Thesis submitted for the degree of Ph.D. :---

"The Benthic Ecology of False Bay, with Notes on the Analysis of Shallow-water Soft Substrata ".

by J.F.C.Morgans M.A. (Cantab.)

Independent Summary of the Work.

This work continues the marine tradition of the Department of Zoology but attempts to open-up a new field by tackling for the first time the ecology of the shallow sea bed. False Bay is accessible and provides a large area that is virtually unaffected by rivers or the works of man. Its situation happens to be particularly interesting. It is the nearest part of the flat, submarine shelf called the Agulhas Bank, where there are valuable fishing grounds: and it lies at the boundary of two very different masses of water. Study of False Bay should, in addition, be of interest in throwing light on the contrast between the shallows of the sea and those of lagoons and estuaries.

Field work started with dredging from hired fishing boats. It was soon obvious that one of the most important regions of the sea was escaping notice, that above the shallowest depth in which dredges could be worked and below low tide level. This region could only be studied by diving and so a programme of diving with frogman kit was started. Dredging and diving meant considerable training in non-academic techniques not only in the field but in designing new gear (eg. dredges, underwater camera and underwater electronic flash).

Frogman-style diving has proved to be a very valuable ecological technique and its application by the author has been gratifyingly commented upon by Dr. Barnard [1], Prof. Smith [2], and Miss. Clark [3].

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1. Ann. S.Afr. Mus., vol.XLII Pt. I, No.1, 1955 .
2. Ann. and Mag. Nat. Hist., vol.8, No.86, XIV, 1955 .
3. Ann. and Mag. Nat. Hist., vol.9, No.101, XLIII, 1956 .

Not only is it rewarding in obtaining new records of species but it has proved invaluable for underwater observation of experimental gear in action.

Two pieces of work arose from the initial programme. Firstly, to put the ecology of underwater rocks in perspective it was necessary to survey some intertidal rocks. Secondly, the dredging work on sands raised problems of suitable methods of analysis of soft substrata and it became obvious that the methods of other workers were very misleading. The matter was investigated and suitable methods are suggested in a paper that is part of this thesis (it is already published in full[1]) .

False Bay is large, about 430 sq. miles in area, and its ecology is probably complicated by its marginal position between conflicting water masses. This first account of the animals and plants that live around its margins and on its bed is far from complete but is presented with the hope that further work will amplify it.

The results are presented in four papers totalling 319 pages, 20 text-figures and 14 plates. The plates comprise photographs on land and underwater : they and the photographic reproductions of the figures were all done by the author. The main features of the thesis are set out below with some of the results that can be shortly stated. In the biological work, however, the descriptions of underwater rocks and dredging grounds are important results in themselves and not all of the conclusions can be condensed into a summary of this length.

<u>Paper 1</u>. "Notes on the Analysis of Shallow-water Soft Substrata". 40 pp., 2 text-fig.. (PUBLISHED [1]) .

(i) A mud, sand or gravel probably affects animals and plants chiefly by its texture and content of dead organic matter.

(ii) Recent work in this field is criticised as unsuitable in technique and bewilderingly diverse in the ways in which results are presented.

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1. Journ. Anim. Ecol., vol. 25 (2), 1956 .

(iii)Procedures of analysis for texture and for organic matter are given with the greatest, feasible detail.

(iv) It is reccommended that there should be a standard way of presenting results. A model is given.

Paper 2. "The Benthic Ecology of False Bay : Pt.I. Annotated List of Species". 100 pp..

(i) Some 850 spp. are listed. They comprise all benthic infratidal species identified during the course of the survey and all reliable records from the literature on False Bay.

(ii) Ecological data are given eg. depth range, type of bottom, general abundance, breeding season, geographical extension east or west.

(iii)A list is given of more than 100 marine papers, chiefly systematic, that were referred to.

(iv) This is the most comprehensive check list of the species of any region of the sea around southern Africa.

Paper 3. "The Benthic Ecology of False Bay : Pt.II. Intertidal and Shallow Infratidal Rocks". 99 pp., 11 text-fig., 14 plates.

(i) Four intertidal transects are surveyed and their biotas are examined. Examination is continued to below low tide level by diving. Biotic differences are discussed, chiefly in relation to exposure to wave action. An analysis of critical levels is made and is particularly valuable because this is the first work in which the lowest levels of the intertidal zone are put into proper perspective (by diving).

(ii) Eleven infratidal sites are examined by diving to a maximal depth of 17 m.. They include vertical and sloping faces and a shallow cave.

(iii)Intertidal and infratidal biotas are compared and the main changes are discussed in relation to environmental factors, particularly emergence, lighting and turbulence.

(iv) The intertidal biota shows little correspondence with work in Great Britain and New Zealand but the infratidal ecology has some striking similarities to work in Britain.

(v) Many underwater photographs are given.

Paper 4. "The Benthic Ecology of False Bay : Pt.III. The Results of Dredging". 80 pp.,7 text-fig..

(i) Dredgings on rocks, gravels, sands and muds to a maximal depth of 90 m. provide data for a preliminary description of the benthic ecology. Knowledge of soft bottoms is amplified by diving observations to 26 m. depth.

(ii) Species show vertical gradients of distribution and the pattern of distribution of species of hard bottoms (rocks) differs from that of soft bottoms. Tentative explanations are advanced.

(iii)Several faunistic "grounds" are described and their faunistic differences are correlated with differences in environment, especially with substratum texture and content of dead organic matter.

(iv) Results are reviewed with those of Part II and with what is known of the ecology of intertidal beaches and of the nearby shelf fauna. An analysis of critical levels is made based on the species listed in Part I, and their depth ranges given there.

THESIS SUBMITTED FOR THE DEGREE OF Ph.D.

THE BENTHIC ECOLOGY OF FALSE BAY,

with

NOTES ON THE ANALYSIS OF SHALLOW-WATER SOFT SUBSTRATA.

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Paper 1 -"Notes on the analysis of shallow-water soft substrata."
As published in The Journal of Animal Ecology, vol. 25:2, pp.367-387.

Paper 2 -"The benthic ecology of False Bay. Part I. Annotated list of species."

Paper 3 -"The benthic ecology of False Bay. Part II. Intertidal & shallow infratidal rocks."

Paper 4 -"The benthic ecology of False Bay. Part III. The results of dredging."

Zanzibar
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NOTES ON ANALYSIS OF SHALLOW-WATER SOFT SUBSTRATA.

BY

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I. GENERAL.

It has long been recognised that the nature of the substratum is of the greatest importance in determining the nature of the bottom flora and fauna. There is a striking difference between the biota of rocks and of soft bottoms whether observed intertidally or sampled by dredging. Again, the various soft bottoms such as gravels, sands and muds show differences in biota and it is natural to try to relate these differences to local substratum characteristics. Various features of soft substrata have received attention as being of particular importance to the biota. As long ago as I89I Murray and Renard analysed substrata with regard to mineralogical constitution and particle size and these features have since received more attention. However interest in mineralogical analysis has dwindled because the rewards of such an elaborate process have not seemed worthwhile. On the other hand analysis of texture has been confirmed as important. More recently the resistance of the substratum to boring has been investigated by Chapman (I949) and Carruthers (I954), the technique being so far only practical intertidally and to a few feet below water level. In I934 Day and Wilson showed that larval settlement is affected by partical size and this line of research has been taken much farther by Wilson (Eg. I953 a and b) who has shown the importance of the presence of organic matter, both living and dead. The amount of

dead/......

organic matter present is important for a variety of reasons summarised by Trask (1939) and Sverdrup, Johnson and Fleming (1942) but in the present context chiefly as food for the benthos. The importance of this is stressed by Davis (1925) amongst others for he thinks "..... it not improbable that the association of various groups of animals with soils of perticular texture is not so much influenced by the texture per se as by the food conditions of which the size of the soil particles is a correlated indication" (quoted from Jones, 1950).

It is axiomatic that the flora and fauna of the bottom in turn modify it, often profoundly. This has been clearly shown for muds by Moore (1931) although it is not so evident with sands and gravels. Moore also shows that several physical and chemical factors change progressively with increasing depth below the surface of the mud.

These notes refer to substratum texture and its content of dead organic matter both of which are undoubtedly very important features so far as the biota are concerned. Unfortunately workers in this field have been hampered by technical difficulties and comparison of their results is further complicated by differing methods of presentation. Experts in the many techniques of mechanical analysis, organic analysis and in the statistical presentation of results are by no means agreed as to the best methods to be followed. Consequently it is not surprising that biologists have tried diverse methods and that the literature on substratum analysis is becoming more and more confusing.

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It has become apparent from the literature that there are dangers in adopting the techniques of other branches of science without modifying them to particular ecological needs. These notes are the result of the author having spent much time following procedures which turned out to be unsuitable for his particular requirements. They are presented particularly to new-comers in this field to provide something of a synopsis of recent work in an attempt to prevent similar waste of time. The problems of texture analysis and organic analysis are first discussed in regard to recent work, and then notes on analytical procedures are given, some proven methods being recommended and others which are controversial being suggested. An effort has been made to avoid the necessity for reference to other papers but this is unavoidable in the complicated matter of the mechanical analysis of particles of sub-sieve size. However, many references are given throughout.

I take great pleasure in thanking Professor J.H.Day for his invaluable advice at all times. In addition Mr B.A.Kantey, of the Department of Civil Engineering, has been kind enough to comment on the manuscript.

Mr C.S.Piper and his publishers have contributed to the completeness of this paper by very kindly permitting me to quote extensively from an analytical procedure set out in his book (Piper (1947).

II. Texture...

II. TEXTURE ANALYSIS.

This is the determination of the relative quantities of particles of different sizes in a sample of the substratum. Most ~~of the~~ aspects of this analysis are admirably considered in Krumbein and Pettijohn (1938) and are summarised by various authors in Trask's symposium (Ed. 1939).

The whole analysis involves Pretreatment, Mechanical Analysis and Presentation of Results. Although each is a separate manipulation it is imperative that they be considered as a whole prior to collection of the sample.

(a) Pretreatment.

All processes from the moment of collection until mechanical analysis come under this heading. The importance of pretreatment often is not realised and lack of foresight easily produces analyses which are invalid in regard to what they purport to express.

Recently ecologists have tended to follow the practices of agricultural soil analysts without suitable modification. Agriculturalists appear to be interested in the analysis of the smallest particles which comprise the crumbs and clods which they find naturally. Consequently they destroy the agents such as organic and carbonaceous matter which bind the particles into larger aggregations. Carbonates are also removed because they give misleadingly high values to the silt and clay grades if finely divided. But surely marine animals are affected by the crumbs of the substratum as present around them and not by the component particles of the crumbs? Carbonates in the form of shell, bits of Polyzoa etc. and the compound crumbs form an integral

part/.....

part of the environment of the marine creature. Therefore ecologists must not dissolve the shell nor break up these crumbs for if they do so they create conditions which are abnormal to the creatures of the substratum. Although this was recognised in I93I by Moore, more recent work can be criticised in this respect.

In the case of particles less than about 0·05 mm. diameter, which are those below the range of most sieves, crumb sizes are affected by the phenomenon of aggregation. In other words these small particles tend to clump together under influences of ionisation, hydration and mechanical agitation. The effect is well illustrated by the coagulation and subsequent deposition of river-borne silt when it meets the sea (Day I95I). For further details the reader is referred to Krumbein and Pettijohn (I938,p57 ff.) and Grippenberg (I939). The effects of the factors influencing aggregation are reversible but the extent to which changes affect crumb aggregation or dis-aggregation cannot be calculated. If mechanical analysis of particles of sub-sieve size is desired it is important that pretreatment should not modify the degree of aggregation of the particles. In the absence of precise knowledge the only way to ensure that this remains unchanged is to collect the substratum sample with some of the water which naturally lies above it and to maintain this water at natural salinity, pH etc. This obviously precludes drying of the sample or treatment with formalin. In estuarine work, particularly, this raises great practical problems and the most urgent need of hydro-biological substratum analysis is to determine what liberties may be taken with samples for the sake of

convenience/......

convenience without significantly altering the degree of aggregation of the particles. Unfortunately time has not permitted the author to start this work.

(b) Mechanical Analysis.

It is unfortunate that particles of different sizes cannot be separated by the same means throughout their size range. Gripenberg (1939) mentions the following methods as best within the following size ranges :-

Sieving	-	larger than 0·100 mm.
Elutriation	-	0·200 - 0·020 mm.
Sedimentation	-	smaller than 0·100 mm.

Krumbein chooses 0·062 mm. as the lowest limit for sieving (Krumbein and Pettijohn 1938) because suitable sieves are readily obtainable and this size is near the upper limit of applicability of Stokes' Law or Wadell's practical sedimentation formula whereby the smaller sizes are calculated. Moreover this size is the lowest limit of sands in the Wentworth classification.

Sieving.

Sieving is the simplest way of separating medium-sizes particles. For precise work the underlying principles of the method should be remembered (Krumbein and Pettijohn 1938). The most important point is that the sorting action of sieves is based on the least cross-sectional area of the particles and this area may or may not have a fixed relation to their volumes. This must be borne in mind when many of the particles are lath-shaped e.g. shell, spines, spicules.

Some workers prefer sieves with round holes but the majority use square-mesh sieves. The difference in results is probably only important in work of the most detailed sort. If sub-sieve particles are to be analysed

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then sieving must be done wet (see "Pretreatment" above) but if not then it is usually more conveniently done dry, often by machine. Krumbein notes that wet sieving is not as satisfactory as dry since "it appears that the film of water in the wet sieve prevents some small particles from passing through".

Analysis of Sub-sieve Grades.

It has already been suggested that mechanical analysis of sub-sieve grades is not worthwhile if the pretreatment of the sample is suspect.

Analysis may be of two kinds:-

(a) The sample is subdivided into discrete grades which can be handled separately. Methods which do this are elutriation and decantation.

(b) The sample is not actually subdivided but the constituent grades are determined by calculation. Various sedimentation methods achieve this. Eg. Pipette and hydrometer methods.

Elutriation was used by Borley (I923), Pirrie et al. (I932) and Fraser (I932). The accuracy of their apparatus is criticised by Beanland (I940), but she does not comment on the type of water used in their elutriators. Certainly in the first two cases it was fresh water whereas the sediments analysed occurred naturally beneath sea water but this criticism is important only where Borley's silt grades are concerned and these are noted to be third in order of abundance in his samples.
Pirrie et al. state that particles smaller than 0·I mm. were negligible in all their samples and larger particles are not significantly affected by agglomeration.
Moore (I93I) used an elutriator worked with sea water to separate marine muds into four grades. These grades are

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not considered in terms of particle size, although current speeds in each chamber of the elutriator are given, for Moore notes a wide range in density of the particles which causes large, light particles and small, dense ones to collect in the same grade. The chief disadvantage of elutriation appears to be the rather elaborate apparatus required and this disadvantage is increased by the necessity to use "natural water". However the method appears to be rapid and simple in manipulation.

Decantation was used by Allen (I899) and Smith (I932) to separate into two fractions the material passing a 0·5 mm. sieve. Allen certainly used "natural water" (sea-water) to suspend the sediment which was then allowed to settle for I minute before decantation: he notes that decantation was usually repeated once. Allen states the time for decantation but does not in fact stipulate the height of the suspension although it probably was standardised. It is noteworthy that Worth (in Allen I899) comments that the "fine sand" separated by this method was of very variable size. Probably this was due, not to sedimentation from differing heights, but to the great variation possible in particles smaller than 0·5 mm. (Eg. see Table I.). Later workers such as Rees (I940) and Holme (I949) also used decantation but followed agricultural practise and disaggregated their samples chemically while Holme (I953 and I954) employed repeated decantation in distilled water to separate particles greater and smaller then 0·03I3 mm. He mentions that pretreatment of the grades included first drying and then treatment with warm hydrogen peroxide. Objections to the methods of these recent workers can be made in respect of the factors discussed above under "Pretreatment".

Decantation is very slow for dispersed soils (Piper 1947). The fact that for ecological purposes, samples must be in "natural water" might make the method more feasible because the particles would remain aggregated and so would settle comparatively rapidly.

In the category of sedimentation methods Beahland followed agricultural practice and used Robinson's pipette method (Robinson 1922) for calculating four grades from 0·2 - less than 0·002 mm. by sedimentation after ammoniacal dispersion. Quicker methods are based on various hydrometer devices (Krumbein and Pettijohn 1938). The Bouyoucos Hydrometer Method (Bouyoucos 1936, Piper 1947) is widely used but would have to be modified as a consequence of using natural water. If the separation of individual grades is not wanted, rapid hydrometer techniques could be developed for dispersions in waters of different salinities.

(c) Presentation of Results.

Both sieved and sub-sieve grades must be evaluated on the same basis even though obtained by different methods. This basis has usually been that of air-dried weight which contains an error in that the finest grades are hydrated more than the coarser due to the constitutional water of the clay particles. In addition grades contaminated with salt contain variable amounts of hygroscopic moisture. Both errors are avoided if results are expressed on an oven-dry basis as recommended by Piper (1947). Pirrie et al (1932) evaluated their grades on the basis of drained, wet weight in the case of particles larger than 2 mm. and claim that the percentage composition so calculated corresponds to within 1% with

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that of samples evaluated by "dry" (air dry?) weights. Unfortunately this simple procedure could not be applied to smaller particles without loss of accuracy and these they evaluated on a "dried" basis, relating the coarse and fine material with a ratio. This method might be advantageous in saving time where many samples have to be analysed but has not been adopted in the model analysis suggested in this paper.

