather

than a desire for food, The total gives 7 taken for 29 rejected.

With the pipi the results are quite the other way, Here the ratio for crabs is 11:15, while for birds it is 8:2 making a total of 19: 17,. When it is considered that the animals would probably be suspicious, and whatever care is taken, the making of observations always disturbs animals, and that the time allowed, although sometimes as long as two hours, was strictly limited, the results for crabs seems to point to the fact that the pipi is a more or less acceptable food to at least *Hemigrapsus crenulatus*, and possibly *Hemiplax hertipes*.

With the birds there is no doubt that it forms a satisfactory meal.

To sum up it might be supposed that, *Amphibola crenata*, being usually enclosed in a hard thick shell, does not form a very important article of food for the ordinary predatory animals of the Estuary.

After I had come to the above conclusions, I found some bushes, quite a distance from the Estuary, behind which were a large number of *Amphibola* shells. The area is usually frequented by the Black-backed Gull, so that it seems that sometimes, at least, it does add *Amphibola* to its diet; but this must <sup>be</sup> only at certain times, as all the shells were old, though the birds still frequent this locality. Possibly they represent a period of food scarcity.

But while the animal is moderately safe from the swift

preying animals, it has two important enemies. The first of these is the scavenger of the Estuary, *Cominella lurida*. I have found this animal crowded in large numbers over shells of *Amphibola*. The largest number that I have observed in the case of *Amphibola* is 83, but the usual number is between 20 and 40. For some time I was not sure whether *Cominella* attacked the live animals or merely feasted on the dead ones. While the latter does occur, I have found crowds of *Cominella* grouped round live shells, apparently waiting for them to open up. In one case I found the long proboscis of *Cominella* thrust in behind the horny operculum of a live *Amphibola*.

*Amphibola* apparently harbours a parasitic worm, as the oviduct is often recorded as distended with eggs of a parasitic Trematode. Farnie states "I have found these several times, and in some animals they are so numerous on the right side in the muscular region of the body between the rectum and the genital duct that both the rectum and the genital duct are hidden from view."

*Amphibola*, though a pulmonate, can withstand complete submersion for a considerable period. Thus Hutton states that he kept them completely immersed for a week while Farnie states, "If kept in a glass of fresh water the cover of which is sealed up, it will live for a week, if completely immersed in fresh water but not so sealed, it will last for a fortnight; if completely immersed in sea water it will last for a month; but if left without water at all it does not live more than a day." The time

the animal will live in a closed vessel depends, as would be expected, on the size of the vessel. In all cases where I have tried these experiments, the animal died in about three weeks. Perhaps the disagreement of these two results is due to the fact that I used Estuary water which would have a smaller Oxygen content.


Where the animal lives on the mud, even at low tide, it is kept quite damp. It is however exposed to the sun for considerable periods, and might be expected to suffer from its rays. Its grey colour which would minimise absorption, and the thick shell are adaptations which meet these conditions.

Sometimes the animal burries itself in the mud but for what purpose is uncertain.

Its flat circular foot is splendidly adapted to facilitate movement over the soft mud. With *Amphibola* the great factor of existence is the presence of inter-tidal mud, free from *Zostera*. Thus, though it can tolerate vast changes in the salinity, and and occurs in large numbers over quarter of the tidal belt, it is very sensitive to change in substratum. Attempts to introduce it into rock pools and sandy beaches have proved futile. This state of affairs is to be explained in the light of the remarks on its food; but what is more difficult to explain is its absence in *Zostera* beds. It will occur right up to the beds and even into the outer fringe, but will go no further although there is apparently no change in the soil. An attempt

to introduce 73 animals into the *Zostera* beds proved futile. At the end of eight days but two individuals could be found. A possible explanation is that the matted roots of the *Zostera* make it impossible for the *Amphibola* to pass the large amounts of soil through its body that it requires. Perhaps the diatoms cannot thrive when they are covered with the thick mat of *Zostera*, thus leaving the ground barren of food for the *Amphibols*. A search for diatoms in this locality provided only negative results. The breeding habits of this animal are fully described by Farnie.

Beginning at  $7\frac{3}{4}$  hours exposure is another surface gastropod, *Monodonta corrosa*. It reaches its maximum at about 4 hours exposure and in some localities, especially where there is more sand, it may reach a density of population of 80 per square metre. It has the low spired character so well shown in *Amphibola* and here it may serve the same function as that in *Amphibola*, namely that of minimising the chance of being upset by the waves and ripples. The sculpture and external pigment is usually badly corroded (Plate 27).

It is worthy of note that on rocks and other pieces of macrolithic substratum, where a firm footing can be found, the same species occurs, but is usually much larger and higher in the spire. Two sub-species of this species occur. *M. corrosa plumbia* and *M. corrosa undulata*, but they differ only in minute details and as far as I can see, have the same habits and relations. As *Monodonta* moves over the mud it leaves a track with a centre line as  . When observed feeding in the

aquarium it is seem to swing left and right and back again. Like *Amphibola* it feeds and moves chiefly when the tide is up.

Another common surface gastropod is *Cominella lurida*. This animal has a range from 7 to 4 hours exposure and differs from the proceeding two in that it is carnivorous and a scavenger. It has large flat foot and an exceedingly long protrusible proboscis. The shell is long and tapering, in striking contrast to that of *Amphibola*, and this fact can be correlated with the difference in habits of the two forms. *Amphibola* is a slow moving animal while *C. lurida* is a rapid moving gastropod and would require to offer the minimum of resistance to the water. In fact the shell is stream lined. The very broad flat foot prevents the animal from sinking into the mud and being smothered or being toppled over by the ripples at high tide.

The outer surface of the shell is usually completely corroded, often resulting in the obliteration of the sculpture, and producing a shell similarly coloured to that of *Amphibola*, (probably serving the same function). The inside of the shell is deep reddish blue, the mantle black.

*Cominella* has a long groove in its shell and it is due to this that it has to keep to the damper parts of this area during low water. Sometimes it partly buries itself.

*Cominella* will eat any animal refuse. In its search for food it is apparently directed by smell. Thus I once saw a number of these animals heading for a dead crab, which from the nature of the ground must have been out of sight. They were

approaching from different directions at distances varying from 3 to 8 inches. It does not seem to have good powers of sight and is not very sensitive to shadows.

On the surface gastropods there is a large number of small *Acmea* forms all showing great variation in colour and shape but all belonging to the one species, *Notoacmea helmsi*. The large forms of this shell occur on rocks and it is quite possible that dispersal over the otherwise impassable mud is secured by thus attaching themselves to these moving gastropods.

This type of habitat group is quite constant throughout New Zealand. In the northern districts it is often replaced by a mangrove growth with these forms still present under somewhat similar conditions; but even here there is a large amount of open mud flats hardly distinguishable from those described, either in species present or in habit.

Hedley (1915) reports a rather similar state of affairs from Sydney.

On the whole this type of community is more dependent on the climate than the open sandy beach; but within a fairly wide climatic belt seems to depend almost entirely on the presence of a more or less land-locked area for its existence.

The common lug worm, *Arenicola assimilis* var. *affinis* is common from 6 to 4 hours exposure. Its habits do not differ noticeably from those described for European forms. Animals taken from here were uncomfortable in pure sea water but soon settled



down. In water from Low Tide at this point they soon died. This may explain their vertical distribution.

*Nephtys macrura* is quite common from five hours exposure down to low water while *Glycera ovigera* becomes common at about two hours exposure, particularly where there is a fairly solid bank.

At about 6 hours exposure the two bivalves, *Chione stutchburyi* and *Tellina deltoidalis* begin to appear.

The distribution of *Chione* in the tidal belt is shown in the summary graph (Fig. 19). It increases right down to low water, the apparent irregularity in the curve at  $3\frac{3}{4}$  hours exposure being probably due to the change in slope and nature of the substratum at this point. It does not extend far below low water, but I have not examined its actual distribution in this region. It occurs from right out on ocean beaches where (there is some shelter) to well past Heathcote Bridge thus having a high water range of 19 - 11 units (C) The low water range is much greater, varying from 19 to .6 units. Just to what salinity change the animal is exposed is uncertain in high parts of the Estuary, as here the animal always closes its shell at low water, while those higher up in the tide may still be open, bathed in the water of higher salinity left by the receding tide. At Monks' Bay, they seem to stay open as long as the water is over them. Experimentally I found that this animal remained open in water of a salinity of not less than 8 units. Within this range, considerable alteration in the general appearance of the shell

can be noticed. Shells from the Estuarine mud are noticeably corroded over the upper half (Plates 28 and 29). Again the size falls, as is shown in the following series of observations made in March.

Locality	Average length over a 100 specimens
Sumner	42 mm.
Just inside Shag Rock	31 "
Mount Pleasant	24 "
Heathcote Bridge	25 "

A somewhat similar result is obtained for the ratio.

Total Breadth of 100 Specimens.

Total Length of 100 Specimens.

Locality	Value of Ratio
Sumner	.90
Just Inside Shag Rock	.8880
Between Rock House Point and Mount Pleasant	.8460
Mount Pleasant	.8550
Heathcote Bridge	.8500

The second table shows a relative lengthening of the shell in the Estuary. It should be pointed out that what seems to be true for the average is not true for the individual which shows a wide variation for this ratio.

Another feature of Estur<sup>a</sup>ine Chione is the extreme thinness of the shell. It can often be broken with a tap of the finger. The large beds of old shell would seem sufficient to keep up the supply of lime, and it is noteworthy that this thinness of shell is more obvious in older specimens and hardly noticeable in the smaller forms below 20 m.m. in length.

Another feature of Esturine Chione are the burrows of a small polychaete (unidentified) which are very characteristic in appearance, and occur on fully 60 per cent of the larger shells. (Plate 28).

What I take to be growth and disturbance rings are shown but not as definitely as was found by Orton (1926) for *Cardium edule*. Motile sperms were present in most of the larger specimens at the end of February and the beginning of March, but various small points make me think that the spawning season is rather extended. The graph of size against numbers (Fig 16) was made on 1st March 1929; but in the light of Orton's work on the way in which one year group "over rides" the end of the previous years group, I am not prepared to give any interpretation of these figures, till I have worked out my other results.

As regards enemies, the birds seem to find it a very

palatable dish. The crabs attack it, while with *Cominella lurida* it is a favourite food. In one case I counted 167 of these scavengers on a single *Chione*. *Cercaria pectinata* (Chilton 1905) is present in the Sporocyst stage in November, but not more than 1 per cent of infection is present. The polychaete, burrowing in the shell may weaken the shell. The birds seem to be the most powerful enemy; but a double commensalism affords some measure of protection.

The first of these is an epizonic anemone. This anemone *Bunodes aureoradiata*, occurs all over the muddy parts of the Estuary, but it requires a solid substance on which to fix its column. Almost every piece of wood every stone half covered with mud, supports a colony of these animals. Dead shells, rock pools, and even tins are studded with them. They are brown grey with a row of tentacles, When the tide is out they retract their tentacles into their column, but on the return of the tide they again show them.

An interesting light is thrown on the life factors of the anemone by a person who for many years lived in the neighbourhood. In talking of Monks Bay he said. "This beach used to be sandy and free from anemones, but as the mud came the anemones began to appear."

But the complications of the life of this anemone are not completed with its attachment to the *Chione*. In the tissues of this animal are symbiotic algae (Stuckey 1908) which assist it in procuring oxygen in return for food and shelter. It is probably

due to this factor that this animal is able to go so far up the Oxygen-poor Estuary, when all others of this group seem to be confined to fairly well oxygenated water.

The other commensal on Chione is a weed, *Scythothamnus australis*. This plant grows on practically any solid substance in the muddier and fresher parts of the Estuary, and even on *Amphibola*.

*Tellina delfordalis* does not increase regularly down to low water, but reaches a maximum at about  $3\frac{3}{4}$  hours exposure where it has a density of 180 per square metre. From there down it drops very suddenly and then continues to fall to low water. It should be noted that this very sudden break in the curve coincides with that in the curve for *Chione* and indicates the position of the change in slope and substratum (see summary Graph - Fig. 19). *Tellina* does not stand vertically but horizontally in the substratum. The valves of the shell are slightly asymmetrical, the end where the siphon comes out being formed into a groove in the upper valve. The siphon comes out and then turns through a right angle up through the two inches of mud to the surface. The general position of the shell is illustrated in Plate 31. This position which would require fair stability of substratum and reduce the burrowing power of the animal would account for the numerical fall as the looser material of the 3 hours exposure mark is reached.

In the Estuary this shell is confined to the narrow triangle between lines drawn from Rock House Point to Pleasant Point, and

from there to a little beyond Mount Pleasant.

These shells are but little corroded, but show a definite dark staining which is only found in <sup>a</sup>Estuarine forms of this species and is perhaps due to sulphur bacteria.

A size-numbers graph, made in March is shown in Fig. 18. From this graph it would appear that three definite year periods are represented, at about, 7, 23 and 34 m.m. respectively. If these are year periods, the curves are exceedingly irregular, and either the growth rate must vary greatly from year to year, or several year periods must be entirely absent; an examination by the methods of Orton (1926), though more difficult than with *Cardium*, might be possible and would settle the matter.

One thing the curve seems to support and that is a doubtful observation of motile sperms in January, for if that is the end of the breeding season, no small shells would be observed in March, which is what the graph shows.

Examination of the food tract showed in Spring, sandy rubbish and diatoms, while in Winter, little but sand, organic debris and rubbish were observed.

The chief enemies are the gulls which often peck off the log siphons. In addition the crabs, *Hemiplax hertipes*, and *Hemigrapsus crenulatus* are of importance, especially as a source of mortality among the smaller individuals.