Fraser (I932) thought it would ".... be of more value to express results as volumes, this not being dependent upon the specific gravities of the various materials and as it is volume that is the biological factor concerned". Although gravels and sands were analysed by him on a volume basis he weighed the sub-sieve grades and the lack of uniformity is confusing. Measurement of volumes involves finicky manipulation and seldom approaches the accuracy of weighing (See Appendix). Although Fraser's contention seems perfectly true the increased manipulation necessary and rather low accuracy obtained outweigh, in my opinion, the advantages of the method.

The presentation of the results of analysis in a comprehensible manner is another problem. One of the difficulties in understanding other workers' results is the variety of grade scales used (see Table I). Usually the scales are arbitrary with the diameters of successive sieves bearing no constant mathematical relationship to one another. Such were the different scales adopted by Allen (I899, followed by Borley I923 and Smith 1932), Fraser (I932), Pirrie <u>et al</u> (I932), Beanland (I940) and Holme (I949). However Rees (I940) followed the logarithmic Atterburg scale of the

agriculturalists/......

Allen 1899 Smith 1932	Borley 1923	Fraser 1932	Pirrie, Bruce & Moore 1932	Rees 1940	Beanland 1940	Holme 1949	Holme 1953, 1954	Went-worth Scale
All holes round.	All holes round.	Holes down to and including 0•75mm round; smaller holes square.	All holes round.	No note on mesh shape.	No note on mesh shape.	No note on mesh shape.	Square mesh.	
•	•	•	•	•	•	•	•	64
•	•	50	•	•	•	•	•	•
•	•	25	•	•	•	•	•	•
I5	I5	•	•	•	•	•	•	•
•	IO	IO	•	•	•	•	•	•
•	•	•	6	•	•	•	•	•
5	5	5	•	•	•	•	•	•
•	•	4•5	•	•	•	•	•	•
•	•	4	4	•	•	•	•	4
•	•	3•5	•	•	•	•	•	•
•	•	3	•	•	•	•	•	•
2•5	2•5	2•5	•	•	2•5	•	•	•
•	•	2	2	2	•	2	2	2
I•5	I•5	I•5	•	•	I•5	•	•	•
I	I	I	I	•	I	•	I	I
•	•	0•75	•	•	•	•	•	•
0•5	0•5	0•5	0•5	•	0•5	0•5	0•5	0•5
•	•	0•35	•	•	•	•	•	•
•	•	•	0•25	•	•	0•256	0•25	0•25
•	0•2	•	•	0•2	0•2	0•22	0•2I	•
•	•	0•I5	•	•	•	•	•	•
•	•	•	•	•	•	•	0•I25	0•I25
?0•I	0•I	0•I	0•I	•	•	•	•	•
•	•	0•06	•	•	•	•	•	0•062
•	0•05	•	•	•	•	•	•	•
•	•	•	•	•	0•04	•	•	•
•	•	0•02	•	0•02	•	0•02	•	•
•	•	•	•	•	0•0I	•	•	•
•	•	•	•	•	•	•	•	0•004
•	•	•	•	•	•	•	0•03I3	•
•	•	•	•	0•002	0•002	•	•	•

Table I. Comparison of the Grade Scales of Some British Ecologists with the Wentworth Scale.

Minimum mesh size in millimetres is given.
Sieved grades are those above the horizontal lines.
It has not been possible to include the grades recognised by Moore (193I).

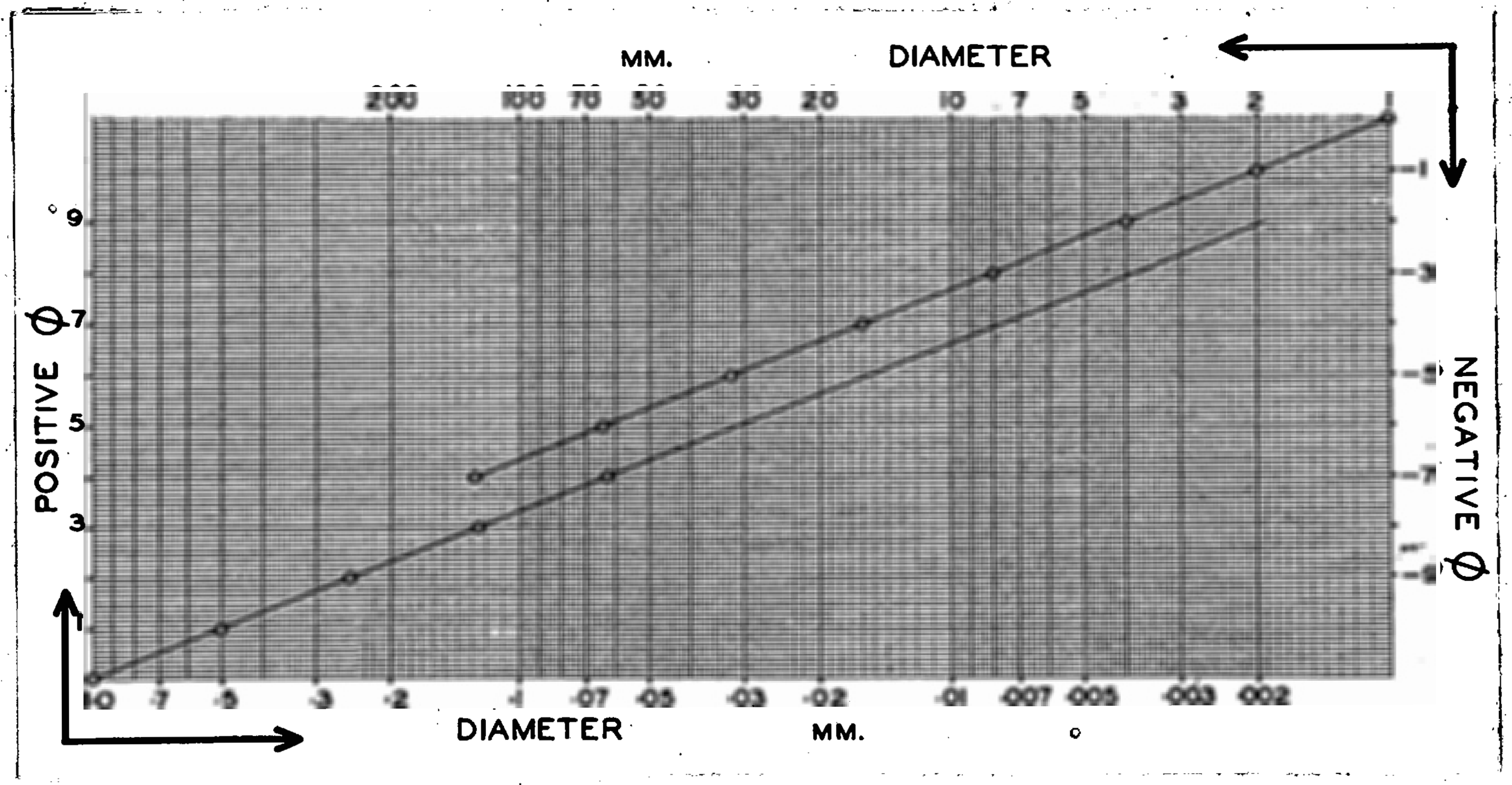

Figure I. Chart for conversion of Phi values into corresponding particle diameters in millimetres.

The lower line applies to the bottom and left-hand scales. (Based on Krumbein) .

agriculturalists and Holme (I953 and I954) followed part of the Wentworth scale into which he inserted an extra grade. Conversion of these analyses to a common basis is virtually impossible. The concept of a grade scale is well discussed by Krumbein and Pettijohn (I938) and the value of a geometric scale such as the Atterburg or Wentworth scales, is emphasised. In the Wentworth scale, which is adopted by practically all American sedimentary petrologists, the minimum diameters of grades are halved successively from 4 mm. for Pebbles to I/16th mm. for Very Fine Sand. This scale gives more suitable gradation for marine sediments than the Atterburg scale the gradation of which was found unsuitable by Holme (I949).

Some workers have expressed their results as the percentage of each grade related to the whole sample. Worth (in Allen I899) attempted to obviate this cumbersome method by calculation of an "Average Grade" for each sample and Borley's "Representative Number" (I923) was an improvement. Recently Holme (I954) employed the "arithmetic mean" which differs only slightly from Borley's "R.N.". All are indices attempting to express by one figure the chief characteristics of the sample. Holme notes one drawback of the arithmetic mean which is "..... more affected by changes in the percentages in the coarser grades than in the finer", and this comment applies also to Borley's "R.N.". This drawback is particularly unfortunate since small differences in silt content may be very important as was shown by Holme (I949, p. 228, difference of 4%). The above methods are, like histograms, based on the assumption of discrete size grades with the inherent drawbacks of the assumption (see Krumbein and Pettijohn I938). The same data can be

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used to construct cumulative curves representing continuous frequency distribution as has been done by Holme (I953 and I954). The cumulative curve shows for any given particle size the percentage of the substratum which consists of particles greater or smaller than that size. Such cumulative curves are used by agriculturalists (Robinson I922, Piper I947) and in many studies of marine sediments (Sverdrup et al. I942). These curves reduce the necessity for qualitative description of the sample for they yield several numerical values which serve descriptively. A detail in which the European agriculturalists and the Americans differ is that the former place particles of smallest size to the left of the figure whereas the latter place them to the right (See Krumbein and Pettijohn I938). Holme (I953 and I954) follows the American practice.

Krumbein (Ed. Trask I939) emphasises the importance of selecting convenient mathematical methods for the simplification of statistical treatment. A variety of methods based on cumulative curves are available and of these the Phi (Ø) scale offers an attractive method. Phi substitutes a logarithm for particle diameter in millimetres and so translated the arithmetically unequal class intervals of the Wentworth scale into equal intervals. Thus the cumulative curve of an analysis can be plotted on squared graph paper instead of semi-logarithmic without changing the shape of the curve. The median (Md_{ϕ}), or the value on the x-axis corresponding to the 50% value on the y-axis, is read in Phi terms and translated into the corresponding diameter in millimetres by use of a conversion chart (Fig. I). Half the substratum is composed of particles smaller than the median diameter and half of larger particles. The median diameter is most graphically

expressed/.....

expressed in microns rather than in fractions of a millimetre.

Because of the possibility of sampling errors at the upper and lower particle size limits the cumulative curves are usually only analysed between the first and third quartiles. Two statistical measures based on quartile values are commonly used. A measure of the slope of the curve is the Phi Quartile Deviation ($QD\phi$) which may be expressed:-

$$QD_\phi = \frac{Q3_\phi - QI_\phi}{2}$$

where $Q3_\phi$ and QI_ϕ are the values of Phi for the third and first quartiles. The slope of the curve indicates the sorting efficiency of the sedimentary agencies. Perfect sorting would be represented by a vertical curve and a QD_ϕ value of zero. Double the Phi Quartile Deviation indicates the number of Wentworth grades between the first and third quartiles or, in other words, the size-spread of the middle 50% of the sample.

Whether the curve is straight or curved between the quartiles is indicated by the Phi Quartile Skewness (Skq_ϕ).

$$Skq_\phi = \frac{Q3_\phi + QI_\phi - 2Md_\phi}{2}$$

A straight line between the quartiles has $Skq_\phi = 0$. Negative values indicate that the mean of the quartile values is to the left of the median value: in other words that the smaller particles are better sorted than the larger.

The arithmetic involved in calculating the Phi Quartile Deviation and Phi Quartile Skewness is simpler than that for corresponding measures based on curves constructed without use of the Phi scale.

To recapitulate: the construction of cumulative

curves/...

Fig. 2.

Cumulative curves of three marine sediments plotted against the Phi scale. Cumulative curves by weight are drawn and the positions of cumulative curves by volume are indicated by plus signs.
The lowest scale of figures gives the equivalent diameters in millimetres for Phi = -6 to +4 . Nomenclature of the grades according to the Wentworth scale is as follows:---

64 -	4 mm.	Pebble.	0·25	-0·I25mm.	Fine Sand.
4 -	2	Granule.	0·I25	-0·0625	Very fine Sand.
2 -	I	Very coarse Sand.	0·0625-0·0039		Silt.
I -	0·5	Coarse Sand.	<0·0039		Clay.
0·5-	0·25	Medium Sand.			

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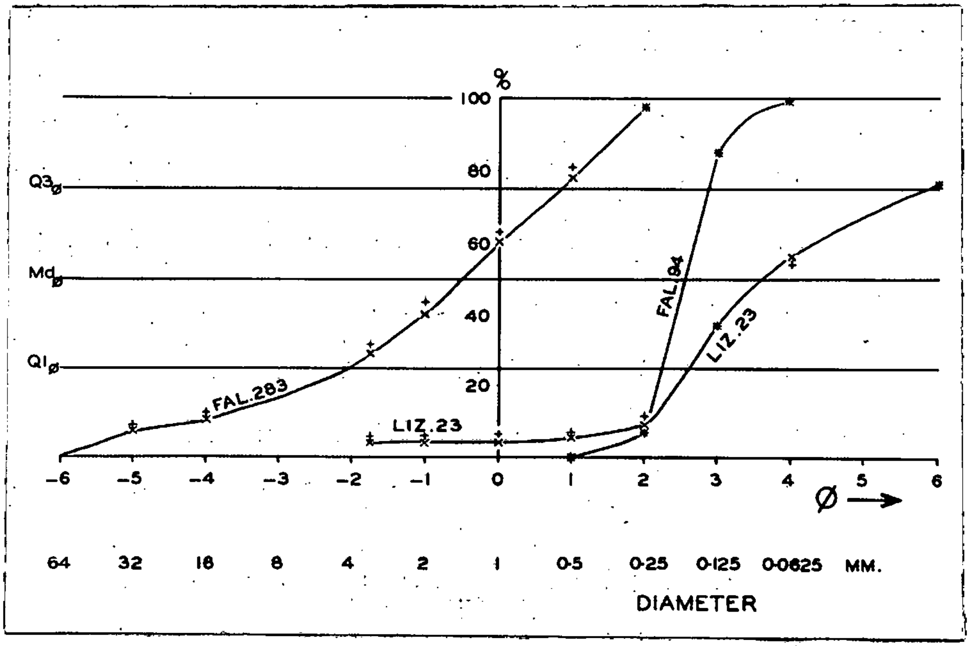

curves with use of the Phi scale involves no more work than in calculating Worth's "Average Grade" or Borley's "Representative Number" or Holme's "Arithmetic Mean" but avoids the drawbacks from which they suffer. In addition several figures are readily obtained from the graph instead of the single index of Worth, Borley or Holme and these figures are more descriptive of the substratum having geometric significance in terms of particle size on the Wentworth scale and being readily visualised in terms of the sedimentary curve.

As an example of this method of presentation the cumulative curves of three marine sediments are shown in Fig. 2. If the curves are examined in the light of their medians, quartile deviation and quartile skewness the following points are apparent:---

(i) FAL. 283, with a median of -0·55 Phi, is a much coarser substratum than either of the others whose medians lie at 2·55 3·60 Phi. The Wentworth grade corresponding to the median of FAL. 283 is "Very Coarse Sand" whereas the medians of FAL. 94 and LIZ. 23 indicate "Fine Sand" and "Very Fine Sand" respectively.

(ii) The Phi quartile deviation of FAL. 94 is 0 ·3 which is near zero and so indicates a very

much/......

much better sorted substratum than FAL. 283 and LIZ. 23 with quartile deviations of I·45 and I·65 respectively. The data may be visualised better if the quartile spread of the sample is considered. This value is twice that of the quartile deviation and indicates the number of Wentworth grades into which the median half of the sample falls. Thus the median half of FAL. 94 falls into 0·6 grades by this reckoning : the curve in Fig. 2. shows that actually 75% is retained by the 0·I25 mm. sieve. In the case of FAL. 283 the quartile spread is 2·9 which means that the median half of the sample is spread over 2·9 Wentworth grades or is contained in three sieves of the series. LIZ. 23 has a quartile spread of 3·3 and so is rather worse sorted than FAL. 283.

(iii) The curve for LIZ. 23 is definitely skewed, having a Phi quartile skewness of 0·6. Being positive this value indicates that the particles larger than the median are better sorted than smaller ones. The Phi quartile skewness for FAL. 94 and FAL. 283 is 0 and -0·I5 respectively, showing that in both samples the efficiency of sorting of the larger and of the smaller particles was of the same order. It should, however, be noted that the skewness of LIZ. 23 may be due to the different methods of mechanical analysis for particles greater than 0·066 mm. (sieving) and for those smaller (hydrometer method).

The field notes on these samples were: FAL. 283 a coarse, shelly sand; FAL. 94 a clean, fine sand with ripple marks; and LIZ. 23 a rather clayey mud. The full curves accord well with these field descriptions. The presence in LIZ. 23 of "Granules" is due to dead Pelecypod shells which presumably derived from animals that grew and died in the mud; therefore, they cannot reflect the sorting action of the overlying water.

It would be possible to evolve statistical measures corresponding to the Quartile Deviation and Quartile Skewness but based on the first and ninth deciles. In that case 80% instead of 50% of the sample would be considered. The validity of this would depend on the efficiency of sampling of the largest and smallest particles of a sample: most samplers tend to miss the largest or to lose some of the smallest. When deciles are to be considered the necessity for sub-sieve analysis increases for it is required if as much as 10% of the sample passes the finest sieve.

III. ORGANIC ANALYSIS.

As considered in this paper the object of this is to determine the amount of dead organic matter available for food purposes although similar analysis might serve organic pollution problems. Analysis could be made on a whole substratum sample but more interesting results accrue if the component grades are analysed separately. Hence analysis for organic matter must follow texture analysis.

Trask (1939) writes that "the quantity of organic matter in sediments is determined indirectly, usually by multiplying by an appropriate factor, some property of the sediment that is related to the organic content - such as the content of carbon, nitrogen, phosphate, or volatile substances". Technical difficulties are considerable. Thus Pirrie et al (1932) considered, and abandoned as inadequate, various methods of estimation including that of loss in weight on ignition which is complicated by the presence of carbonates (shell) and soil colloids. This method of estimation was used by Beanland (1940) after removal of carbonates by acid but her results still include loss of constitutional water of the colloids which must have been abundant in the muds met with. Sverdrup et al (1942) state that oxidation either by ignition or by "wet combustion" is different and time consuming and that the organic content is commonly obtained indirectly by estimation of nitrogen.

Various methods of analysis for agricultural purposes are discussed by Piper (1947) and three are described in detail. Of these, the Walkley and Black method of wet-oxidation by hot chromic acid followed by titration offers a rapid and not very expensive technique which is apparently the only wet-oxidation technique approved by the International Society of Soil Science. Piper gives full details of the method in its (then) latest form. The method estimates the percentage of carbon of organic matter excluding carbonates. It is unaffected by elementary carbon and nitrates only interfere if present in amounts in excess of one-twentieth of the carbon content. Perhaps the most attractive feature is that interference by chlorides can be suitably corrected. Piper quotes that "...... Walkley finds that the percentage recovery ...... varies from 60% for some subsoils to 90 or more per cent for peat soils, taking values obtained by dry combustion as the standard ~~of comparison. For the majority~~

Samples	FAL. 94	FAL. 283	FAL. 2I7	FAL. 222	FAL. 228	FAL. 237	LIZ. 23
Field description	Clean, fine sand.	Shelly, very coarse sand.	Shelly, medium sand.	Shelly, coarse sand.	Shelly, coarse sand & khaki mud.	Green, faecal-pellet mud.	Sticky, greyish mud.
Depth	2-3 m	I4 m	I8 m	40 m	64 m	78 m	38 m
Minimum particle diameter in millimetres.							
32		0·4		0·2			
I6		0·3	0·4	) 0·2			
8		) 0·4	) 0·2	)			
4		)	)	*	) 0·I		*
2		0·3	0·2	0·3	)		*
I		0·3	0·2	*	0·2		*
0·5	0·4	0·3	0·0	0·I	0·3	I·5	*
0·25	0·2	0·2	0·I	*	0·3	4·4	*
0·I25	0·4	)	0·I	0·I	0·3	4·6	0·I
0·066	0·I	) 0·3	) 0 ·I	I·I	0·3	2·8	0·3
<0·066	I·6	)	)	3·7	I·6	3·4	I·4
"Available" organic carbon of sample, W. &B. value	0·004	0·000	0·000	0·03I	0·I44	3·20	0·433
"Available" organic matter present in sample	0·0I0	0·000	0·000	0·074	0·346	7·73	I·039

* --- Grades not analysed.

Table 2. Percentages of Organic Carbon (Walkley and Black values) of the grades comprising various substratum samples. For each sample percentages have been calculated for the total "available" carbon and for the total "available" organic matter present in the sample (see p. 32) .

of comparison. For the majority of agricultural surface soils the mean recovery lies between 75% to 80%".

There is a definite indication that the results of Walkley and Black analyses of marine soils must be treated with reserve. In a test 43 different grades of 7 different substratum samples were analysed(see Table 2) after the composition of each grade had been observed microscopically. The great majority of the grades were more than half composed of shell of various kinds, Polyzoa fragments and spicules. No grades gave Walkley and Black values below 0·04% (which occurred in FAL. 2I7) and thirty-three analyses gave values from this figure up to 0·4% although visually they there were all noted as "free of organic matter". The organic carbon determined was that of the dead shell etc. which cannot be regarded as available for use as food. The remaining I0 grades had values from I·I% to 4·6% and half of these were the grades of one substratum sample FAL. 237) which was composed almost entirely of faecal pellets. Although Walkley and Black values for the faecal pellets were so high it was problematical how much of this carbon was available as food, for it had already passed through the gut of some animal. Microscopic observation of each sample noted that organic matter, appearing as "fluff", was confined to the finest grades, particularly to the sub-sieve grade (smaller than 0·066 mm.) and in general this contention was confirmed by the analyses. Apart from the sample composed of faecal pellets only one sieved grade (in FAL. 222) had a high value.

To convert the percentage of carbon to the percentage of organic matter a factor must be used, which depends on chemical composition of the organic matter. This is discussed by Trask (I939), Sverdrup <u>et al</u>. (I942)

and/.....

and Piper (I947) and factors from I·67 to 2·0 have been suggested. Trask recommends I·8 which corresponds with a carbon content of 56%.

IV. NOTES ON ANALYTICAL PROCEDURES.

(a) Preface.

This section is intended as a guide to procedures of analysis of sediment texture and organic content and to presentation of the results of these analyses. It would have been helpful to present step by step schemes for each analysis but this has not seemed worthwhile for reasons which will be given below. Full procedural details are only given for organic analysis where one method has appeared to be far more suitable than others. This method has been extracted from a book and the text is left in its original form. In the case of mechanical analysis of coarse sediments the methods adopted depend upon whether analysis of particles of sub-sieve size will also be attempted, and whether organic analysis is contemplated. Procedures for mechanical analysis by sieving are so well known that it would be pointless to give step by step instructions covering the variations that might be required when a few comments suffice. The third type of analysis considered here, that of mechanical analysis of particles of sub-sieve size, is the most controversial. A great number of methods are possible with many variations of detail and no single method is pre-eminently suitable. Furthermore no method has been fully investigated with regard to its accuracy when the sediment is dispersed in natural water. In such circumstances a detailed procedure cannot reasonably be recommended.

(b) General.

It is assumed that samples are truly representative of the substratum.

In the case of sands and muds a suitable quantity for field collection is 450 cc. (the volume of a I lb. preserve jar) but this quantity should be doubled for gravels.

It must be decided at the time of field collection whether analysis of sub-sieve grades is to be attempted or not because if it is desired then the sample must be collected with some natural water. As shown earlier sub-sieve analysis is usually only necessary if more than 25% of the sample passes the finest sieve. With most gravels and sands sub-sieve analysis is probably unimportant due to the small quantity of silt present. With muds such analysis seems unavoidable despite the difficulties involved.

All sieves used should conform to the Wentworth grade scale (See Fig. 2) with minimum mesh size of 0·062 mm. It should be noted that the Phi scale can be used even if the Wentworth grade scale is not adhered to since any mesh-size has a corresponding Phi value. This is convenient if one or two of the sieves available do not fit the Wentworth series: but if none of the sieves fit then the graphic value of the Phi Quartile Deviation and Phi Quartile Skewness is greatly diminished. B.S. Sieves of mesh 5, 8, 16, 30, 60, I20, and 240 fit the scale reasonably from 4 -0·0625 mm. but the first and last sieves, which have mesh sizes of 3·353 mm. and 0·066 mm., must be given Phi values of - I·75 and + 3·9 respectively as can be calculated from Fig. I.

(c) Analysis/...

(c) Analysis of Gravels and Sands.

It is presumed that with most gravels and sands sub-sieve analysis is not desired and in these cases samples may be treated with preservative for the animals they contain or the animals may be removed and the samples put into bags and air dried.

An aliquot is taken for grade analysis, about I50 cc. being sufficient with sieves of 20 cm. diameter; a larger sample is unwieldy and reduces sieving efficiency.

Salt should be leached-out before analysis since its weight is otherwise added to that of the grades. There are two further possible reasons for salt removal: (1) its hygroscopic properties would interfere with the separation of fine particles if dry sieving were proposed (ii) if organic analysis were to be done on the grades then they must either be free of salt or their salt content known.

Leaching and sieving are combined if samples be wet-sieved under fresh water. Animals in the preserved samples can be removed at this stage. Care must be taken that fines passing the finest sieve be not lost for their weight must be known. The separated grades should finally be washed with a jet of fresh water.

Probably dried samples could be leached by immersing the bags in changes of fresh water but the author has no experience of this. The samples could then be dried again and sieving done in a nest of sieves on an automatic shaking machine. This procedure might be the easiest if a great number of substrata were to be analysed.

All grades should be oven-dried at I05 $^{\circ}$C. and evaluated on the basis of oven-dry weight.

The/.....

The results of mechanical may be tabulated as follows ; ---

		Cumulative percentage.	Phi value equivalent to sieve mesh size.
Weight retained by 4 mm. sieve	g_I gm.	$\frac{g_I}{G}$ x IOO	-2
" " 2 mm. "	g_2 gm.	$\frac{g_I+g_2}{G}$ x IOO	-I
" " I mm. "	g_3 gm.	$\frac{g_I+g_2+g_3}{G}$ x IOO	0
" " 0·5mm. "	g_4 gm.	$\frac{G}{G}$ x IOO	I
Weight of sample	G gm.		

The cumulative percentages are graphed against Phi and so a cumulative curve, such as those of Fig. 2, is quickly constructed.

From the cumulative curve of each sample the following should be calculated and presented : ---

Median diameter in microns (see p. I4) ;
Phi Quartile Deviation (see p. I4) ;
Phi Quartile Skewness (see p. I4) ;
and comments on the curve should be made, particularly regarding its extremes and any points of inflection.

(d) Analysis of Muds.

If analysis of sub-sieve particle sizes is desired a laborious procedure ~~is~~ seems inevitable. As has been mentioned research is very necessary to determine what liberties may be taken without affecting the agglomeration of the sub-sieve particles but which will simplify pretreatment and analysis. The notes below may prove to be over-cautious: it is to be hoped that they stimulate detailed investigations.

Collection/......

Collection and Pretreatment.

The sample is retained with a little natural water in an air-tight jar. No preservative may be added and so animals must be removed before decomposition starts, this being especially important if analysis for organic matter is subsequently to be made.

A water sample must be simultaneously taken for determination of salinity and pH.

Mechanical Analysis.

The aliquot of 150 cc. is passed through successively finer sieves under "natural water". Probably natural water can be replaced without great resulting error by fresh or sea water which has been adjusted to correct salinity and pH. About 2 litres should be sufficient for the complete analysis unless an elutriometer is used. The separated grades are then washed free of salt with tap water, this having negligible effect on the aggregation of particles as large as those retained by sieves. The grades are transferred to weighed dishes, oven-dried at 105° C. and weighed: the oven-dry weight of each grade can thus be calculated. 9-13 cm. flat and round-bottomed porcelain dishes are suitable and weighing is greatly speeded if their empty weights (to the first decimal place) are scratched on with a diamond pencil. Weighing should, however, be accurate to the second decimal.

It is necessary to know the oven-dry weight of the fines which pass the 0·062 mm. sieve in order to determine the weight of the whole aliquot. This cannot be done before sub-sieve analysis and so care must be taken not to lose any in the process. Three methods of sub-sieve analysis are tentatively suggested:-

(i) Elutriation with artificial "natural" water (see above).

The/.......

The water can be continuously circulated through a filter, This method affects subdivision into several grades.

(ii) Separation into 2 grades can be done fairly simply by decantation if no great accuracy is required. The suspension is thoroughly mixed in a I or 2 litre measuring cylinder and allowed to settle. At a known time interval the liquid is divided into two at a known depth by drawing-off the upper layer with an up-turned syphon or by means of a built-in tap. To effect complete separation by this method is tedious because the lower portion of the suspension contains particles smaller than those at the level of separation and therefore it must be diluted to original volume and the separation repeated. Probably 2 repetitions would be accurate enough for most purposes.

(iii) The gradation may be calculated from hydrometer readings without the grades actually being separated. The author used the following simple prodedure but the results require confirmation as to their accuracy. The sub-sieve fines in the sieving water were concentrated by prolonged standing and removal ~~removal~~ of clear water. They were transferred to a I or 2 litre measuring cylinder with the aid of a wash-bottle containing "natural water" and their volume noted. They were thoroughly mixed by means of a perforated plunger (Piper I947, p.65 "stirring paddle") and the time at which stirring ceased was noted as "zero" time. A hydrometer was gently inserted and readings of the top of the meniscus taken as soon as possible and then roughly every 2 minutes at noted times, the instrument being left in the suspension. The bottom of the meniscus could not be read because of excessive turbidity. The hydrometer used was of glass, reading I,000 - I,050 , bulb about 12 cm. long and stem about II cm. long. After about

30/......

30 minutes the reading was almost constant and the temperature of the suspension was noted. The salinity of the "natural water" used was noted. The method of calculating results is given below.

After sub-sieve analysis by any of the above three methods the weight and volume of the dry grades must be determined so that the full weight of the sample is known and so that the density of the sub-sieve grades can be calculated. The grades are concentrated by standing overnight under covers to avoid evaporation, and the clear water is drawn off. Some loss of colloids is usual but with care the weight lost is negligible compared to that of the whole aliquot. Each grade is transferred to as small a weighed measuring flask as possible and the volume made up to the mark with natural water. The whole is weighed and so the combined weight and combined volume of grade and water is calculable. The contents are shaken and poured without loss into a large, weighed, evaporating dish. A round-bottomed dish of 15 cm. diameter is about the smallest that can be used. The flask is cleaned with distilled water which is added to the dish. The dish and contents are oven-dried at 105° C. to constant weight and the weight noted. The difference between the oven-dry weight of the grade plus salt and the weight of the grade plus natural water in the measuring flask gives the volume of water present in the flask and so the volume of the grade is found by difference. Since the salinity of the natural water is known the weight of salt present in the dry grade is known and subtraction gives the oven-dry weight of the grade alone. The approximate density of the grade can be calculated, the figure not being very accurate because of the crudeness of the volume determination.

Holme (1954) speeds sedimentation by flocculating the particles with a little alum solution and a few drops of acetic acid, later filtering the suspension through a weighed filter paper and then washing out the contaminants. A method based on this might be preferred to that outlined in the above paragraph.

Calculation of Sub-Sieve Grades.

(i) The calculation of the particle sizes determined by an elutriometer is largely dependent on the apparatus and so cannot be discussed here. The oven-dry weights of the grades are directly determined as above.

(ii) In the decantation method the size corresponding to that of the particles at the level of division is calculated by means of Stokes' Law: this is more conveniently dealt with under method (iii) below. Decantation is probably the simplest method for determining the position of the third quartile if no more than this is required.

(iii) In the hydrometer method used by the author the readings were converted to bottom-of-the-meniscus readings by applying a correction for its estimated height and these readings were graphed against time from "zero".

Results were calculated by substitution in the equation of Stokes' Law:-

$$v = \frac{2}{9} \times \frac{gr.}{\eta} \quad (D-d) \qquad \text{(Piper 1947)}$$

where v = velocity of sedimentation

g = acceleration due to gravity

η = coefficient of viscosity of the fluid

r = radius of the spherical particles

D = density of the spherical particle

d = density of the fluid

all in c.g.s. units.

For/......

For any time (t. secs.) the corresponding hydrometer reading was read from the graph. The effective depth of the hydrometer was the height(h. cm.) from the centre of flotation (marked by a dot on the bulb) to the stem reading at the bottom of the meniscus. $\frac{h}{t} = v$

Sverdrup et al. (1942. p.69) give a short table of the viscosity of pure and saline waters at 5 deg. C. intervals from 0 - 30°C. The table is "after Dorsey" whose book I have not seen but possibly it contains a fuller table. Salinity has a small effect on viscosity but temperature a large effect. The figures are in $\mu \times 10^3$ c.g.s. units and consequently have to be divided by 10^3 for substitution in Stokes' Law above.

The density (D) of the particles was determined directly as described above (p. 26)

The density (d) of the fluid was calculated with the aid of Knudsen's Tables (1901) where: $d = \frac{\sigma t}{1000} + 1$ this being possible since its salinity and temperature were known. Sverdrup et al. (1942 p.57) state that tables for computing σt directly from temperature and salinity have been prepared by two separate workers.

For each sample Stokes' Law was rearranged as follows:

$$r = \sqrt{\frac{h}{t} \cdot K}$$

where K was a constant $= \frac{9\eta}{2.g.(D-d)}$

and for any given time (t) the diameter of the particles at the effective depth of the hydrometer (h) = 20 r mm.