The crab, *Hemigrapsus crenulatus*, lives in muddy places under stones from high tide to low water, and occurs practically

throughout the Estuary. It is found far up the Avon and Heathcote Rivers at a high water salinity of 8 units but here it is small and apparently lives on the small shell, *Potamopyrgus antipodum*, as I have found fragments of this shell on the hand and mouth parts. In the other direction it can be found but in coastal pools and under stones at Shag Rock, in situations, typical of the ordinary rock shore crabs. Such a range is unique in New Zealand crabs and probably not surpassed in any group of animals. It is of an ochreous shade with deep green brown blotches and a large number of reddish-brown spots on the carapace, and part of the limbs. The outer surface of the hand is a deep yellowish cream, and inside there is generally a dense tuft of hair, covering part of the finger and hand. The anterior border of the second third, fourth and fifth legs has a thick double row of amber coloured hairs, while the inside border of the last two of these is similarly provided. The pad on the inside of the hand does not appear in immature males and only slightly in mature females and may be a sexual character or perhaps of use in copulation. All these hairs and even the pads may help to keep mud out of the gills; but when it is combined with the flattened nature of the limbs and the horizontal movement of the last two pairs, and even the third pair, it is probably more specially directed towards preventing sinking in the mud and to render progress across the soft mud more easy (Plate 32). A comparison of the gait of this crab in muddy places with that of rock crabs brought in for the test seemed to show that

there was more in favour of *Hemigrapsus crenulatus* than mere familiarity with muddy conditions.

These same hairs are typical of *Hemiplax hirtipes* found in the same locality and burrowing in the mud. It is probably this character which has allowed these two crabs to thrive where *Hemigrapsus sexdentatus* and even *Helice crassa* have failed to establish themselves.

There is a relatively large difference in the sizes of the sexes. The largest male I have collected is 30 mm. long by 35 mm broad, while my largest female is 20 by 22mm. Chilton and Bennett (1928) quote the same state of affairs. When I have taken these animals in copula, the male has always been a large specimen while the female was always comparatively small. The female has always much smaller hands, less markedly toothed.

I have a series of females with abdomens varying from almost the narrow one of the male to the exceedingly large one of the female. This development seems to coincide with progress towards sexual maturity, females with eggs invariably having the large broad abdomen. It is by means of this and the appendages of the abdomen that the eggs are kept in place. One female with eggs which I watched walking on mud, carried herself much higher off the mud than is usually the case, perhaps to prevent injury to the eggs. The eggs are about .18 mm. in diameter.

This crab is preyed on by the gulls and the Smooth Hound (*Mustelus antarcticus*). I have often taken 20 - 30 specimens of this crab and of *Hemiplax hirtipes* from the gut of this fish.

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Just inside Shag Rock, occurs another crab of somewhat similar habits. This is *Cancer novae zealandiae*, and is very similar to the English edible crab of the same genus. As a large number of eggs of the latter had been liberated at Portobello (Dunedin) from which the northerly currents would bring them up in this direction (?), I was rather doubtful if this were our native species or the English form. The specimens I obtained agreed well with some identified by Chilton and Bennet as *C. novae zealandiae*.

These crabs move about when covered by the water and seem to feed on shell fish and worms, portions of which I have found in their stomachs. Probably other marine animals are devoured but I have not been able to identify their remains. At low water they almost bury themselves at the base of a rock in the soft mud. There they lie hidden with their eyes, upper margin of the carapace, and the top of their maxillipedes above the surface. These large flat maxillipedes are well fitted to keep mud out of the mouth.

In the same area as that in which *Cancer* is found but rather above the *Chione* beds, is a small crab which does not burrow. This is *Hymenicus pubescens*. This animal as the name implies, is strongly pubescent, and this hairiness is especially marked over the dorsal surface. It possesses a flatish body and long spidery legs. In its natural surroundings it does not move quickly when disturbed as do so many crabs. Even in ordinary life it moves with a slow deliberation which may easily go unobserved. It is a grey colour and its hairy body picks up

a little mud so that it looks like a blob of that material. With such a disguise, rapidity of motion would be a disadvantage. The slow deliberate mode of progress is well calculated to maintain the deception.

Another crab *Hemiplax hertipes*, very occasionally occurs low down in the Estuary. It is rarely found above half tide, and is confined to the soft sticky mud and to the water channels and the very sloppy parts of the Estuary. It does not go far up the river and is, in fact, rather restricted in its distribution.

This crab is much broader than long, the ratio factor being about 1.56. The carapace is slaty grey, speckled with black. The last three pairs of legs have the same thick bands of amber coloured hairs on the outer margin as was noted for *Hemigrapsus crenulatus*. They have the practically horizontal movements and thickened joints noted there. The second leg alone is almost devoid of hair and it differs too, in that it has a more vertical movement, though this is not completely so. The first pair of legs differ in the two sexes. In the female the hand is relatively small with the fingers making a very obtuse angle with the hand. In the mature male the palm is very large, being half as long or more than the greatest carapace width; while the fingers are about .7 of the length of the palm. The angle made between the slope of the fingers and the palm seems to alter as the animal becomes mature. The following series of 7 individuals would seem to show this.

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<u>Width of Carapace.</u>	<u>Angle between Palm and fixed Finger</u>	<u>Width of Carapace. Length of Hand.</u>	<u>Length of Hand Length of Fixed Finger.</u>
31mm.	113%	1.724	1.385
30.5 mm.	121%	1.7	1.286
28 mm.	120%	1.807	1.477
22 mm.	132%	2.44	1.125
22 mm.	140%	2.44	1.125
20.5 mm	134%	2.278	1.2
19.8 mm.	140%	1.98	1.357

The above facts are of interest because the identity of the animal is largely dependent on the relative size and shape of the hand. There were originally two supposedly different animals named by the same name by Jacq. and Lucas, and Heller respectively. The distinction was dependent on the shape and size of the hand. Chilton and Bennet (1928) have united these supposedly different species, assuming that the differences mentioned are but differences in growth stages. The above series, while far too short to base a decision upon, seem to support this conclusion. The underside of the animal is white to pinkish cream, a marked contrast to the dull upper surface. When the animal is disturbed it may settle into the mud. If it cannot do this it will rear back till the dorsal surface of the carapace almost touches the mud. In so doing it suddenly flashes from dull grey to white and the effect is quite startling. In this position it spreads the

hands out in a "terrifying attitude," the whole effect being to give an intruder a start. It is quite possible that this terrifying attitude is a means of protection from other animals. Another possible reason for the posture is that the downcurved hands can be used for attack or defence towards the upper surface, only by assuming this position (Plate 33).