The hydrometer reading (x_0) corresponding to that of zero time was obtained from the graph by extrapolation; this reading corresponded to 100% of the fines in suspension.

The/.......

The final hydrometer reading (x_f) when all fines were settled was similarly found.

Then: $x_o - x_f$ = 100% of fines in suspension

and : each hydrometer-unit = $\frac{100}{x_o - x_f}$ % of fines in suspension. Therefore, at any time (t), and corresponding hydrometer reading (x_t), the percentage of fines which had dropped below the effective depth of the hydrometer

$$= \frac{(x_o - x_t)\ 100}{(x_o - x_f)}$$

For each time (t) at which particle sizes had been calculated the weight of the particles fallen below the hydrometer was also calculated. It should be noted that this includes some of the finest particles.

Presentation of Results.

All grades are evaluated on the basis of oven-dry weight and cumulative percentages are calculated as described above (p. 23) and plotted against corresponding Phi values. In the case of the sub-sieve grades equivalent Phi values are obtained from Fig. I.

The same results should be presented as suggested at the end of the sub-section dealing with Analysis of Gravels and Sands (see p. 23).

(e) Organic Analysis.

For estimation of organic carbon content by the Walkley and Black method aliquots of about 2 gm. are taken, finely ground in a mortar and then oven-dried on watch glasses; afterwards they are cooled in a desiccator.

The following details of analysis are extracted from Piper (1947), by kind permission of the author, with some slight modifications and additions.

Reagents:

N Potassium Dichromate; Dissolve 49·4 gm. of $K_2 Cr_2 O_7$ (analytical reagent grade) in distilled water and dilute to I litre.

Sulphuric Acid; Not less than 96%

Phosphoric Acid; 85%

Diphenylamine; Dissolve 0·5 gm. diphenylamine in a mixture of IOO ml. conc. sulphuric acid and 20 ml. of water.

N Ferrous Sulphate; Dissolve 278·0 gm. of $FeSO_4 \cdot 7H_2O$ (analytical reagent grade) in distilled water, add 15 ml. of conc. sulphuric acid and dilute to I litre. Standardise by titrating against IO·5 ml. of N potassium dichromate, as described in the method given below. The ferrous sulphate is quite stable if kept under an atmosphere of hydrogen in the reservoir bottle of an automatic burette. A very convenient arrangement, using a burette with an automatic zero, is figured by Piper (I947 p.225)

Method:

Piper recommends transferring each accurately weighed-out sample to a 500 ml. Erlenmeyer flask; but a simpler procedure is to weigh-out each sample into a 15 cm. round-bottomed porcelain dish. Calculation is simplified if the assay be made on samples which weigh in multiples of 0·3 gm.. Samples of I·2 gm. are suitable for non-salty grades which appear to be free of organic matter and 0·6 gm. of salty grades or those rich in organic matter.

Add IO ml. of N potassium dichromate followed by 20 ml. of conc. sulphuric acid. Where large numbers of analyses have to be carried out the dichromate is most conveniently added from a burette with an automatic zero and the sulphuric acid from an automatic pipette. In very shelly grades the addition of sulphuric acid must be cautiously made. Not more than about I ml should be added initially and the dish should be rocked until the effervescence dies down. The remainder of the acid can usually be added rapidly. The dish is placed on an asbestos sheet and stirred for a minute with a thin glass rod, then left to stand for about 30 minutes.

Add about 200 ml. of water, IO ml. of phosphoric acid and I ml. of diphenylamine indicator solution. Titrate by adding ferrous sulphate from the burette until the solution is purple or blue. Continue to add the ferrous sulphate in small lots of about 0·5 ml. , until the colour flashes to green. Then add 0·5 ml. of N potassium dichromate to restore an excess of dichromate and complete the titration by adding ferrous sulphate drop by drop until the last trace of blue colour disappears. If more than 8 ml. of the IO ml. of potassium dichromate originally taken have been reduced during the digestion, repeat the determination using a smaller sample. The blue colour frequently does not reappear on the addition of 0·5 ml. of excess potassium dichromate but it soon redevelops after the addition of ferrous sulphate.

Large amounts of calcium sulphate (precipitated from calcareous soils) or silver chloride (if silver sulphate is used to prevent chlorine interference in saline soils---- see below) tend to alter the shades of the colours produced. The colour change at the end point, however, is still quite sharp and easily recognised.

Where chlorides are present in amounts not in excess of the molecular equivalent of carbon, I·25 gm. of

silver/......

silver sulphate should be dissolved in each IOO ml. of conc. sulphuric acid. Twenty ml. of this acid then contain sufficient silver to precipitate the whole of the chlorides as silver chloride and so prevent their oxidation by the chromic acid.

Calculation and Presentation of Results:

One ml. of the N potassium dichromate is equivalent to 3 mgm. of carbon. The amount of carbon oxidised, expressed as a percentage of the sample, is therefore given by the expression:--

$$\frac{V_I - V_2}{W} \times 0{\cdot}003 \times IOO$$

where V_I = volume of N potassium dichromate (IO·5 ml.)

V_2 = volume of N ferrous sulphate in ml..

W = weight of sample.

V_2 is obtained by slide rule according to the concentration of the sulphate as determined by the standardisation.

If the sample contained chlorides and the silver sulphate modification was not used then the chlorides would be oxidised by the chromic acid with the liberation of free chlorine. A correction must be made for the chromic acid used in this way by deducting one-twelfth of the percentage of chlorine present from the organic carbon value calculated above. N.B. II·83 gm. of chlorine are equal in reducing power to I gm. of carbon.

The results of the analyses can be corrected for three reasons.

Firstly they should be modified to represent more truly the organic carbon "available" as food (see p. I9) It is suggested that all values of 0·4% and less be disregarded and that 0·4% be subtracted from higher values where the grades are composed of shell or faecal pellets. The resulting percentages would be those for "Available" organic carbon (Eg. Table. 2.).

Secondly a correction can be made because the Walkley and Black method does not affect full recovery of organic carbon (see p. I7). If it is assumed that recovery is 75% then the figures obtained by the Walkley and Black method must be multiplied by a factor of I·3 to give percentages of "Available" organic carbon present in the sample.

Thirdly a correction can be applied to convert values for organic carbon into those for organic matter (see p. I9). Let Trask's factor of I·8 be adopted.

The second and third corrections can be combined in one factor, 2·4, by which the percentage of "Available" organic carbon, W. and B. value, is multiplied to estimate the percentage of "Available" organic matter present in the sample.

Thus, the following values may be presented according to requirements:-

"Percentage of organic carbon, Walkley and Black value".

"Percentage of available organic carbon, Walkley and Black value"

"Percentage of available organic carbon present in the sample"

"Percentage of available organic matter present in the sample"

The definition of "available" must be clearly stated and any factors used, given.

SUMMARY/.........

SUMMARY

Some features of soft substrata which affect the benthos are noted and it is suggested that two of them, namely texture and content of dead organic matter, are both important and amenable to study.

Some recent work in this field by ecologists is reviewed and the desirability for uniformity in methods and presentation of results is stressed.

Some ecological work is criticised on the grounds that the methods of analysis have altered the natural state of the substratum.

In texture analysis Pretreatment, Mechanical Analysis and Presentation of Results must be considered together prior to actual collection of the sample.

The following suggestions are made:--

(i) If sub-sieve analysis is to be attempted samples must be kept in "natural water" prior to and throughout mechanical analysis so that the degree of agglomeration of the fine particles is not altered.

(ii) Neither carbonates nor organic matter may be eliminated prior to mechanical analysis.

(iii) Sieves must conform to the Wentworth scale, the minimum mesh being 0·062 mm..

(iv) Grades to be evaluated on the basis of oven-dry weight.

(v) Results to be translated into cumulative curves related to the Phi scale. The following to be given:-

Median diameter in microns;

Phi Quartile Deviation;

Phi Quartile Skewness;

Notes on special features of the curves.

Notes are given on procedures of mechanical analysis.

Methods/...

Methods of organic analysis are very briefly reviewed and the Walkley and Black method for estimation of organic carbon is put forward as suitable.

It is noted that corrections must be made to the Walkley and Black values to approach more nearly the figure for organic carbon available as food. Also the factor of 2·4 is suggested for converting the pereentage of available carbon, Walkley and Black value, into percentage of available organic matter in the sample.

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APPENDIX.

Seven substratum samples were analysed and the grades evaluated both on a by-weight and by-volume basis. The object was to determine whether there were important differences in the results.

The method of analysis was as follows. An aliquot was wet-sieved in natural water. The separated grades were washed free of salt in tap water and transferred to measuring cylinders of the minimum size campatible with the diameter of the particles and the quantity of the grade. In general the capacity of the cylinder was 2-3 times as great as the apparent volume of the grade. The combined volume of grade plus water was read and both transferred without loss into a weighed dish. The weight of grade plus water was noted and the whole oven-dried at I05°C. and then reweighed. Loss in weight on drying gave (approximately) the original amount of water present and since the combined volume of grade and water had been measured the volume of the oven-dry grade could be calculated. In the case of sub-sieve grades the water used was saline and so the oven-dried grades contained weights of salt which could be calculated from the known salinity of the water. Thus the weight of each grade alone could be calculated.

The weight of each grade was accurate to the second decimal place ± 0·0I. The volumes, as read from the cylinders, were probably accurate to the first decimal ±0·I where the grades were less than 20 cc; and to the nearest whole number in larger grades. The method of volume determination was fairly susceptible to errors of manipulation but was preferred to that of adding water to the dry grade (adopted by Fraser I932) because the grade ended up dry

and/......

and ready for organic analysis. In check of accuracy however, two dry grades were reconstituted with the weight of water lost on oven-drying and the combined volume agreed with that originally determined with the margin of error mentioned.

For each substratum cumulative percentages by weight and by volume were calculated and graphed against the Phi scale. The values of three of the substrata are entered in Fig. 2 where curves are only drawn for the by-weight values. In all seven samples the by-weight and by-volume curves were very similar. In two substrata they were effectively identical (including FAL. 94) and in the other five varied differently with each, in some running parallel (e.g. FAL. 283) and in others crossing (e.g. LIZ. 23) or diverging. But the maximum divergence of the cumulative percentages by weight and by volume at any particle size was 2·6% (FAL. 283). In comparing the results of analysis the by-weight and by-volume figures correspond as follows:-

Median diameter	±	25 microns
Phi Quartile Deviation	±	0·05
Phi Quartile Skewness	±	0·I

The following conclusions were drawn :-

(i) analysis by volume is more laborious and less accurate than analysis by weight.

(ii) in view of the low accuracy of analysis by volume the small differences in the by-weight and by-volume cumulative curves are not held to be important.

(iii) in view of the above comments analysis is best done on the basis of weight.

Paper 2

THE BENTHIC ECOLOGY OF FALSE BAY :

PART I :

"ANNOTATED LIST OF SPECIES."

THE BENTHIC ECOLOGY OF FALSE BAY.

Part I. ANNOTATED LIST OF SPECIES.

There is no comprehensive check list of species for any marine region in southern Africa, still less one annotated with ecological data. Such a list would stimulate local ecology and help overseas workers in world zoogeography.

A complete list of species from the marine region around southern Africa would be very large because of the wide range of hydrographic conditions to be found but a start can be made by listing those below tide marks in False Bay which has been studied now, off and on, for some nine years. This Bay has no appreciable estuarine influence : it is a slightly sheltered arm of the sea some 400 sq. miles in area, situated south of Cape Town. The maximum depth is about 90 m. which is found in the mouth. Further details, and maps, are given in parts II and III of this series. The important point is that False Bay is readily accessible and one can assume that further work will be done augmenting the data given here until a fairly full picture of its ecology is obtained.

Two aspects of local benthic ecology are now well documented, namely the intertidal rocks and estuaries. Students of the intertidal region must know of the survey directed by Professor T.A.Stephenson from Cape Town University. Stephenson (I944) lists the most important animals and plants encountered and adds to the list of plants in a later paper (I947). His survey expressly rejected the idea of compiling a list of all species to be found for the cogent reason that they were pioneering the ecology of a coastline I800 miles long and which supported, as they showed, at least four major geographical groups of animals and plants.

Unfortunately no list of all animals collected by them has been published yet. Lists which approach nearer to check lists have been published for various South African estuaries in the survey conducted by Professor J.H.Day. Reference may be made to Scott, Harrison and Macnae (1950); Day, Millard and Harrison (1951); Day, Millard and Broekhuysen (1951); Millard and Harrison (1951); Millard and Scott (1953); Day and Morgans (~~in press~~ 1956). These lists include intertidal soft bottom species as well as those of rocks and often include dredged and pelagic species as well.

This series of papers considers only the shallow infratidal region of the sea. In this first paper all reliable records of benthic species of False Bay are listed, some 850 in all. Their depth ranges are given and the types of bottom on which they have been found together with their general abundance. Since False Bay is but part of the continental shelf the depth ranges have been extended according to reliable records from nearby so that a truer understanding is obtained of the vertical distribution of each species in this part of the world. In addition the horizontal distribution of some species is indicated and various notes are given.

Part II of the series describes the biotas of infratidal rocks as observed by diving and compares them with ~~infra~~ intertidal biotas nearby. In part III the results of dredging in the bay are reviewed with diving observations of soft bottoms. Part III concludes with an analysis of the vertical distribution of the infratidal species of False Bay as given in this check list and relates the analysis to the conclusions drawn from diving and dredging results.

Species Listed.

False Bay was investigated by both dredging and diving and the collections are recorded in two catalogues, from 1946 until 195I in the "FB" catalogue and subsequent work in the "FAL", which is still current. These catalogues and reference specimens are lodged at the University of Cape Town. The following tabulated list summarises the whole of the identified material in the FB catalogue and that of the FAL catalogue as far as the entry "FAL.32I" of the 24th April 1955.

The bulk of this was identified by the author who had to hand the Department's large collection of homoeotypes. Even so much material was passed on to specialists and it is a great pleasure to acknowledge here their invaluable aid.

For almost complete identification of the following groups:-

Hydrozoa ------ Dr. N.A.H. Millard, Zoology Dept., University of Cape Town.
Nemertea, Turbellaria ------ Dr. S. Prudhoe, British Museum of Natural History, London.
Brachiopoda ------ Dr. J.W. Jackson, Buxton, England.
Sipunculoidea ------ Miss C.M. Jones, Zoology Dept., U.C.T.
Polychaeta ------ Professor J.H. Day, Zoology Dept., U.C.T.
Tanaidacea ------ A.C. Brown, Zoology Dept., U.C.T.
Amphipoda and Isopoda ------ Dr. K.H. Barnard, The Director, South African Museum, Cape Town.
Holothuroidea ------ Dr. G. Cherbonnier, Museum National d'Histoire Naturelle, Paris.
Tunicata ------ Dr. R.H. Millar, Marine Station, Millport, Scotland.

For assistance with the following groups :-

Non-coralline Algae ------ Professor W.E. Isaacs, and Miss J. Graves, Botany Dept. U.C.T.
Alcyonaria ------- Mme. A. Tixier-Durivault, Museum National d'Histoire Naturelle, Paris.
Opisthobranchiata ------ W. MacNae, Zoology Dept., Rhodes University, Grahamstown.
Streptoneura, Pelecypoda ------ Dr. H. Rehder, Smithsonian Institute, Washington, U.S.A. and Dr. K.H. Barnard, Director, S. African Museum, Cape Town.
Decapod Crustacea, Pycnogonida ------ Dr. K.H. Barnard, Director, S. African Museum, Cape Town.
Echinodermata (except Holothuroidea)--- Miss A.M. Clark, British Museum of Natural History, London.
Pisces ------ Professor J.L.B. Smith, Ichthyology Dept., Rhodes University, Grahamstown.

On the other hand it is very regrettable that certain important groups in the collections are only partially identified, if at all. Many Algae remain unidentified, including virtually all the jointed corallines and the encrusting forms, so important in the shallows, which are referred to as "Lithothamnia"-type for the coralline forms and "Ralfsia"-type fpr the non-coralline. No sponges or hard Polyzoa are identified, both these groups containing numerous species and being abundant in quantity. Lesser deficiencies occur with the anemones and the Alcyonaria (Mme. Tixier-Durivault has recently kindly accepted another collection of the latter for examination).

As a rule only well identified species are listed, most being referable to homoeotypes. A few species are included which are very characteristic yet not fully identified and these are suffixed with the code numbers of reference specimens: the same is done with new species for which descriptions are not yet published.

A surprising number of species not found by us have been recorded from False Bay by various expeditions. Many references in the literature to species found " in Simon's Bay", "in False Bay" or "at the Cape of Good Hope" are vague but where precise locality and depth are given records are included here and indicated by prefix of an asterisk.

Depth Range.

The datum to which all heights and depths are related in this work is that of the tide guage operated by the South African Railways and Harbours in Cape Town harbour. This choice should simplify future work at different places nearby. The datum is stated to be at L.W.O.S. (or M.L.W.S.) level for Table Bay but in False Bay M.L.W.S. level is about 3½ inches below this datum, a negligible difference for most purposes. This datum demarcates by definition the intertidal Zone from the infratidal: the matter is further discussed in part II.

The shallowest and deepest records of each species have been noted from FB and FAL catalogue entries and then extended on the following lines.

Ranges have been extended upwards according to Departmental records of intertidal collections around the Cape Peninsula ; also from intertidal records between Yzerfontein and Still Bay as found in the literature and Stephenson's survey. The abbreviation "Int." is used to indicate that a species has been recorded intertidally.

Ranges have been extended downwards according to some Departmental records of trawling between the longitudes of Cape Point and Cape Agulhas. Where possible depth extensions have also been made according to information from this area in the literature but it has been impossible to treat all species uniformly because of continual addition of species to the list. However, all common species are probably adequately treated.

Depth ranges have not been extended according to records from estuaries and lagoons (e.g. Langebaan Lagoon, Saldanha Bay, Durban Bay) since conditions there are not truly marine .

The following table provides ready conversion from metres to feet and fathoms (adjustment of the decimal point and addition gives intermediate figures).

m.	ft.	fath.	m.	ft.	fath.
5	I6	2·7	40	I3I	2I·9
I0	33	5·5	45	I48	24·6
I5	49	8·2	50	I64	27·3
20	66	I0·9	60	I97	32·8
25	82	I3·7	70	230	38·3
30	98	I6·4	80	263	43·7
35	II5	I9·I	90	295	49·2

Bottom Type.

An indication is given of the types of bottom upon which species are found in False Bay but the possibility of errors in assessing bottom types must be borne in mind.

The symbols used are as follows :-

co	Coarse	so	Soft	Sn	Shingle
f	Fine	w	White	G	Gravel
gn	Green	M	Mud	St	Stones
k	Khaki	S	Sand	R	Rock
l	Limestone	Sh	Shell	L	Twiggy "*Lithothamnion*"-type coralline

The symbols of different bottoms are separated by commas; for mixed bottoms the symbols of the components are separated by "&". Doubtful bottom types are entered in brackets.

Abundance.

Only abundance below tide marks in False Bay is considered. Hard and fast systems of assessment are impracticable but an attempted assessment is better than none. The following symbols are used ;--

A Abundant
C Common
F Fairly common
P Present
L Locally

Reference to literature.

Where a species is mentioned in the literature as found in False Bay an author and date reference is given for which there are full details in the bibliography following the list. This is not intended as a complete bibliography of local, shallow marine work much of which is given by Stephenson (1947).

Geographical Notes.

In dealing with the horizontal distribution of South African intertidal species Stephenson (1944) postulated a series of categories related to the western, southern and eastern coasts and found that in fact the categories combined in such a way that four major biotic components emerged. Many of the species found in his survey are listed here and so some further details as to their intertidal distribution are obtainable from Stephenson's papers of 1944 and 1947 (a map of localities is given in the latter).

Unfortunately the distribution of infratidal species is by no means as well known as it cannot be assumed that the same components are present as intertidally. Therefore only general notes on geographical distribution are given, principally whether the species is found westward ("W") and eastward ("E") of the False Bay region which is taken as from the mouth of Saldanha Bay to Still Bay. Distribution within these limits is given in brackets as being of rather local importance only. This information on geographical distribtuion is by no means complete and should be amplified by future work.

Distributions in estuaries and lagoons is noted in brackets since their conditions are not truly marine.

Acknowledgements.

Much help has been given by friends in the Department and outside it who I hope will accept this brief and general note of sincere thanks. I wish to thank in particular Professor Day and to express my pleasure in acknowledging his advice and encouragement that so stimulated this work.

My gratitude to the many specialists who have identified material is already recorded.

	Depth Range (metres)		Bottom Type	Abundance	Notes	References	Geographical Notes
ALGAE							
Chlorophyceae							
Byropsis near tenuis Levring (FAL.III S) Bryopsis	2	7	R	P	B.tenuis occurs intertidally	Stephenson 1947	B.tenuis extends W of False Bay
Caulerpa bartoniae Murray	0	4	R	P,LC	--	--	--
" filiformis (Suhr.)Hering	Int.	17	coS,Sh, St,R	C,LA	Olim C.ligulata Virtually confined to northern half of False Bay	Stephenson 1947	Extends E of False Bay
" holmesiana G.Murray	Int.	7	St,R	C,LA	--	Stephenson 1947	E
Codium duthieae Setch.	Int.	6	S,St,R	P	--	Stephenson 1947	W & E
" stephensiae Dickinson	Int.	6	S,St,R	P,LF	--	Stephenson 1947	(W to Melkbosch), E
Ulva spp.	Int.	26	kS,R	F	--	Stephenson 1947	--
Phaeophyceae							
Bifurcariopsis capensis (Aresch.) Papenf.	Int.	4	R	P	--	Stephenson 1947	W & E
Carpomitra chytraphora Kütz	0	1	R	P	--	--	--

Colpomenia sinuosa (Roth.) Derb. & Sol.	Int.	4	R	P	Sometimes epiphytic on Patellids	Stephenson 1947	E
Dictyota dichotoma (Huds.) Lamour	Int.	6	St,R	C,LA	--	Stephenson 1947	E
" naevosa (Suhr.) J. Ag.	8	12	R	P	--	Stephenson 1947	E
Ecklonia maxima (Osbeck) Papenf.	Int.	10	St,R	P-A	Virtually confined to southern half of False Bay	Stephenson 1947	W, (E to Danger Point)
Leathesia difformis (L.) Aresch.	Int.	7	Sh,R	F,LC	Often epiphytic on Patellids	Stephenson 1947	W & E
"Ralfsia"-type spp.	Int.	6	R	F,LA	Commonly epiphytic on Patellids, <u>Turbo</u> spp., & <u>Argobuccinum</u>	--	--
Sargassum heterophyllum (Turn.) Ag.	Int.	12	St,R	C	--	Stephenson 1947	E
Zonaria ? cuneata (Kütz.) Papenf.	Int.	7	R	C	Often epiphytic on <u>Pyura</u>	Stephenson 1947	Z.cuneata extends E
" ? harveyana (Pappe ex Kütz) Aresch.	Int.	9	R	P	Occasional epiphyte on Patellids	Stephenson 1947	<u>Z.harveyana</u> extends E

Rhodophyceae ~~?Int~~

A. Corallinaceae

Amphiroa ? ephedraea (Lamk.) Decaisne	?Int.	11	R	F,LA	--	Stephenson 1947	A. ephedraea extends E
" ? peruana Aresch.	?Int.	12	Sh,R	F,LA	A.peruana has been recorded intertidally in False Bay	Stephenson 1947	--
Arthrocardia ? attenuata Manza	?Int.	6	St,R	P,LA	--	Stephenson 1947	A.attenuata extends E
" ? stephensonii Manza	?Int.	4	R	P,LA	--	Stephenson 1947	A.stephensonii extends E
Cheilosporum ? cultratum (Harv.) Aresch.	?Int.	5	R	P,LA	--	Stephenson 1947	C.cultratum extends E
Corallina spp.	Int.	17	R	P	Epiphytic on Pyura	Stephenson 1947	--
Jania ? digitata Manza	?Int.	3	R	P	--	Stephenson 1947	J.digitata extends E

B. Other Rhodophyceae

Acrosorium acrospermum (J.Ag.)Kylin	Int.	14	R	P	--	Stephenson 1947	E
Aodes orbitosa (Suhr.) Schm.	Int.	11	St,R	C	--	Stephenson 1947	W, (E to Cape Agulhas)
Champia compressa Harv.	Int.	4	R	F	Sometimes epiphytic on Patellids	Stephenson 1947	(W to Oudekraal), E

Chylocladia capensis Harv.	Int.	2	R	P,LC	Often epiphytic on Patellids	Stephenson 1947	W & E
Dicurella fragilis (Ag.) J.Ag.	Int.	4	R	F,LC	--	Stephenson 1947	W, (E to Cape Agulhas)
" scutellata (Her.) Papenf.	Int.	5 (possibly 17)	R	F,LA	Small specimens like this species were found at 12-17 m.	Stephenson 1947	W & E
Falkenbergia rufolanosa (Harv.) Schmitz.	Int.	6	R	P,LA	Only observed as an epiphyte of seasonal occurrence	Stephenson 1947	E
Gelidium cartilagineum (L.) Gaill.	Int.	5	R	P	--	Stephenson 1947	W & E
Gigartina stiriata (Turn.) Aresch.	Int.	2	R	P	Small epiphytes on Patellids	Stephenson 1947	W, (E to Cape Agulhas)
Hypnea spicifera (Suhr.) Harv.	Int.	5	R	F	--	Stephenson 1947	W & E
Laurencia glomerata Kütz	Int.	6	St,R	F,LC	Often epiphytic on Patellids	Stephenson 1947	E
"Lithothamnion"-type spp.	Int.	18	coSH,coS St,R	C,LA	Very characteristic of shallows; often epiphytic on Pyura, Patellids & other Gastropods. Only the bramched type fpund on sandy bottoms.	Stephenson 1947	--

Plocamium corallorhiza (Turn.) Harv.	Int.	5	R	F,LC	--	Stephenson 1947	(W to Melkbosch), E
" cornutum (Turn.) Harv.	Int.	6	St,R	F,LC	--	Stephenson 1947	W, (E to Arniston)
" ? membranaceum Suhr.	?Int.	17	coS & Sh,R	F	--	Stephenson 1947	--
" rigidum Bory	Int.	12	R	P	--	Stephenson 1947	W & E

PORIFERA

* Desmacidon conulosa Ridley & Dendy	18	37	?	2 Specimens	--	"Challenger" 1895	--
* " (Homoeodictya) grandis Ridley & Dendy	18	37	?	1 Specimen	--	"Challenger" 1895	--
* Esperella simonis Ridley & Dendy	18	37	?	3 Specimens	--	"Challenger" 1895	--
* Geodia peramata Bowerbank	33	46	R	P	Found at Rocky Bank	Burton 1926	--
* Higginsia bidentifera (Ridley & Dendy)	18	37	?	P	--	Govt. Biol. 1903, "Challenger" 1895	--
* Proteleia sollasi Ridley & Dendy	18	37	?	1 Specimen	--	"Challenger" 1895	--
* Raspailia flagelliformis Ridley & Dendy	18	37	?	1 Specimen	--	"Challenger" 1895	--

* Rhaphidolphus lobatus (Vosmaer) var. horrida Ridley & Dendy	18	37	?	1 Specimen	--	"Challenger" 1895	--
* Tetilla bonaventure Kirkpatrick	40	40	?	1 Speci~~/~~men	--	Kirkpatrick 1902	--
* " casula Carter	40	40	?	1 Specimen	--	Kirkpatrick 1902	E
BRACHIOPODA							
Kraussina crassicostata Jackson	4	48	Sn,St,R	F	Very common on rocks at 25-35 m. Found intertidally at Mossel Bay	Jackson 1952	E
Terebratulina sp. (FAL. 136 Z)	0	2	R	P	Very young specimen, possibly T.meridionalis Jackson	--	~~E~~ --
POLYZOA							
Alcyonidium nodosum O'Don.	Int.	17	(Sh),St,R	F,IA	An apparently inseparable epizoon of Cominella papyracea (Brug.)	--	W
* Beania magellanica Busk	35	146	M,probably also S&Sh	P	--	O'Donoghue 1922, Hastings 1943	"World-wide"

Bugula ? calanthus Norman	14	23	Sh,R	P	--	--	--
" ? dentata (Lamx)	?Int.	38	Sh,St,R	F,LC	--	--	B.dentata extends E
" ? robusta (MacGillivray)	?Int.	3	R	P	--	--	B.robusta extends E
* Chorizopora brongniartii (Audouin)	33	33	?	P	--	"Challenger" 1895	N.Atlantic, Mediterranean
Electra verticillata Lamx.	Int.	22	S,R	P	Only found on soft bottoms if *Pyura* present	--	W & E
" " " var. curvispina O'Don.	?Int.	15	S	P	Only found on soft bottoms if *Pyura* present	--	--
Hippothoa hyalina (L.)	Int.	27	S,R	P	Only found on soft bottoms if *Pyura* present	--	E
* Idmonea atlantica Forbes	33	33	?	P	--	"Challenger" 1895	--
Menipea crispa (Pallas)	0	73	coS,Sh, ~~GoSSh~~ kSh&G, St,R,~~IR~~ lR	C	Although typically a species of rocks this is frequently found on shells & stones of soft bottoms, as an epizoont	--	--

Menipea marionensis Busk	26	27	fS	P	--	--	--
" ornata (Busk)	0	64	cokS,R	F	--	--	--
" triseriata Busk	Int.	50	Sh,R,lR	C	Often epizoic on *Pyura* etc.	--	W & E
Onchoporella bombycina (L)	Int.	38	coS,L,Sh, R,lR	C	--	--	W & E
HYDROZOA							
Gymnoblastea							
* Bougainvillea ramosa (van Beneden)	70	126	?	P	--	Stechow 1925	E (Agulhas Bank)
Coryne sp. (FAL.311 T)	Int.	1	R	P	--	--	--
Eudendrium ? antarcticum Stechow (FAL.288 H)	18	18	?R	P	--	--	--
" ? parvum Warren	0	3	R	P	--	--	--
" n.sp. (FAL.52 V)	0	73	kSh&G,R	F	Typically a hard bottom species	--	--
Hydractinia altispina Millard	Int.	24	R	P,LC	Commensal on *Thais aquamosa Lamk.*	Millard 1955	W
" carnea (M.Sars)	15	82	Sh,(S,St)	F	Often commensal on the Gastropod *Hinia speciosa*	--	--

Hydractinia n.sp. (FAL.183 N)	73	73	kSh&G	P	On Clavus tumida. Material too poor for description	--	--
Hydrocorella africana Stechow	Int.	100	fSn,R	F	Very characteristic. On small, empty Gastropod shells	Stechow 1921	(W to Oudekraal), E
Leuckartiara octona (Fleming)	3	82	S,Sh	F	Often commensal on the Gastropod Bullia annulata	--	--
Myriothela capensis Manton	Int.	27	R	P	--	--	E
Tubularia sp. (possibly solitaria Warren)	?Int.	3	R	P	Not identifiable further. T.solitaria is found intertidally	--	T.solitaria extends (W to Oudekraal), E
Haleciidae							
Halecium beanii (Johnston)	0	73	Sh,kSh&G,R	F	Typically a hard-bottom species. In interdidal pools	--	--
" dichotomum Allman	14	33	R	P	In Francis Bay, 100 m.	Stechow 1925	E
" parvulum Bale	0	73	kSh&G,R	C	Typically a hard-bottom species. In interdidal pools	--	--

Halecium parvulum Bale n.var. (FAL.247 R)	0	58	(S),R	F	--	--	--
" tenellum Hincks	40	40	?	P	--	--	--
Hydrodendron caciniformis (Ritchie)	14	17	R	P	--	--	--
<u>Campanulariidae</u>							
Campanularia integra (MacGil.)	Int.	22	L,S,Sh, St,R	C	<u>Orthopyxis caliculata</u> is a synonym. Common on <u>Pyura</u>	--	--
" n.sp. (FB.119 L)	15	109	(gnM),R	F	Probably is typically a hard-bottom species	--	--
Clytia gracilis (M.Sars)	5	126	Sh,R	C	--	Stechow 1923	E (Agulhas Bank)
* Laomedia calceolifera (Hincks)	70	70	?	P	--	Stechow 1925	--
Obelia dichotoma (L.)	Int.	27	S,Sh,R	F-C	--	--	--
<u>Campanulinidae</u>							
Lovenella n.sp. (FAL.288 J)	5	18	R	P	--	--	--
<u>Lafoeidae</u>							
Hebella scandens (Bale)	0	100	(fSh),R,lR	C	Frequently on soft bottoms from 15-75 m.	Stechow 1925	E (Agulhas Bank)

Hebella n.sp. (FAL.58 Y)	12	18	R	P	--	--	--
Reticularia serpens (Hassall)	11	40	Sh,R	P	--	--	--
Scandia mutabilis (Ritchie)	?	?	?	P	"Off Buffels Bay". Material from S.Afr. Museum.	--	--
Zygophylax cornucopia Millard	Int.	18	R,lR	P	--	Millard 1955	(W to Table Bay)
<u>Syntheciidae</u>							
Synthecium ? elegans Allman (FAL.66 H)	16	73	R	P	--	--	--
" sp. (FAL.214 G)	42	42	R	P	--	--	--
<u>Sertulariidae</u>							
Amphisbetia bidens (Bale)	16	19	R	P	--	--	--
" minima (Thompson)	0	3	R	P	Only found in a shallow cave	--	--
" operculata (L.)	Int.	70	L,S,Sh St, R, lR	C	Often on <u>Pyura</u>	Stechow 1925	(W in Saldanha Bay), E
Dictyocladium coactum Stechow	0	73	kSh&G,R	C	--	--	--
Salacia articulata (Pallas)	Int.	62	S,Sh,R	C	Typically a rock-bottom species. Intertidally usually in pools	--	--