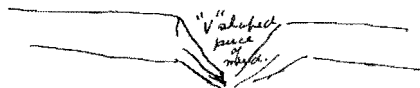
The eyes are prominent and on very long stalks. It is not uncommon to find the animal with the carapace on a level with the mud and the two eyes turned almost vertically upwards. If alarmed it will depress them and then raise them or perhaps only one. The prominent spine at the anterior lateral margin of the carapace may serve as a protection for the eyes.

The possible use of the hairs on the limbs, and the horizontally moving legs have already been mentioned.

This animal burrows quite freely, but its burrows (Plate 34) are quite different from those of *Helice crassa*. Once an observer is acquainted with this animal, he can readily identify its handiwork. The methods of work of this crab were observed in the laboratory and in the field. The process may be divided into the following steps.

1. The crab either carries out a motion similar to that described for the first motion for *Helice crassa*, or, more usually merely settles its body down into the mud with a shuffling backward and forward motion of the carapace.

2. The long hands are thrust far in under the ventral surface. The inside of the hands form a "V" shape as



Then the hands are drawn forward, the tips of the fingers being kept together. In this way a wedge shaped piece of mud is pushed out from under the crab.

3. Next the settling motion is repeated to be followed by a repetition of stage 2.

As the crab works only in muddy, water-saturated ground, I was unable to watch its progress more than  $\frac{1}{2}$  inch below the ground. As far as I could see it continued the same method down all the way. This idea is supported by the fact that all the holes that I have seen begin by a more or less muddy pool, and the crab was found at the back of this. The hole, while having no definite shape like that of *Helice crassa*, is very characteristic. One specimen in the laboratory burrowed a rather spiral hole, but this may have been due to an obstruction.

In the field I have seen the animal carrying off *Tellina*. In the laboratory it ate *Chione*, *Amphibola*, Worms and even broke a small piece of *Tellina deltoidalis*. All these may enter into its diet. Examination of the digestive tract provided no identifiable matter, nor was it expected that it would. The tearing to which all the food of crabs is subjected would make it unrecognisable.

I have twice found this animal in copula. In April I found several cases. The male lies on his back with the pointed

abdomen inserted under the flat broad abdomen of the female. The latter is curved over the dorsal surface of the male. The female lies on the ventral surface of the cephalothorax of the male. The female was completely enveloped in the long first limbs of the male, and the hairy inner sides of these appendages were tightly pressed against the dorsal surface of the female. In each case the female was much smaller than the male and the male had the greatly angulated hands. I have never found the smaller specimens in copula. In the beginning of June I found two more copulating pairs. In each case the pairs were lying out above the water (it was low tide) and it took a great deal of annoyance to get any response from the animals. One pair remained in this position for 18 minutes after I first observed them.

111b. Macrolithic Substratum, or Stable Beach Sub-formation.

(A) Community on Piles at Brighton Beach. Plates 35 and 36.

At low water *Mytilus canaliculus* occurs as small specimens up to 40 mm. They are almost covered with a sertularian. The whole being matted into a thick clump, fading into the sand below and *Modiolus ater* above. The latter at first closely covers the pile but gradually fades away into scattered groups and give way to *Elminius modestus* (a barnacle) at between high water spring and neap tide. There are three definite associations here.

(1) Low water to one third tide. Zone *Mytilus canaliculus* Association.

*Mytilus canaliculus* grows in thick clumps up to 6 or 8 inches in depth. The whole is bound together by byssal threads and contains some sand. The sertularian is confined to the outer end of the mussel probably on account of its food supply.

In the mixture is found the polychaete *Eulalia microphylla*. It is exceedingly plentiful and is found crawling over the mussels at low tide. Its deep green colour forms an excellent match to the mussels, probably protecting it from birds. In my experience it is almost always found on mussels.

In and among the shell and byssus, and even gliding over the mussels is a large black nermetine. I have seen specimens which stretched to fully 3 feet in length. When irritated it knots itself and even breaks itself into pieces. It is covered with a thick coating of slime.

(2) The third tide to High Water, neap tide Zone.

The *Modiolus ater* association.

This association is very dense for the first half of this area. I have some evidence that the barnacle association developed first and that it once stretched well down below the present limits of this association below the present limits of the mussel association in the presence of dead barnacles, below the mass of mussels. If this is so it affords an excellent example of succession in time.

(3) High water neap tide to spring tide Zone.

The *Elminius modestus* association.

This association is fairly thick. In addition to the dominant form are the Gastropods, *Litorina cincta*, *L. maritiana* and *Risellopsis varia*.

(B) Community on Rocks at Shag Rock. (Plate 37)

This area at the mouth of the Estuary, is formed by a spur of the main Banks Peninsula volcanic mass. Its rocks are hard black basalt, not friable and therefore suitable for the support of the barnacles. It is largely open to the surf and its salinity change is not great (See X 4 Fig. 12). It resembles the rocky coast far more closely than the Estuary.

The area divides naturally into ~~four~~ zones, separated by different dominant forms but most easily defined by tide levels.

(1) From the road to <sup>mean</sup> high tide-Zone.

*Litorina mauritiana* sub-association.

Here there is very little life of any sort. Two species of spider occur. Both are of the quick moving, hunting type, and show remarkably close resemblance to the black-grey background. Rather typical of protectively coloured animals as distinct from protectively shaped animals, they move in little spurts of speed followed by periods of stillness. They both make a rather irregular web among the rocks and one forms a tunnel shaped nest in exposed places.

*Litorina mauritiana*, the dominant form here, is quite different in habit. It apparently lives on lichens on the rocks, as there is little else here to live on. It is often found high up among



the weeds, and while it haunts the more sheltered side of the rocks during periods of bright sun light, it is very tolerant of dryness. Hedley describes a very similar condition in Sydney, and this group seems to hold a similar position in almost all parts of the world.

The fly, *Coelopa littoralis* is seen here all through the Summer and Autumn.

The small barnacle *Elminius modestus* is found here but is more often dead than alive, especially at the end of the Summer. It seems to be a mere stray from the region below.

This region, on account of its aridness and barrenness is not very productive of life. It is almost a vacant space between the truly marine and the truly terrestrial fauna. It is perhaps a barrier between the land and the sea.

(2) High water mark to 1/3 tide.

The *Elminius modestus* sub association.

In this region *Elminius modestus* is the commonest form. *Litorina mauritiana* is present in large numbers and with it is *L. cincta*. As the lower levels are reached the limpet form becomes more common. Among these may be mentioned *Helcioniscus ornatus*.

The only vegetation here is *Ulva* and an unidentified alga but the former seems to disappear in the winter. It provides shelter for a small mussel, *Modiolus ater*, quite common here. *Thais scobia albimarginata* is quite common here on and under rocks

and in sheltered places are occasional clumps of tube worms, *Vermilia carinifera*. These latter are but strays from the next zone. Many of the organisms characteristic of the next zone are common here in damp secluded places.

*Siphonaria obliquata* is quite common here. It seems to descend in the zone when about to deposit its eggs, which is done from about December to March. The eggs are laid in a thick gelatinous mass, thickly coiled on itself in the form of a snake coil.