Sertularella	africana Stechow	Int.	17	R	P	--	--	E
"	arbuscula (Lamx.)	Int.	100	S,Sh,kS&G, R,lR	C-A	Many synonyms. Very frequent -ly found on soft bottoms almost throu-ghout its range	Marktanner-Turneretscher 1890, Allman 1885, Kirchenpaur 1884	(W in Saldanha Bay), E
"	flabellum (Allman)	18	155	S,G,R	P	--	Stechow 1925, Allman 1888	E, (Agulhas Bank)
"	fusiformis (Hincks) forma glabra Broch	0	18(70)	S,Sh,St,R	F	Sometimes on Pyura. Prob-ably S.lineata Stechow is syn-onymous: this has been found in False Bay at 70 m.	Stechow 1923	--
"	goliathus Stechow	18	40	coS&fSh,R	P	--	--	--
"	mediterrania Hartlaub	Int.	73	kSh&G,R	P	--	--	(W to Oudekraal), E
"	megista Stechow	0	73	kSh&G,R	F	--	--	--
"	polyzonias (L.)	12	36	R	P	--	--	--
* "	pulchra Stechow	70	70	?	P	--	Stechow 1923	E
"	xantha Stechow	18	46	S,Sh	P	--	--	--
"	n.sp. (FB.119 C)	0	27	S,R	P	Sometimes on Pyura	--	--

Sertularella n.sp. (FB.114 A)	27	38	S,Sh,fSn,R.	P	--	--	--
Sertularia distans (Lamx.) var. gracilis Hassall	0	17	R	P	--	--	--
" marginata (Kirch.)	33	33	R	P	--	--	--
Symplectoscyphus macrogonus (Trebilcock)	0	17	R	F	In intertidal pools	--	--

Plumulariidae

* Aglaophenia attenuata Allman	18	37	?	P	--	Hartlaub,1905, Allman 1883	--
" pluma (L.) var. dichotoma (M.Sars)	Int.	30	S,Sh,Sn,St	C (LA 15-25 m.)	Apparently the commonest variety on soft bottoms	--	--
" pluma (L.) var. parvula Bale	Int.	70	S,R	C (LA 5-15 m.)	The commonest intertidal form, incorrectly referred to as A.dichotoma in the Stephenson survey(Stephenson 1944 & 1947). Not confined to pools & crevices intertidally. Apparently the commonest variety on rocks	Stechow 1925	W (including Saldanha Bay), E

Aglaophenia pluma (L.) var. typica Bedot	11	25	S,Sh,R	P	A.chalerocarpa is a synonym	Vervoort 1946	W, (E in Knysna Est. & Durban Bay)
Antenella africana Broch	Int.	100	Sh,R,lR	C (LA 5-15 m.)	Typically a hard-bottom species	Stechow 1925	W & E
Antennopsis scotiae Ritchie	Int.	73	coS,Sh,R,lR	F	Although common on soft bottoms from 35-50 m. this is probably more typically a hard bottom species	--	--
Halopteris constricta Totton	12	19	R	P	--	--	--
" valdiviae (Stechow)	33	33	R	P	--	--	--
Kirchenpaureria pinnata (L.)	Int.	22	(S),Sn,R	C	A truly intertidal sp., not limited to pools & crevices. Often on Pyura. K.unilateralis is a synonym	--	(W in Langebaan Lag.), E
Lytocarpus filamentosus (Lam.)	Int.	24	(S),R	F (LA 15-25 m.)	Typically a hard bottom species	--	E

Nemertesia cymodocea (Busk)	5	56	S,Sh,Sn,R.1R	C	Often on <u>Pyura</u>	--	--
" ramosa Lamx.	36	62	S,R	P	--	--	--
Paragattya intermedia Warren	8	70	R	P	--	~~Thomson 1921~~ Stechow 1925	E
Plumularia lagenifera Allman	2	17	R	P	--	--	--
" pulchella Bale	0	27	Sh,R	C	Typically of rock bottoms	--	--
" setacea (Ell. & Sol.)	Int.	40	coS,Sh,R,1R	C-A	Typically a hard-bottom species, often on <u>Pyura</u>	--	E
" spinulosa Bale var. obtusa Stechow	--	--	--	P	Position of collection vague	--	--
Pycnotheca mirabilis (Allman)	8	17	R	P	--	--	--
Thecocarpus giardi Billard	?	?	?	P	"Off Buffel's Bay": material lent by S.Afr. Museum	--	--

MADREPORARIA

* Cladocora arbuscula M-Edw. & Haime	I8	37	?	I specimen	--	"Challenger" I895	--
* Manicina areolata (L.)	I8	37	?	I Specimen	--	"Challenger" I895	--

CORALLIMORPHARIA

Corynactis (Melactis) annulata (Verr.)	Int.	73	kSh&G, Sh,St,R	A	Frequent on hard bottoms from 5-25 m.. Often epizoic but typically a hard-bottom species.	Carlgren I938 //	W & E

ACTINIARIA

Actinia equina L.	Int.	6	R	P	--	--	W & E

Anthothoe (Cereus) stimpsoni (Verr.)	Int.	40	(S),Sh,St, R,lR	A	Typically a hard-bottom species; common on *Pyura* on which it may be found on soft bottoms	Carlgren 1938	W & E
* Bolocera capensis Carlgr.	91	200	?	?	Noted from mouth of False Bay, probably not found within bay	Carlgren 1938	W
?Bunodactis (Cystiactis) reynaudi (M-Edw.)	?Int.	18	S,Sh,R,lR	F	--	--	*B.reynaudi* extends W & E
Bunodosoma (Actinia) capensis (Less.)	Int.	20	Sh,Sn,R,lR	F-C	Often on *Pyura*	--	W & E
?Edwardsia capensis Carlgr.	88	(91)	gnM	P	*E.capensis* found in False Bay at 91 m.	Carlgren 1938	--
* Halcampa capensis Carlgr.	91	91	?	1 Specimen	--	Carlgren 1938	--
?Halianthella annularis Carlgr.	?Int.	4	R	P	--	--	*H.annularis* extends W
* Haloclava capensis (Verr.)	22	22	S	P	--	Verrill 1899, Carlgren ~~1938~~ 1949	--
* " (Edwardsia) brevicornis Stimps.	32	32	?	P	--	Verrill 1899	--
?Isanthus capensis Carlgr.	?Int.	24	Sh,St,R	P	--	--	*I.capensis* extends W

Pseudactinia (Comactis) flagell-ifera (R.Hertw.)	Int.	46	S,Sh,St,R,lR	A	Typically a hard-bottom species; Often on Pyura	Carlgren 1938, "Challenger" 1895	W & E
" varia Carlgr.	Int.	27	R	P, ?C	Identificat-ion not easy in preserved specimens	Carlgren 1938	E
ZOANTHERIA							
Epizoanthus similis Carlgr.	46	91	S,kS,Sh, kSh & G	A	Very charact-eristic of deep, soft bottoms. Commensal on shells inhabited by Anapagurus hendersoni	Carlgren 1938	--
?Palythoa capensis Hadd. & Shackl.	73	73	kSh,& G	P	P.capensis found from 18-37 m.	Carlgren 1938, "Challenger" 1895	--
* Parazoanthus capensis Deurd.	62	62	?	P	--	Carlgren 1938, Deurden 1907	--
* Zoanthus capensis Carlgr.	18	37	?	P	--	Carlgren 1938, "Challenger" 1895	--
ALCYONARIA							
Actinoptilum molle Kükthl.	20	90	S,Sh	P, ?C	--	Thomson 1924, Hickson 1905, Hickson 1900, Brock 1939	--

* Alcyonium (Metalcyonium) novarae Kükthl	18	46	?	R	--	Thomson 1924, Thomson 1921	--
* " purpureum Hickson	Int.	24	Sh	P	--	Thomson 1924, Thomson 1921, Thomson 1910	--
?Capsella rugosa Kükthl.	?Int.	17	Sh, R	P, LC	--	--	C. rugosa extends (W to Oudekraal) & E
* Clauvularia cylindrica W. & S.	20	20	R	P	--	Thomson 1924, Thomson 1921	--
* Eunephthya thyrsoides Verrill	37	37	R	P	--	~~Hickson 1900~~, Hickson 1902 Hickson 1905 Thomson 1910	--
Eunicella alba (Esper)	25	25	?	P	--	--	--
Eunicella ? papillosa (Esper)	0	48 (91)	(Sh), Sn, St, R, 1R	F, LC	E. papillosa found at 0-91 m.	Hickson 1905, Thomson 1924, Thomson 1916-17, Thomson 1911, Brock 1939	(W to Table Bay)
?Gorgonia albacans Külliker	4	46	(Sh), R	F, LC	G. albicans found at 11-26 m.	Hickson 1905, Thomson 1924, Thomson 1916-17	--
?Heteroxenia capensis Hickson	14	46 (80)	(S), Sh, G, R, 1R	F, LC	H. capensis found at 37-80 m.	Hickson 1905, Brock 1939, Hickson 1900	--
~~Lophogorgia flammea (Ell. & Sol.)~~	~~Int.~~	~~73~~	~~(Sh), St, R, 1R~~	~~C-A~~	~~Very typical of rocks down~~	~~Hickson 1905,~~	~~E~~

Lophogorgia flammea (Ell. & Sol.)	Int.	73	(Sh),St,R, lR	C-A	Very typical of rocks down certainly to 25 m.	Hickson 1905, Gilchrist 1898, Hickson 1900, Thomson 1924, Brock 1939	E
* " lütkeni W. & S.	15	26	R	--	--	Thomson 1924, Thomson 1916-17	--
* Malacacanthus rufus St J.Thomson	20	60	R	--	--	Hickson 1930, Thomson 1924, Thomson 1921	--
* Melitodes dichotoma Pall.	7	75	R	--	M.africana Kükth. in Thomson 1924 & Hickson 1937 is probably this species	Hickson 1905, Hickson 1900, Hickson 1937, Thomson 1924, Thomson 1911	--
Parerythropodium roseum Tix.-Dur.	27	28	S & R	P	--	--	--
* Veretillium sp.	57	66	fS	--	--	Gilchrist 1898	--
* Virgularia schultzei Kükthl.	60	183	M,gnS	"C"	--	Gilchrist 1898, Thomson 1924, Thomson 1915, Brock 1939	--

<u>NEMERTEA</u>

Amphiporus africanus Wheeler	1	22	S & R,R	F	Found intertidally at East London	Wheeler 1940, Wheeler 1934	(W in Saldanha Bay), E

Cephalothrix sp. (FAL.22 Z)	11	12	Sh	P	--	--	--
Cerebratulus sp. (FAL.51 V)	8	88	gnM,S,Sh, kh Sh & G,(R)	C	Frequent on soft bottoms below 35 m. Usually olive-coloured, but also almost black. C.fuscus M'Intosh found intertidally in False Bay	Wheeler 1940 Wheeler 1934	(C.fuscus found W in Saldanha Bay)
Lineus ruber (Müller)	Int.	42	S,R	F	--	Wheeler 1940, Wheeler 1934	(W in Saldanha Bay)
Oerstedia maculata Wheeler	0	36	R	C	Found intertidally in Saldanha Bay	Wheeler 1934	(W in Saldanha Bay)
Tubulanus nothus (Bürger)	2	73	kh Sh&G,R	F	Found intertidally in Saldanha Bay	Wheeler 1940, Wheeler 1934	Mediterranean (W in Saldanha Bay)
Zygonemertes capensis Wheeler	Int.	14	coS&Sh,R	C	Found intertidally at Oudekraal & East London	Wheeler 1940, Wheeler 1934	W & E

<u>TURBELLARIA</u>

Near Echinoplana Haswell (FAL.86 Q)	2	17	R	P	Probably a new genus	--	--
Neostylochus n.sp. (FAL.14 N)	0	36	Sh,R	C	--	--	--

Notoplana patellarum (Stimpson)	Int.	7	R	P,IA	Associated with Patellids	--	W & E
Prosthiostomum delicatum Palombi	0	24	L,S,R	F	--	--	--
" russoi Palombi	4	18	S&St&R	P	--	--	--
Stylochoplana sp. (FAL.279 P)	Int.	19	R	P	--	--	--
Stylochus sp. (FAL.279 R)	4	17	R	P	--	--	--
Thysanozoon ?~~brocchii~~ brochii (Risso)	?Int	18	S&R	P	Only a juvenile found	--	T.brocchii extends E
SIPUNCULOIDEA							
Dendrostoma stephensoni A.C.S.	Int.	24	L&coS	P	--	--	E
Phascolion ? n.sp. (FAL.229 Q)	64	64	cokS	P	--	--	--
Phascolosoma capense Teusch.	Int.	50	S&R,R,lR	F,LC	--	--	W & E
Physcosoma japonicum Grube	Int.	42	R,lR	F,LC	--	--	W & E
POLYCHAETA							
Aphroditidae							
?Eunoe capensis McIntosh	12	14	coS&Sh	P	--	--	--
Euthalenessa oculata (Peters)	Int.	82	L,S,Sh,cokS, S&Sh&Sn&St	P	--	--	W & E
Harmothoe aequiseta (Kbg.)	Int.	40	coS&fSh, Sh, R	F-C	---	Monro 1930	E

Harmothoe goreensis Aug.	0	82	S,St,R	F-C	--	--	(W to Table Bay)
" waahli Kbg.	Int.	40	S,R,lR, coS&fSh	F-C	--	--	W & E
" sp. "C". (FAL.223 C)	40	40	coS&fSh	P	--	--	--
" sp. "D" (FAL.229 X)	64	64	cokS	P	--	--	--
Lepidonotus clava Mont. var. semitecta Stimps.	Int.	73	gnS,kSh&G, R,lR	A	Very typical of rocks down to 25 m. but also common on soft substrata	Monro 1930, Ehlers 1906	W & E
Pholoë minuta Fabr. var. inornata Johnston	4	26	kS,S&St&R,Sh	P	--	--	--
Polynoe scolopendrina Sav.	Int.	18	wS,S&Sh&lR,R	P	--	--	W & E
Psammolyce sp. (FAL.117 R)	22	42	coS&L,R,S&Sh &lR	P	--	--	--
Scalisetosus pellucidus Ehl.	Int.	73	wS,Sh,kSh&G, R	F-C	--	Monro 1930	W & E
* Sthenelais boa (Johnst.)	70	70	gnS	P	--	Ehlers 1906	--
" limicola (Ehl.)	62	82	gnM,coS, Sh,kSh&G	C	--	--	--

Chrysopetalidae

Bhawania goodei Webster	Int.	42	Sh,R, S&Sh&lR	C-A	--	--	E

Paleonotus chrysolepis Schm.	O	40	coS,Sh,R	C	Probably is typically on hard bottoms	--	--
<u>Amphinomidae</u>							
Euphrosyne capensis Kbg.	Int.	42	Sh,St,R,lR	C	--	--	E
Eurythoe chilensis Kbg.	28	28	Sh	P	--	--	--
<u>Hesionidae</u>							
Kefersteinia cirrata (Kef.)	12	14	coS&Sh	P	--	--	--
Syllidia armata Quatref.	Int.	36	coS,Sh,R	F	--	--	--
<u>Phyllodocidae</u>							
Eteone foliosa Quatref.	3	64	S,cokS,R	P	Occurs intertidally at Langebaan Lag. & Knysna Est.	--	(W in Table Bay infratidal & at Langebaan Lag. E in Knysna Est.)
Eulalia (Eumida) sanguinea (Oersted)	Int.	26	S,kS,R	P	--	--	W & E
" cf. trilineata St. Jos.	Int.	24	Sh,R,lR	C	--	--	W & E
" viridis (O.F.M.) var. capensis Schm.	Int.	36	(S),Sh,G,St,R	C	Found on soft bottoms when <u>Pyura</u> present	--	W & E
Notophyllum splendens (Schm.)	Int.	36	Sh,St,R	F	--	--	W
Phyllodoce castanea Marenz.	Int.	28	(S),R	F	Found on soft bottoms when <u>Pyura</u> present	--	(W in Saldanha Bay infratidal) E

Phyllodoce (Anaitides) madeirensis Langerhans	Int.	64	kS&Sh&G	P	P.oculata Ehl. Monro 1930 is a synonym		E
Syllidae							
Amblyosyllis lineolata Costa	Int.	7	R	P	--	--	W & E
Autolutus charcoti Grav.	18	18	S&Sh&lR	P	--	--	(W to Hout Bay)
" pictus (Ehl.)	3	7	R	P	--	--	--
" tuberculatus (Schm.)	Int.	24	Sh,R,lR	C	Probably is typically on rocks	--	--
Exogone cf. clavator Ehl.	I	12	St,R	F	Found intertidally in Knysna Est.	--	(E in Knysna Est.)
" verugera (Clap.)	Int.	24	coS&Sh,R	F	--	--	(W to Sea Point)
Grubea rhopalophora Ehl.	I	9	R	P	Found on Patellids	--	--
Myrianida phyllocera Aug.	Int.	2	R	P	Found on Patellids	--	(W to Kommetjie)
Odontosyllis polycera (Schm.)	Int.	36	S&R,Sh,R	F	--	--	W & E
Pharyngeovalvata natalensis Day	Int.	7	R	P	--	--	E
Pionosyllis magnidens Day	Int.	7	R	P	Sometimes found on Patellids	--	W
? " sp. (FAL.269 Q)	14	73	R	F,(LC 15-25 m.)	--	--	--