The animals have to withstand not only the periodic drying, at low tide but also the force of the waves. The result is that all the shells are more or less solid. The tent like form is the normal form and often it is strengthened with ribs. This is well illustrated in *Siphonaria obliquata*.

In the debris at the bottom of this area, in among the small mussels, is the very dark green polychaete, *Eulalia microphylla*. Under stones at the bottom of this zone are occasional specimens of *Chilton quoyi*.

Crabs (*Petrolisthes elongatus* and *Hemigrapsus sexdentatus*) are common here only at high tide. These animals seem to perform a periodic motion up and down in phase with the tide.

(3) Half tide to  $\frac{1}{4}$  tide.

This zone is rather a set of small communities than a true community. In damp places between the rocks huge masses of the worm tubes, are found while the loose rocks harbour a multitude of crabs. Chief of these latter are *P. elongatus*, but *H. sexdentatus*

and *H. crenulatus* are quite common. *H. sexdentatus* may come here for shelter during the time the female carries the eggs, as in March and April by far the greater percentage of these animals were females with eggs.

A small Isopod, *Isocladus spiniger*, is quite common running about among the rocks. It is quite easy to miss it as its grey dorsum is an excellent match for the rocks.

A simple sertularian is common on the rocks in damp places. *Turbo smaragdus* and *Monodonta lugubris* like seclusion. The latter is never found out in the broad day light, but always under stones.

The Chitons, *C. pelliserpentis* and *C. quoyi* are common here, the former on top and the latter under stones. With this difference in the position may be correlated the larger and thicker girdle of *C. pelliserpentis*.

(4) Zone 4 -  $\frac{1}{4}$  to low tide.

This zone also has several associations. Chief of these are the *Mytilus magellanicus* and *M. canaliculus* Associations. The former shows great development on some of the outlying rocks, just at low water mark. Here they form such a dense mat as practically to shell the whole rock face. The difference of habitat of this form and *Modiolus ater* is well shown in this place. There each of these forms cover the rock densely, the one at low water, the other at half tide. In between these is an area comparatively free from fauna. Very definite growth bands are seen on the shell of *M. magellanicus*.

Such areas, covered with shells, afford protection for some weaker forms, but other forms tend to be crowded out. Thus where *Mytilus* is well established it soon crowds out *Elminius modestus* and *E. placatus* (which are replaced by *E. sinuatus* (?) on the shells themselves). *Siphonaria obliquata* and *Helcioniscus* are also crushed out, while motile forms such as worms and amphipods are more plentiful there than on the open rocks.

In some places where the rocks are well broken up a fair amount of small material has collected, and here worms can be found burrowing. The most noticeable one of these is *Glycera ovigera*. It is pale pink to white in colour with a very pointed anterior. It does not appear to make permanent burrows but seems to burrow in search of food.

Under stones is a rather interesting little polychaete, *Lepidonotus polychroma*. This animal has horny, dull grey elytra on its dorsal surface.

The short stumpy body of this animal fits into any nook in the rocks so that when a stone is overturned it may easily be missed. Another animal occupying the same position is *Leptoplana australis*. These are very abundant in rocky situations. Here it attaches itself to the under side of rocks and its colour so nearly matches the colour of the situation that it would pass unobserved if it were not for its movements. These movements are almost amoeboid and are accomplished with extraordinary changes in shape. In one specimen observed the ratio, Length/Breadth varied from .7 to 0.9. It swims freely in the water the movements being accomplished by a

kind of "flapping" movement of the lateral lobes.

The animal is sometimes found inside shells of Pelecypods where the mollusc, although alive seems unable to close its shell.

The animal is rather sensitive to change of salinity and will rupture if washed in fresh water.

A small protectively coloured amphipod is often found under these rocks, but I have not been able to identify it. It slides along on its side in a very curious manner.

Quite a common animal is a red nemertine. It occurs in clumps under stones. When irritated it protrudes a long pharynx which is exceedingly sticky.

The polychaete *Nereis amblyodonta* is quite common here and has more or less permanent burrows under the rocks, in the sandy debris.

Except for *Litorina*, this area shows almost all the forms seen in the other zones.

Besides the Crustacea mentioned, a small shrimp, *Beateus aequimanus* is sometimes found. It is reported as varying in colour from green to red and this could probably be correlated with the colour of the environment. It has a curious way of using its antennae, which are long and thick, to leap about on land.

Swimming in the open water and extending well up the Estuary, is the shrimp, *Palaemon affinis*. This animal is so transparent that it often escapes observation.

Down at low water there is some plant growth but this does not

reach the magnitude of the marine forests found on so many rock coasts, as for instance at Diamond Harbour. It seems that these large growths of seaweed will not develop in the presence of a large amount of fresh water. It is true that some of the smaller growths seem to be able to tolerate a fair admixture of fresh water but nearly all the prolific algae turn into a gelatinous mass if put into fresh water. This absence of these great algal growths more or less distinguishes the rocky area of the Estuary from that of the open shore.

In this area are rock pools. These support a variety of highly specialised forms of life. These conditions lead to specialisation of form and many of the animals in this position are rarely found elsewhere. What was said for mud pools with regard to salinity, temperature etc., applies equally for the rock pools and they should be classed as a separate group. Salinity readings for a rock pool of characteristic type gave 24.3 units of Chlorine, Klug (1924) who studied the Biota in Tide Pools came to the conclusion that the temperature was the deciding factor and salinity was not. It is desirable that further observations should be made to see if this generalisation holds.

The dominant form is usually a species of sea anemone. One very interesting form (*Oulactes plicatus*) has its column studded with small sucker like processes, to which pieces of shell adhere. Thus when the animal is closed up it appears to

be but a piece of shell sand. In April I observed this animal pouring clouds of white substance, presumably genital products, into the water.

Particles of shell fish placed over the animal were often stuffed into the column. After such a process the animal usually remained closed for a time.

Examination of the stomach showed it to contain amphipods and other minute crustaceous animals. In addition, there were very small protozoa.

The large sessile barnacle, *E. plicatus*, has not so far been mentioned as it does not seem to belong to any of the associations discussed. It occurs on exposed rocks from  $\frac{1}{4}$  to  $\frac{3}{4}$  tide in more or less branched clumps. Unlike *E. sinuatus*, it does not seem to protect itself by close growth. In fact the close growing type seems to be a form from which this animal departs more and more as it grows older. With the isolated, exposed position may be correlated the very solid, conical shape supported by ridges.

(C) Shag Rock to Monks Bay. A muddy transition area.

This area is a transition from clean surf rocks to muddy rocky area, just as on the other side of the channel, inside the Brighton Spit, there is a transition from clean surf beach to mud. This zone has largely been altered by artificial works and as a result the associations are ill defined.

(1) Low Water to  $\frac{1}{4}$  tide Zone.

This association, a cockle association, has been already described. Under and on rocks a rather different association is

met with. The chitons, *C. palliserpentis* and *C. quoyi* are common, as are also the crabs, *Petrolisthes elongatus*, *Cancer novae-zealandiae*, and *Hemigrapsus crenulatus*. A few mussels, *Mytilus canaliculus*, occur and here the pea-crab is still common. The crab lives within the mantle cavity of the mussel, and apparently depends on the respiratory current of its host for food. The mussel does not seem to mind its presence but will let it go in and out, when the touch of a straw would cause it to close. Its white colour and weak legs are the result of its sedentary, concealed mode of life, but its rounded angle-less form is well calculated to give the least possible annoyance to its host. The crab is not confined to this pelecypod but is found in all the common ones.

(2) Zone from  $\frac{1}{4}$  to  $\frac{1}{2}$  tide.

The only association is that of the worm tubes, already described for Shag Rock. A curious pulmonate, *Onchidella nigricans* is found here. This animal has a thick skin and secretes a thick coating of slime which no doubt serves the same function as the shell in ordinary mollusca. Anteriorly it has an orifice to its pulmonary chamber and when submerged it closes this aperture.

The barnacle *E. modestus* is common here and both here and below in muddy places are the gastropods, *Monodonta lugubris* and *Euthria littorina*.

In the mud in secluded places is a small grey and a black nemertine. The large polychaete, *Nereis amblyodonta*, is common here and the evidence of an accident is sometimes shown in a



curiously narrowed tail.

Among patches of *Modiolus ater* are found the characteristic polychaete, *Eulalia microphylla*.

From  $\frac{1}{2}$  tide up the area is similar to that at Shag Rock except that there are fewer individuals. The curiously flattened barnacle *Tetraclita purpurescens*, is found in sheltered places.

(D) The community of isolated portions of Macrolithic Substratum in Mud.

Rocks in mud form rather a definite association. Below are worms, *Thelepus plagiostoma*, a tube worm being one of the most noticeable. This animal is confined to the lower portions of the Estuary. Its tube has a membranous base to which are attached pieces of shell and odds and ends. The result is an admirable camouflaged, though from its position, it is doubtful if this is the function it serves.

Another worm from the same locality, but with a much simpler tube is *Nereis australis*. Other worms are *Scoloplos cylindrifer* and *Lumbriconereis sphaerocephala*. In addition are chitons in the lower portions of the Estuary, while small *Acmea* forms (*Notoacmea helmsi*) are common. On the upper side of the rocks are a few barnacle, *E. modestus*, and a large form of *Monodonta corrossa*.

The association is then divided into two fairly definite strata, one above and one below the rock.

Quite common under these rocks is the Amphipod, *Melita inaequistylis*. While quite different from the animal found at Shag Rock it has the same habit of sliding on its side. I think

that it lives on some small growths on the under sides of the rocks

Another member of this group is *Sphaeroma quoyana* (M.E.).

I have twice come across this animal,. I have found it burrowed into rocks<sup>to</sup> a depth of 2 to  $2\frac{1}{2}$  inches. At one time it was thought that it only inhabited the holes already bored by other animals (Dana) but it is practically certain that this is not so. In the case of the piece of sand stone the holes differed from those of *Barnea similis* in that they were bored in all directions and not only at right angles to the surface as is the case with *Barnea similis*. In addition each animal approximately fitted its burrow, a case not to be expected where the animals were merely using burrows already made. Again I know of no other animal, that will burrow into stone, that will go so far up an Estuary. The animal seems to be able to withstand a fair admixture of fresh water with the salt, the minimum salinity of the water in which I found it being about 10 gms per litre. I have also found it burrowing into wood and it seems to be able to rise as high as  $\frac{1}{4}$  tide in the littoral belt but no further. Once I kept an animal alive in salt water for 4 days. The hole in which it was working was cut back so that I could watch it at the face. The animal was working in wood. Once it was seen to move slowly from the face, keeping the posterior two appendages closely pressed against the wood so that a little wood dust was pushed out of the groove. This may be the regular use of these appendages. During this time (4 days) the animal bored about  $\frac{1}{16}$  inch. The animal was about  $\frac{1}{3}$  inch long.

Another borer, the Teredo, was found in a drift log. It was alive though it is the only time I have found it here.

Much of the wood, especially at the lower end of the Estuary showed some boring, which seems to me to be the work of the Gribble (*Limnoria lignorum*). I have failed to find the animal itself

#### 11.c. Other Considerations.

##### A. Birds of the Heathcote Estuary.

The general habits of the gulls were sketched in the account of the Brighton Beach. In the Estuary they add various worms, the siphons of bivalves, and offal to their diet. When several Black-backed Gulls are gathered together they hold quite a chorus of dismal cries, suggested of a native mourning ceremony.

An even more graceful bird is the White-fronted Tern (*Sterna striata striata*). It is rather swallow like when in flight, with long pointed wings and forked tail. When in good condition its breast is a beautiful shade of palest pink. This, however, usually fades in the mounted specimen. (Plate 40).

Although this animal is so showy in the air, it is comparatively inconspicuous when seen on the mud flats. This is partly due to the broken outline produced by the black head.

When a large number of them are feeding together there seems always some individuals who do not feed but are always ready to give the alarm if anyone approaches. Though not recorded as migrating it disappears from the Estuary about the beginning of May. It is an exceptionally fine diver. One gut examined contained crustacean remains.

The Banded Dotterel (*Cirrepidemus-bicinctus*) occurs in the Estuary, and its habits on the mud flats have already been noted (Plate 41).

During the summer months, two Shags are found at Shag Rock. These are the Black Shag (*Phalacrocorax carbo steadi*) and the Spotted Shag (*Stictocarbo punctatus*). The former seems to stay all the year but the latter disappears about May. They never seem to dive but can stay under water for a long time, the longest time I have noted for the Black Shag being 65 seconds. They rise from the water in a most ungraceful and laboured manner

(B) Fish of the Estuary.

During the work, a few facts relating to the habits of the fish found, were recorded.

*Mustelus antarcticus*, the Smooth Hound, comes up the Estuary with the tide and goes out as it ebbs. Examination of the digestive tract showed specimens of the crabs, *Hemigrapsus crenulatus*, and *Hemiplax hertipes*, in large numbers.

*Anguilla australis* occurs throughout the Estuary in muddy places. The specimens found are usually small, not exceeding 10 inches.

*Physiculus bachus*, the Red Cod, is common in the lower part of the Estuary and up as far as Mount Pleasant at the time of high tide. Examination of the digestive tract showed small flounders, seaperch, pipe-fish, sprats, crabs (*Cancer novae-zealandiae*, *Hemigrapsus crenulatus*, *H. sexdentatus*, *Hemiplax hertipes*) and worms.

*Rhombosolea plebia*, the Sand Flounder, comes into the Estuary from March to May. It does not go further up the Estuary than Rock House Point. Examination of the digestive tract, showed detritus, and portions of crustacea too disorganised for closer identification. In the gills is the parasitic isopod, *Livonica raynaudii*.