Syllides longocirrata Oersted	14	38	Sh,R	P	--	--	--
Syllis armillaris O.F. Muller	Int.	188	S&wM&Sh, Sh,St,R	A	Frequent on hard bottoms down to 25 m.	--	W & E
" (Ehlersia) ferrugina Langh.	4	31	kS,S&St&R	P	--	--	--
" gracilis Grube	Int.	18	Sh,R	P	--	--	--
" prolifera var. zonata Hasw.	0	36	Sh,St,R,lR	C	Frequent on hard bottoms down to 25 m.	--	--
" variegata Grube	Int.	73	R	C (LC 25-35 m.)	--	--	W & E
" vittata Grube	Int.	17	R	P	--	--	W & E
" sp. (FAL.171 Z)	1	7	R	P	Sometimes on Patellids	--	--
Trypanosyllis gemmulifera Aug.	Int.	73	kSh&G,St, G,R	F	--	--	W
" prampramensis Aug.	Int.	3	R	P	Infratidally Only found in cave	--	W
" zebra Grube	Int.	19	S&Sh&R	P	--	--	(W to Kommetjie), E
" sp. (FAL.216 M)	42	42	R	P	--	--	--

Nereidae

Laeonereis n.sp. (FB.302 J)	3	40	(coS&fSh),R,lR	C,(LC 15-25 m.)	Typically on hard bottoms, found on soft bottoms where *Pyura* present	--	--
Nereis lamellosa Ehl.	15	88	gnM,coS,Sh, kSh&G	F-C	A typical estuarine species	--	(E in estuaries)
" operta Stimps.	Int.	28	wS,coS&Sh, Sh,R,lR	A	Probably is typically on hard bottoms. Heteronereids attracted by light on waters' surface at night	--	W & E
" willeyi Day	Int.	18	(Sh),St,R	A	Found on Patellids, & on soft bottoms where *Pyura* is present	--	E
Perinereis capensis (Kbg.)	Int.	17	R	F	Common in infratidal cave; & common on Patellids	--	E
Platynereis calodonta Kbg.	Int.	2	R	P	--	--	E
" dumerilii (Aud. & M.-Edw.)	Int.	38	S,Sh,Sn,St,R	A	More typically of hard bottoms. A frequent epizoont & so is often on soft bottoms.	Monro 1930	W & E

Pseudonereis variegata (Grube)	Int.	4	R	P	--	--	(W to Oudekraal), E
Sphaerodoridae							
Ephesia gracilis Rathke	40	40	coS&fSh	P	--	--	(W in Saldanha Bay infratidal)
Glyceridae							
Glycera capitata Oersted	30	30	S&Sh	P	--	--	--
" " var. benguellana Aug.	18	78	gnM, cokS&Sh, Sh	P	--	--	--
" convoluta Kef.	Int.	88	gnM, S, kS, Sh, kS&Sh&G	C-A	Frequent on soft bottoms from 35-80 m.	--	(W in Langebaan Lag.)
" longipinnis Grube	22	22	S&Sh&lR	P	--	--	--
" papillosa Grube	27	28	S&R	P	--	--	--
" prashadi Fauvel	Int.	27	fS, Sh&lR	P	--	--	--
" rouxii A. & M. Edw.	78	78	gnM	P	--	--	--
" cf. tenuis (FAL.51 E)	18	22	S	P	--	--	--
" unicornis Sav.	23	106	fS, cokS	P	--	--	(E in Zwartkops Est.)
Glycinde sp. (FB.306 C)	15	78	gnM, S, Sh	P	--	--	--
Goniada sp. (FAL.240 K)	78	88	gnM	LC	--	--	--
Ophioglycera eximia (Ehl.)	48	48	cokS&Sh&Sn&St	P	--	--	--

Nephthydidae							
Nephthys capensis Day	Int.	3	S	P	A typical soft bottom & estuarine species	--	(W on Langebaan Lag.)
" hombergi Aud. & M.-Edw.	Int.	46	Sh	P	A typical estuarine species	--	(W in Langebaan Lag.)
" spherocirrata Wesenberg-Lund	Int.	78	gnM,S,cokS	P	--	--	(W in Langebaan Lag.)
Eunicidae - Eunicinae							
Eunice aphroditois (Pallas)	Int.	18	S,R	P	--	--	W & E
" australis Quatref.	Int.	36	S,Sh	P	Olim E.murrayi McIntosh	McIntosh 1885, "Challenger" 1895	E
" vittata (Delle Chiaje)	Int.	82	S,Sh,kSk&G, R	F	--	Monro 1930	E
Lysidice natalensis Kbg.	Int.	22	Sh,R,lR	F-C	--	--	W & E
Marphysa purcellana Willey	18	40	coS&fSh, S&Sh&lR	P	--	--	--
-- Onuphidinae							
Diopatra ≠ meapolitana D.Ch.	7	86	S,Sh,kSh	C,(A 5-25 m.)	This characterises a large part of the bay from 10-40 m.	Day 1934	--

* Epidiopatra hupferiana Augener	35	35	S	P	--	Monro 1930	--
Nothria sp. (FB.311 E)	18	24	L&S,S&Sh&lR	P	--	--	--
Onuphis emerita A. & M.-Edw.	22	82	S,kS&Sh&G,Sh	F,(LC 50-80 m.)	--	Monro 1930	--
* " holobranchiata (Marenz.)	70	70	gnS	P	--	Ehlers 1906	--
* " quadricuspis Sars	77	77	S&Sh	P	--	McIntosh 1923-25	--
Rhamphobranchium sp. (FB.307 J)	12	28	S,Sh,(R)	P	--	--	--
-- Lumbrinereinae							
Arabella mutans (Chamberlin)	64	73	cokSh, kSh&G	P	--	--	--
" iricolor (Montagu) var. caerulea (Schm.)	Int.	55	R,lR	F	--	--	W & E
Drilonereis sp. (FAL.219 M)	18	18	S&Sh&lR	P	--	--	--
" n.sp. (FAL.237 D)	78	88	gnM	LC	--	--	--
Lumbrinereis albidentata Ehl.	23	88	gnM,gnS, kS,Sh,G	F-C	Typical of soft bottoms from 50-90 m.	Ehlers 1906	--
" cavifrons Grube	Int.	36	fS,S,Sh, G,R	A	Typical of rocks from 5-25 m.	--	E
" coccinea Renieri	Int.	42	R	C	--	--	W & E

Lumbrinereis hartmani Day	Int.	3	R	P	Infratidally found in cave only	--	--
" latreilli Aud.& M.-Edw.	Int.	28	S&Sh,S&R	P	--	--	E
" tetraura (Schm.)	Int.	31	S,kS,S&R	P	A typical estuarine species. Found in Simon's Town Dockyard basin	Monro 1930	(W in Lengebaan Lag. E in various estuaries)
Notocirrus sp. (FB.306 G)	15	64	S&Sh&St,cokS	P	--	--	--
--<u>Dorvilleinae</u>							
Dorvillea egena (Ehlers)	12	14	coS&Sh	P	--	--	--
* " neglecta (Fauvel)	0	2	?	P	From Simon's Town dockyard basin. Found intertidally in Langebaan Lag.	Monro 1930	(W in Langebaan Lag.)
<u>Orbiniidae</u>							
Nainereis laevigata (Grube)	Int.	36	Sh,R,lR	C	Typically on hard bottoms. Recorded from Simon's Town dockyard basin	Monro 1930	W & E
Orbinia angrapequensis (Augener)	Int.	88	kS,ngM	P,(LC 80-90 m.)	--	--	(W in Langebaan Lag; E in Knysna Est.)

Scoloplos sp. (FAL.243 N)	77	82	S&Sh&G	P	--	--	--
<u>Magelonidae</u>							
Magelona cincta Ehl.	78	78	gnM	P	--	--	--
<u>Spionidae</u>							
Aonides oxycephala (Sars)	30	30	fS	P	--	--	(E in Knysna Est.)
Laonice cirrata (Sars)	88	88	gnM	P	--	--	--
Polydora capensis Day	Int.	2	St,R	P	Found in the shells of Patellids	--	W & E
" ? ciliata (Johnston) (FAL.258 Q)	10	11	coS&Sh	P	--	--	--
" flava Clap.	50	50	?	P	--	--	--
" hoplura Clap.	Int.	42	R	P-F (LC 45-75 m.)	--	--	(W in Saldanha Bay & Langebaan Lag.), E
Prionospio pinnata Ehl.	78	88	gnM	LC	--	--	--
<u>Chaetopteridae</u>							
Chaetopterus variepedatus (Renier)	Int.	42	L&coS,S,Sh,R	C	--	--	(W to Oudekraal), E

Phyllochaetopterus socialis Claparede	Int.	33	S,R	F,LC	When preserved this species is often scarcely to be distinguished from Spiochaetopterus. Identification of early records is doubtful & they have been omitted	--	W & E
Spiochaetopterus typicus Sars	12	14	coS&Sh	P, probably C	Only recently recognised: see note under Phyllochaetopterus	--	--
Opheliidae							
Ophelia ? dannevigi Benham	22	22	S&Sh&lR	P	--	--	--
" ? formosa Ehl.	22	82	S&Sh&G, S&Sh&lR	P	--	--	--
Tachytrypane sp. (FAL.243 L)	77	82	S&Sh&G	P	--	--	--
Travisia forbesii (Johnst.)	46	73	gnS,kS&Sh &G,Sh	LC	--	Ehlers 1906	
Cirratulidae							
Audouinia australis (Stimps.)	Int.	24	Sh,R,lR	C	Found in Simon's Town dockyard basin	Monro 1930	W & E
" tentaculata (Montagu)	Int.	3	S	P	--	--	W & E

Cirratulus ? cirratus Müller	Int.	7	R	P	--	--	C. cirratus extends W
" cf. concinnus Ehl.	I	9	R	P	Found on Patellids. With eggs in August	--	--
" ? filiformis Kef.	42	88	gnM,R	P	--	--	--
Dodecaceria ? afra (FAL.219 L)	18	18	S&Sh&lR	P	--	--	--
" ? fistulicola Ehlers (FAL.50 F)	18	18	S&R	P	--	--	--
* Heterocirrus capensis Monro	0	2	?	P	From Simon's Town dockyard basin	Monro 1930	--
Flabelligeridae							
Flabelligera affinis Sars.	Int.	36	Sh,R	P	Found in Simon's Town dockyard basin	Monro 1930	W & E
Stylarioides laevis (Stimps.)	Int.	33	R	P	--	--	W, (E to Hermanus)
" n.sp. (FB.315 A)	0	55	(S),Sh,St, R	C-A	Frequent on rocks from 45-75 m.	--	--
" n.sp. (FAL.206 N)	62	82	Sh	P	--	--	--

<u>Capitellidae</u>							
Dasybranchus bipartitus (Schm.)	Int.	24	L&coS	P	--	--	W & E
" sp. (FAL.106 D)	4	36	S&G&R	P	--	--	--
Notomastus ? fauvelii Day	?Int.	24	L&coS	P	<u>N.fauvelii</u> found intertidally in Simon's Bay: a typical estuarine species	--	(<u>N.fauvelii</u> found (E in estuaries)
<u>Scalibregmidae</u>							
Hyboscolex longiseta Schm.	Int.	24	R,lR	P	--	--	W & E
Scalibregma inflatum Rathke	78	78	gnM	P	With eggs in September	--	--
<u>Maldanidae</u>							
Asychis cf. theodori Aug.	46	62	Sh	P	--	--	--
Axiothella sp. (FAL.113 Y)	0	42	L&coS,Sh,R	P	--	--	--
<u>Oweniidae</u>							
Owenia fusiformis Delle Chiaje	64	64	kS&Sh&G	P	--	--	(E in Durban Bay)
<u>Sabelariidae</u>							
Sabellaria spinulosa Leuckart var. alcocki Grav.	Int.	51	S&R,Sn,R	P	--	Day 1934	E

Pectinariidae							
Pectinaria pseudokoreni Day	20	27	fS,S&Sh	P	A typical estuarine species	--	(E in estuaries)
Ampharetidae							
Amphicteis gunneri (Sars)	15	62	L&coS,S,kS, Sh,R	P	--	Monro 1930	--
? Lysippe sp. (FB.323 E)	30	30	fS	P	--	--	--
? Lysippides sp. (FAL.251 A)	88	88	gnM	P	--	--	--
? Pterolysippe sp. (FAL.226 D)	36	36	? S&Sh	P	--	--	--
Sabellides octocirrata Sars.	6	64	coS&fSh,R	P	--	--	--
" sp. "B" (FAL.43 J)	14	64	cokS,Sh,R	P-F	--	--	--
" sp. "C" (FB.306 L)	15	73	S&Sh,kSh&G	P	--	--	(W in Saldanha Bay)
Terebellidae							
Lanassa capensis Day	Int.	4	R	P	--	--	(W to Kommetjie, E to Still Bay)
Lanice wollebacki Caullery	17	17	wS	P	--	--	--
Lanice sp. (FB.302 Q)	7	9	S	P	Found on sand where Pyura & algae common	--	--
Nicolea macrobranchia (Schm.)	Int.	73	L&S,(S),Sh, R,lR	A	More typical of hard bottoms	--	W & E

Nicolea venustula (Mont.)	I	38	(S),Sh,R	C	More typical of hard bottoms	--	--
Pista foliigera Caullery	Int.	42	R	P	--	--	W & E
" qolora Day	Int.	26	kS,R,lR	P	--	--	E
? Polycirrus sp. (FAL.65 W)	37	38	Sh	P	--	--	--
Polymnia nebulosa (Mont.)	Int.	64	L&coS,R	P	--	--	E
Terebella pterochaeta (Schm.)	Int.	36	S&G&R,R,lR	P	--	--	W & E
" schmardaei Day	Int.	42	coS&fSh,Sh, R,lR	C (LA 5-25 m.)	More typical of hard bottoms	--	W
Terebellides stroemi Sars.	82	88	gnM	P	--	--	--
Thelepus pequenianus Aug.	Int.	75	kSh&G,R	P	--	--	W & E
<u>Sabellidae</u>							
Amphiglena mediterrania (Leydig)	I	7	R	P	Found on Patellids	--	--
Branchiomma quadrioculatum Willey	Int.	22	S,R	F	Found on sand where <u>Pyura</u> present	--	W & E
Dasychone ? capensis McIntosh	15	40	S,Sh	P	--	--	--
" nigromaculata Baird	Int.	24	Sh,St,R	C	More typical of hard bottoms	--	E

Dasychone violacea (Schm.)	Int.	24	Sh,R,lR	C, (LC 15-25 m.)	More typical of hard bottoms. Found in Simon's Town dockyard basin	Monro 1930	W & E
Fabricia sp. (FAL.82 L)	I	17	R	P	--	--	--
Myxicola infundibulum Renier	16	37	Sh,R,lR	P	--	--	(E in Zwartkops Est.)
Oridia sp. (FAL.82 F)	O	17	R	P	--	--	--
Potamilla reniformis O.F. Muller	Int.	188	S,Sh,R,lR	C	More typical of hard bottoms	McIntosh 1923-25	W & E
" torelli Malm.	Int.	36	R	P, (LC 15-25 m.)	--	--	E
Sabella pavonina Sav.	7	188	L&S,S,kSh&G, Sh	C, (LA 50-80 m.)	--	Monro 1930	--
<u>Serpulidae</u>							
Filograna implexa Berkely forma salmacina Clap.	Int.	7	R	P	--	--	W & E
Hydroides dipoma (Schm.)	Int.	27	(S),coS&Sh, Sh,Sn,R	C-A	More typical of hard bottoms	--	E

Hydroides norvegica Gunnerus	27	200	S,kSh&G	P	--	Monro 1930	(W to Table Bay)
Protula bispiralis (Sav.)	Int.	17	R	P	--	--	E
" tubularia Mont.	36	36	S&G&R	P	--	--	--
Serpula vermicularis L.	Int.	188	R	F-C	--	--	E
" " L. var. echinata Mörch.	73	73	kSh&G	P	--	--	--
Spirorbis borealis Daudin	Int.	21	R	C	--	--	W & E
" corrugatus (Mont.)	0	5	R	P	--	--	--
" sp. "A" (FAL.44 N)	21	22	S & R	P	--	--	--
" sp. "B" (FAL.95 Z)	36	36	S&G&R	P	--	--	--
Vermiliopsis glandigerus (Grav.)	Int.	28	coS&Sh,Sh,R	F	--	--	(W in Langebaan Lag.), E

NUDIBRANCHIATA

* Armina euchroa Bergh	29	91	gnM,S,Sh	F	--	Bergh 1907, Barnard 1927	--
* Chromodoris sp.	42	42	R	3 specimens	--	Bergh 1907	--
* Dendrodoris caesia Bergh	18	18	S & Sh	1 specimen	--	Bergh 1907, Barnard 1927	--
* " callosa Bergh	31	49	R	P	--	Bergh 1907, Barnard 1927	--