*Rhombosolea leporina*, the Yellow Belly, is well distributed in the Estuary. It goes well up the mouths of the river when the tide is high but retreats to below Rock House Point as the tide recedes. Gut contents, similar to those of *R. plebeia* were found.. Some habits and food notes of the young Yellow Belly have already been recorded.

*Agnostomus forsteri*, the Yellow-eyed Mullet, is quite common in the Estuary, and goes up the rivers. Its gut contained closely packed wads of *Ulva*.

*Pseudolabrus celidotus*, the Spotty, is common at and around Shag Rock. Its gut contained remains of bivalve (small *Mytilus*) and Gastropod mollusca.

#### (C) Erosion of Shells.

Erosion is one of the most typical features of Estuarine shells yet the cause of this erosion is not fully understood. Oliver states "Erosion in molluscan shells has been ascribed to acidity in the water by nearly all authors who have written on it. The following are the facts as I have observed them.

1. Forms within the Estuary are more eroded than those outside the Estuary.

2. The further up the Estuary the greater the extent of erosion.
3. Forms on sand are less eroded than forms on mud.
4. Forms completely buried show little erosion.
5. Forms partially buried show greatest erosion at about the surface line.
6. Forms with a membranous coat e.g. *Amphibola*, are better able to withstand erosion.
7. On the whole, areas of greatest erosion are those of lowest Ph, value, but to this rule there are many exceptions, when the detailed cases are considered.

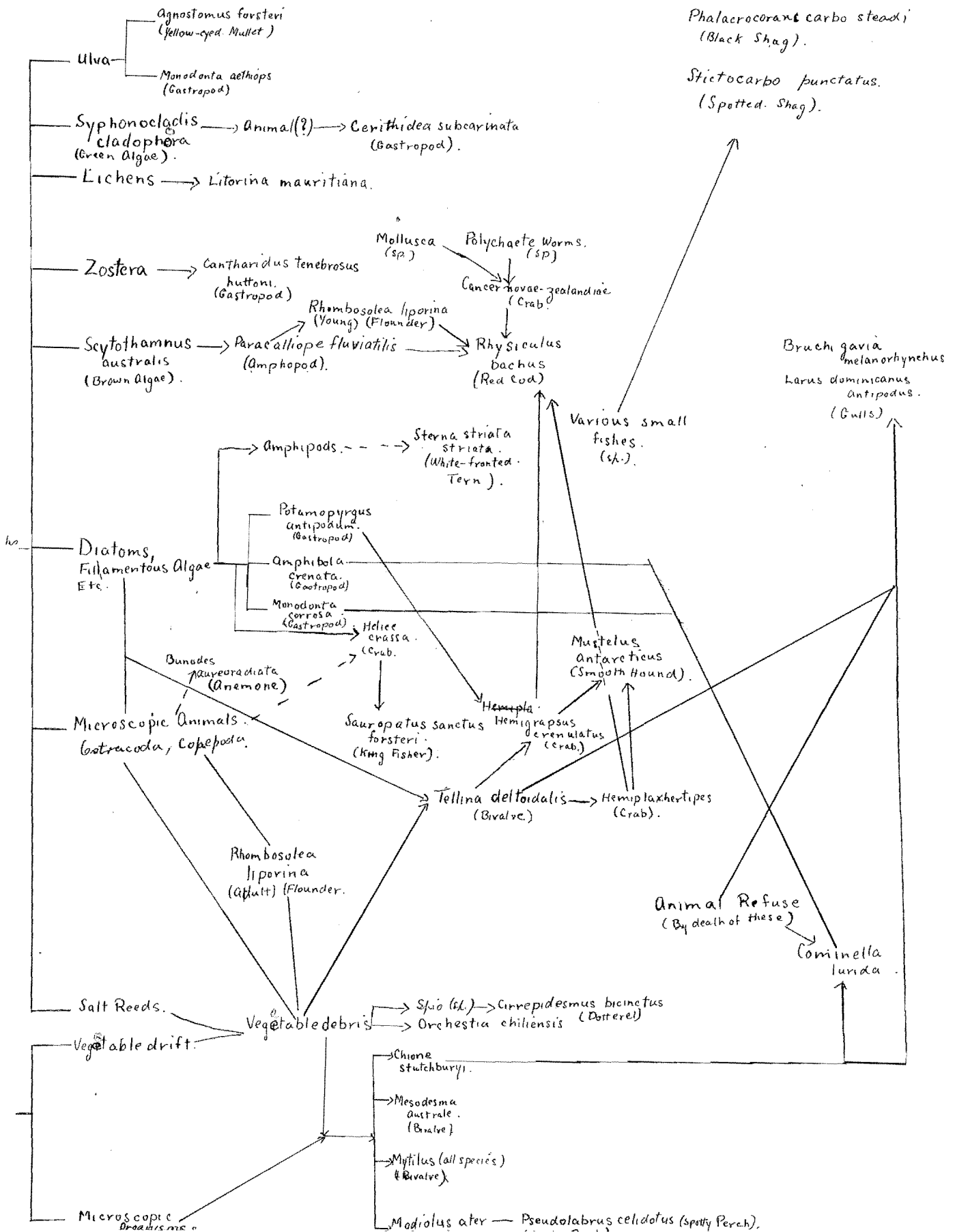
From the above it might be argued that erosion is largely due to a small Ph. value, produced by

- a. River water relatively rich in  $\text{CO}_2$ .
- b. Acidity produced by organic decay of the mud.

But the process is by no means a simple one, for water collected from the mud showed a higher Ph. value than that collected from water channels. Again exposure to the air seems greatly to accelerate the process.

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11. d. Comparison of the Brighton Beach and Heathcote Estuary.

It is worthy of note that some of the same genera are represented in the Estuary as are found on the Brighton Beach; but rarely is the same species common to both. Thus: ~~2~~

	<u>New Brighton</u>	<u>Estuary</u>
Mesodesma	M. subtriangulatum	M. australe
Macra	M. discors	M. ovata (scarse)
Tellina	T. alba	T. deltoidalis
Chione	C. yatei	C. stutchburyi
Nephtys	N. macrura	N. macrura
Talorchestia	T. quoyana	Orchestia chiliensis.



Some elements present on the beach are absent from the Estuary as for instance Arachnoides, the cake urchin. But in general the mud is much richer than the sand, both in species and in individuals. Storms are greatly reduced in violence so that wave action does not injure the <sup>Estuarine</sup> ~~Estuarine~~ Fauna to the same extent. The mud is less mobile and therefore less corrosive than the sand. Perhaps the most important feature of all is the comparatively stable substratum, which while sloppy enough to allow worms to burrow in it, is stable enough and sufficiently free from commotion to allow of the development of a rich, microscopic fauna and flora, and allow crabs to make permanent burrows. It will be noted that all these are factors which tend to reduce the dependence on chance.

But against these advantages of the Estuary, must be mentioned the muddy nature of the water, the variation in salinity from time to time, the greater temperature changes, the commotion and ~~alteration~~ caused by a change in path of a tidal creek, the toxic and perhaps corrosive properties of the products of decomposition, and the reduction in oxygen concentration.

Comparison of the charts summarising the Brighton Beach and the selected area in the Heathcote Estuary, shows that while in the former the stratification is very distinct, in the latter some merging of zones is apparent. This lack of distinctness is to be explained on the following grounds.

(a. Smaller angle of slope in the Estuary would tend to spread the distribution of each species.

(b) The three-fold food sources.

(i) Sea and River Water.

(ii) Microscopic growth on and in the mud.

(iii) Vegetable debris from the region above.

This would tend to promote two strata of life, burrowing animals and surface feeders.

(c) The milder conditions allowing surface animals to feed when they are covered with the tide.

Except in the somewhat doubtful case of Chione and Tellina, two animals with similar feeding habits do not occupy the same zone. In this way much interspecific competition is avoided.

### III. Conclusion.

An investigation of the intertidal zone, the boundary between sea and land, will inevitably bring before the investigator the problem of the movement from land to sea and vice versa; for whatever view is held as to the place of origin of life, the solid fact remains that migrations from land and fresh water to the sea and from the latter to the former have undoubtedly taken place and are at present progressing. The present investigation is not sufficiently advanced to add much to the large amount of evidence available. (Pearse (1927b) summarises the various lines of evidence, and emphasises the fact that it is not a question of one route excluding all others, but of many independent lines of progress.

It has been pointed out by various workers that there is a definite stratification in the tidal zone (eg. Huntsman 1918).

In the areas studied this was very definitely so. It has been suggested that these zones are established by animals seeking to avoid competition, and this may well be the case for in these areas, the zones are practically never occupied by two competing animals. This leads to a very suggestive speculation as to why animals should move up in the tidal belt. The majority of animals can feed only either when the tide is over them or when the tide is off them, very few being able to feed at both periods. If an animal passes the 6 hour exposure line, it will generally be feeding on products of the mud or of the fauna and flora above the tidal belt, and owing to the movement of water it will be easiest for it to become adapted to feed when not covered by the moving water. That such is the case would seem to be instanced by *Talorchestia quoyana*, *Actaecia euchroa*, *Helice crassa* and *Orchestia chiliensis*. When once this stage is reached it is obvious that the higher the animal moves in the tidal belt, the greater will be the time during which it can feed, so that demand for food might be expected to produce an upward movement in these animals.

In his work at Tortugas, Pearse (1929) has studied cases where, there being no fresh water, migration must take place directly from sea to land, without fresh water as an intermediate. He has shown that -

(a) Animals with a landward tendency can withstand longer periods in the air than in fresh water.

(b) Such animals are more tolerant of fresh water than

ones without such a tendency, living in the open ocean.

In these investigations similar results were obtained. *Talorchestia quoyana* lived eight days without sea water but died in four hours when saturated with fresh water. *Mesodesma subtriangulatum* cannot tolerate Estuarine conditions, *Actæcia enchroa* will live days longer in sand than in fresh water and the same is true of many rock forms which were tried. All such results must yet be revised in the light of the many experiments which have shown that, if the change were made sufficiently gradually, marine animals could survive far greater variations in salinity than were normally fatal. The crab, *Helicæ crassa*, failed to establish itself in fresh water, but when the water was gradually diluted over a period of a month, it lived quite happily in fresh water for two months and was quite healthy when the experiment was discontinued. Strangely enough, though this fact has been known for a considerable time, the majority of workers has not applied it, probably because of the time involved. But it is obvious that such experiments throw much more light on the real ability of animals to move into freshened water, than the rather crude method of hurling organisms into fresh water, and recording them as "stenohaline" because they died.

Pearse (1929) gives a rather interesting discussion of the decrease in % of gill to body volume as crabs ascend in the tidal belt. I have tried his method with the crabs of the Estuary, but my results do not give any definite relation.

A factor which seems to have been omitted in all discussions on factors influencing rise in the tidal belt is that of change of salinity. I have shown in my graphs that a species which was undergoing the lowest salinity which it could tolerate at low water at Shag Rock, would find no difficulty from a salinity point of view, in accommodating itself to conditions at high water at the Heathcote Bridge. It can be seen that benthic species, moving up an Estuary with a large change of salinity with tide, would have three lines of adaptation open to them.

(a) Develop "euryhalinism".

(b) Develop some means of excluding water during extremes of freshness.

(c) Rise in the tidal belt.

(a) This is the usual scheme suggested for tidal animals. I consider it is largely due to the failure of many observers to note the exact position in the tidal belt, and the change in salinity with the tide level. I feel satisfied that when the facts are considered from this point of view, many of the present salinity ranges will have to be greatly modified. In the Estuary, certain species have amply succeeded in this direction as a glance at Fig 20 will show.

(b) The exclusion of water during extremes of freshness is illustrated in *Chione stutchburyi*. It appears to occur in mussels and may be an explanation of the close fitting valves of so many so called "Euryhaline" polycypods. The absence of such close fitting valves in *Tellina*, may have a definite bearing on its

confined distribution. Such a method, however, cannot be altogether satisfactory as it greatly curtails the time available for feeding. It is however a very important adaptation and the ignoring of it by many workers is to be regretted.

(c) Rise in the tidal belt is an obvious means of overcoming the lack of salt in the low tide area in such places as the Estuary. Observations on *Helice crassa*, would seem to show that this is taking place, as in the upper parts of the rivers it is confined to the marshy area at high tide. In the light of my observations on this animal in pure ~~fresh~~ water, I am disinclined to give too much weight to this evidence till I have had time to consider it more fully, in connection with food supply and exposure. It will be noted that such a rise would involve a gradually increased adaptation to life in the air.

Such a method of "pushing" animals out of the water by salinity changes, is of considerable appeal for the following reasons.

(a) Estuarine conditions being muddy, would show an exceedingly slow gradation in substratum. Hence most of the microscopic life would be able to "go up" with the animals which preyed on them.

(b) In such places the upper limit of the tidal zone often extends into marshy conditions where life would be sheltered from the full vigors of exposure to sun and desiccation. In other words the "vacant space" barrier is absent. (Plate 44).

(c) Pearse's observations (1929) on the greater ability of

landward moving animals to withstand desiccation than freshening water, is significant.

But however these facts work out, I am not going, after but a provisional survey of a local area, to add to the tangle of theories as to the method of migration. I mention this matter here because I consider that the possibility of animals being "pushed" up to terrestrial habitats by freshening of water has been overlooked and is worth investigating, not as a complete theory, but as an addition to the factors involved.

N.B. For Bibliography on this matter see Pearse 1927b, 1929

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