Dendrodoris kalkensis Brnrd.	Int.	28	(S),S&R	P	Only found on sandy bottoms if <u>Pyura</u> present	--	(E to Still Bay)
* " sp.	18	18	Sh	1 specimen	--	Bergh 1907, Barnard 1927	--
* Dolabrifera triangularis Watson	27	37	?	P	--	"Challenger" 1895	--
* Doris glabella Bergh	55	55	S	1 specimen	--	Bergh 1907	--
Doto pinnatifida Montagu	16	19	R	P	--	--	--
Duvaucelia sp. (FAL.135 P)	0	2	R	P	--	--	--
Euphurus lucidus (Stimps.)	17	24	S&R,R	P	--	--	--
Euplocamus croceus Phil.	27	28	S&R	P	--	Bergh 1907	--
Glossodoris capensis Brnrd.	Int.	17	R	P	--	--	(E to Still Bay)
Godiva quadricolor (Brnrd.)	Int.	24	(S),Sn	P	Only found on sandy bottoms if <u>Pyura</u> present	Barnard 1951	E
Janolus capensis Bergh	Int.	55	(fS,S),Sh,R	F	--	Bergh 1907	(W to Oudekraal), E
Melibe rosea Rang.	Int.	7	R	P	--	Barnard 1951	W & E
Nembrotha capensis Bergh	Int.	24	R	F	--	Bergh 1907 Barnard 1951	--
* Thordisa punctulifera Bergh	42	42	R	3 specimens	--	Bergh 1907	--

* Tritonia pallida Stimps.	?35	?35	R ?	1 Specimen	--	Bergh 1907	--
TECTIBRANCHIATA							
Aplysia juliana Q. and G.	Int.	22	(S),St,R	P	Only found on sandy bottoms if *Pyura* present	--	(E in Hermanus Est.)
Philine aperta (L.)	3	40	L&S,S,kS, Sh,fSn	A	Very typical of soft bottoms	Bergh 1907	--
* " berghii O'Donoghue	53	53	fS	1 Specimen	--	Bergh 1907	--
* Pleurobranchaea capensis Vayssiere	60	60	fS	8 Specimens	--	Bergh 1907	--
STREPTONEURA							
Actaeon albus (Sowerby)	27	28	fS,S&R	P	--	--	--
Alia apicata Smith	7	23	S,Sh,S&R	F	--	--	--
? Alcira elegans Adams	0	3	R	P	--	--	--
* Alvania fenestrata (Krauss)	27	37	?	P	--	"Challenger" 1895	--
Amblychilepus scutellum (Gmelin)	Int.	17	R	F	Also in Langebaan Lag.	--	W

Ancilla cf. errorum Tomlin	46	82	Sh,kSh&G	C	Typical of soft bottoms	--	--
" fasciata Reeve	36	82	Sh,kSH&G	F-C	Typical of soft bottoms	--	--
* " obtusa (Swainson)	27	37	?	P	--	"Challenger" 1895	--
" pura Sowerby	46	46	S	P	--	--	--
Argobuccinum ~~Gmelin~~ argus Gmelin	Int.	24	(S&Sh),Sh, St,R	C-A	Typically on hard bottoms. Spawning in September	--	W
* Astralium (Astraea) taylorianum (Smith)	37	?90	?	P	"In the deeper parts of False Bay"	Barnard 1951	W (& shallows of Agulhas Bank)
Bullia annulata (Lam.)	0	62	S,Sh	C-A	Very typical of soft bottoms. Found at E.L.W.S.T. in Simon's Bay. Often bears the commensal hydroid <u>Leuckartiara octona</u>	--	(W to Table Bay. E in Knysna Est.)
" digitalis (Dillwyn)	Int.	25	S,Sn	P-F	Also in Milnerton Est.	--	W, (E in Knysna Est.)
" laevissima (Gmelin)	0	46	S,Sh,Sn	C-A	Found at E.L.W.S.T. in Simon's Bay. Very typical of soft bottoms	"Challenger" 1895	(W to Table Bay)

Bullia tenuis Gray	37	73	coS&fSh, kS&G,Sh	P	--	--	--
* Burnupena cincta (Bolten)	18	37	?	P	Synonym of <u>B.porcata (Gmelin)</u>	"Challenger" 1895	--
~~Burnupena~~ puncturata (Sowerby)	0	24	S,coS&Sh,R	F-C	Typically on hard bottoms	--	(E in Knysna Est.)
Calyptraea capensis Tomlin	7	82	S,S&Sh&G,Sn	P	--	--	(W to Table Bay)
Clavatula fultoni Sowerby	13	46	S,Sh	P	--	--	--
Clavus taxus (Chemnitz)	14	14	wM&S&Sh	P	--	--	--
" tumida (Sowerby)	46	73	Sh,kSh&G	P	Sometimes bears a commensal hydroid <u>Hydractinia sp.</u>	--	--
Cominella cincta (Röding)	Int.	6	St,R	F	Is this synonymous with <u>Burnupena cincta</u> ?	--	W & E
" ? elongata (Dunker)	?Int.	17	R	P	--	Stephenson 1947	<u>C.elongata</u> extends (W to Oudekraal), E
* " lacertina (Gould)	Int.	?5	?	P	"In kelp roots"	Stephenson 1947	Chiefly W
" papyracea (Brug.)	Int.	18	R	C-A	Invariably supports the commensal Polyzoon, <u>Alcyonidium nodosum</u>	Stephenson 1947	W (E to Hermanus)

Conus ? elongatus Chemnitz	14	17	R	P	--	--	--
" ? textile L.	14	17	R	P	--	--	--
Crepidula hepatica Deshayes	Int.	17	coS&Sh,R	C-A	Usually epizootic. With spawn in September	--	W & E
"Daphnella" cf. capensis (Smith)	7	23	S,Sh	P	--	--	--
Demoulia abbreviata (Wood)	46	46	Sh	P	--	--	--
Eburna papillaris Sowerby	40	40	coS&fSh	P	--	--	--
Epitonium tenebrosum (Sowerby)	82	82	?gnM&S	P	--	--	--
Euthria ? lacertina Gould	0	11	R	P	--	--	--
Fasciolaria filamentosa Chemnitz	4	6	S&St&R	P	--	--	--
Fisurella mutabilis (Sowerby)	Int.	24	L&coS,R	C	Found in Hermanus & Khysna Estuaries	--	W & E
Fusinus ocelliferus (Lam.)	3	50	L&S,S	P	Olim <u>Fusus verruculatus Lamk.</u>	"Challenger" 1895	--
* Gibbula benzi (Krauss)	27	37	?	P	--	"Challenger" 1895	--
" capensis (Gmelin)	Int.	6	R	P	--	--	(W to Oudekraal)
" cicer Philippi	Int.	17	R	P	--	--	E

* Gibbula fulgens Gould	27	28	fSn	P	--	--	--
" ? loculosa Gould	26	27	fS	P	--	--	--
" rosea (Gmelin)	Int.	14	coS&Sh	P	--	--	W
Haliotis midae L.	Int.	4	R	LA	--	--	W & E
" sanguinea Hanley	Int.	1	R	P	Specimens not obtained in routine collections but observed several times	--	E
Helcion ? pruinosa (Krauss)	?Int.	5	R	P	--	--	<u>H. pruinosa</u> extends (W to Yzerfontein) E
Hinia (? Reticunassa) sp. (FB 966 A)	22	24	S	P	--	--	--
" speciosa (A. Adams)	7	82	L&S, S, Sh, kS&Sh&G, Sn	C-A	Typical of soft bottoms. Frequently bears the commensal hydroid <u>Hydractinia carnea</u>	--	(W in Langebaan Lag; E in Knysna Est.)
Marginella bairstowi Sowerby	Int.	27	S, Sn, R	C	--	--	(W to Oudekraal)
" diadochus Adams & Reeve	64	64	cokS, kS&Sh&G	P	--	--	--
" ? floccata Sowerby	23	27	S	P	--	--	--
" zonata ~~Kuener~~ Kiener	12	14	coS&Sh	P	--	--	(W in Langebaan Lag.)

Melanella insignis Turton	8	18	R	P	--	--	--
Melatoma sinuata (Born.)	Int.	4	R	P	--	--	W
Microsetia halia Bartsch	1	6	St,R	P	--	--	--
Nassarius circumtextus (von Martens)	82	88	gnM	F	--	--	--
Natica forata Reeve	46	82	Sh,S&Sh&G	F	--	--	--
" saldontiana Bartsch	46	64	Sh,kS&Sh&G	P	--	--	--
* Odostomia sp.	27	37	?	P	--	"Challenger" 1895	--
Oxystele sinensis (Gmelin)	Int.	7	St,R	C,LA	--	--	E
Patella barbara L.	Int.	4	R	F-C	--	Koch 1949	W & E
" compressa L	Int.	2	(R)	P	Normally lives on <u>Ecklonia maxima</u>	Stephenson 1947	W
" miniata Born.	Int.	11	R	C	--	--	W & E
" tabularis Krauss	Int.	4	R	F,LC	--	Stephenson 1947	E
Pupillaea aperta (Sowerby)	Int.	24	R	P	--	--	E
Pyrene (Anachis) kraussi (Sowerby)	Int.	4	R	F	--	--	E
Rissoa nigra Krauss	Int.	7	R	F, probably C	--	--	W

Seila africana Bartsch	Int.	14	coS&Sh	P	--	--	E
Solariella cogener Sowerby	64	82	S,kSh&G	LC	--	--	--
" dilecta (A.Adams)	22	28	S,fSn	P	--	--	--
Terebra lightfooti Smith	73	73	kSh&G	P	--	--	--
Thais cingulata L.	Int.	15	S	P	With eggs in December	--	W
" scrobiculata (Dunker)	0	3	R	P	--	--	--
" squamosa (Lamk.)	Int.	24	S,R	P	Bears the commensal hydroid <u>Hydractinia altispina</u>	Stephenson 1947	W & E
Tricolia capensis Dunker	Int.	17	coS&Sh,Sh,R	F,probably C	--	--	W & E
" (Chromotis) neritina Dunker	Int.	7	R	F,probably C	--	--	E
Turbo (Ocana) cidaris (Gmelin)	Int.	11	St,R	C	--	Barnard 1951	(W to Oudekraal), E
" sarmaticus L.	Int.	7	St,R	C	--	--	E
Turritella carinifera Lamk.	Int.	17	R	P	Found in Knysna Est.	--	W & E

* Turritella knysnaënsis Krauss	27	37	?	P	Could this identification be a confusion with *T. sanguinea* ?	"Challenger" 1895	--
" sanguinea Reeve	30	82	fS, coS, fSh, kS&Sh&G, Sh	F-C	A typical species of this depth	--	--
Vermetus ? corallinaceous Tomlin	?Int.	18	S&R	P	--	--	*V. corallinaceous* extends W & E
" ? natalensis Mörch.	?Int.	18	S&R, R	P	--	--	*V. natalensis* extends E
Xenogalea zeylanica (Lam.)	26	38	S	P	--	--	(E in Knysna Est.)

PELECYPODA

Anomia ephippium L.	0	73	S, Sh, kSh&G, R	C	A typical hard-bottom species but presence in old shells & on stones makes it frequently found on soft bottoms	--	~~(E to Arniston)~~
Brachidontes capensis (Krauss)	Int.	18	S&R, S&Sh&lR	P	--	--	(E to Arniston)
* Carditella capensis Smith	27	37	?	P	--	"Challenger" 1895	--

Chlamys tincta (Reeve)	Int.	21	(S),R	F-C	Found on sand where Pyura present	--	(E to Still Bay)
?Clistoconcha insignis Smith	12	12	S&R	P	--	--	--
Donax burnupi Sowerby	14	30	S(&R),S&Sh, S&Sh(&lR)	F	--	--	--
" (Capsella) sp. (FB.906)	27	28	fSn	P	--	--	--
Dosinia pubescens Philippi	46	88	gnM,Sh	F,LC	Very characteristic of green mud. This supposedly identical with a species found in the intertidal sands of Durban lag. (bathed in sub-tropical water).	--	--
Gari (Psammobella) sp. (FB.910 B)	15	82	L&S,Sh, S&Sh&G	P	--	--	--
Gastrochaena ? rüpellii Deshayes	?Int.	42	(coS&S), R,lR	F	--	--	G.rüpellii extends E
Hochstetteria limoides Smith	0	18	R	F	--	--	--
Kellia rotundata Deshayes	Int.	36	R,lR	F	--	--	(E to Still Bay)

Lima (Mantellum) rotundata Sowerby	0	36	S,Sh,R	F-C	More typical of hard bottoms	--	(E in Knysna Est.)
Mactra capensis Sowerby	46	62	Sh	F	--	--	--
" glabrata L.	3	22	S,Sh	P	--	--	--
Musculus cuneatus (Gould)	Int.	40	S&Sn,Sh,St, R,lR	C	This small species frequent in the growths of sponges etc. on rocks	--	E
Mytilus crenatus Lam.	Int.	56	(Sh),R,lR	C,(LA 0-25 m.)	Juveniles often found on Patellids	--	W (E to Arniston)
" ? meridionalis Krauss	?Int.	7	R	P	Only juveniles found in False Bay	--	<u>M.meridionalis</u> extends W; (E to Hermanus)
" perna L.	Int.	24	(S&)Sh, (S&)Sn,R	FC-C	Found on sandy bottoms where <u>Pyura</u> present	--	(W to Yzerfontein), E
Nuculana belcheri Hinds	62	77	cokSh, kS&Sh&G	F	--	Sowerby 1908	--
Ostrea atherstonei Newt.	8	14	R	P	Found in the Bushman's River Est., 1½ miles from the mouth	--	(E in Bushman's River Est.)
Pecten ? sulcicostatua Sowerby	46	46	Sh	"Scarce"	--	Barnard 1951	--

Petricola robusta Sowerby	7	9	S&R	P	--	--	--
Philobrya africana Bartsch	0	17	R	F	--	--	--
* Pinna sp. probably squamifera Sowerby	64	66	fS	P	--	Gilchrist 1898	(P.squamifera extends W to Table Bay)
Pteria (Electroma) physoides (Lam.)	19	20	Sn,	P	~~[illegible]~~	--	--
Saxicava ? arctica L.	0	42	Sh,R,lR	C	Frequent in the growths on rocks	--	--
Solenomya occidentalis Deshayes	23	64	L&coS,cokS	P	--	--	--
Tapes (Myrsus) corrugatus (Gmelin)	Int.	22	S&R,Sh,R	F-C	Specimens mostly juvenile	--	W
Tellina madagascariensis Gmelin	1	3	S	P	--	--	--
* " (Angulus) natalensis Krauss	27	37	?	P	--	"Challenger" 1895	--
" triangularis Chemnitz	1	3	S	P	--	--	(W in Langebaan Lag.)
" ? tulipa (Hanley)(FB.914)	20	88	gnM,S,kS,Sh	P-F	--	--	--
Thecalia concamerata (Brug.)	Int.	3	R	P	--	--	W & E
Tivela compressa (Sowerby)	1	46	S,Sh	F (?C)	--	--	--
Trachycardium turtoni (Sowerby)	8	27	S,R	P	--	--	--

Venerupsis rugosa (Deshayes)	18	18	S&Sh&lR	P	--	--	--
Volsella capensis (Krauss)	12	14	coS&Sh	P	--	--	(E in Hermanus & Knysna Estuaries)
SCAPHOPODA							
* Dentalium belcheri Sowerby	55	64	?	P	--	Sowerby 1904 b	--
CEPHALOPODA							
* Hemisepius typicus Stn.	33	33	S&Sn	P	--	Massy 1927-29	--
Polypus granulatus (Lam.)	0	37	L&coS,St,Sn,R	F	This includes Octopus rugosus Box which is said to be unrecognisable	"Challenger" 1895, Massy 1927-29	--
* Rhombosepion australis (Q & G.)	31	58	fS	P	--	Massy 1927-29	--
OSTRACODA							
* Bairdia ovata Bosquet (?)	27	37	?	P	--	"Challenger" 1895	--
* Cythere craticula Brady	27	37	?	P	--	"Challenger" 1895	--
* " exilis Brady	27	37	?	P	--	"Challenger" 1895	--
* " flabellicostata Brady	27	37	?	P	--	"Challenger" 1895	--

* Cythere lepralioides Brady	27	37	?	P	--	"Challenger" 1895	--
* " stolonifera Brady	27	37	?	P	--	"Challenger" 1895	--
* Cytherella dromedaria Brady	27	37	?	P	--	"Challenger" 1895	--
* Cytherura clausi Brady	27	37	?	P	--	"Challenger" 1895	--
* " mucronata Brady	27	37	?	P	--	"Challenger" 1895	--
* Loxoconcha subrhumboidea Brady	27	37	?	P	--	"Challenger" 1895	--
* Macrocypris maculata Brady	27	37	?	P	--	"Challenger" 1895	Recorded from Australia, West Indies etc.
* Pontocypris (?) subreniformis Brady	27	37	?	P	--	"Challenger" 1895	Recorded from Australia
* Xestoleberis africana Brady	27	37	?	P	--	"Challenger" 1895	

CIRRIPEDIA

* Acasta fossata Brnrd.	22	22	?	P	--	Barnard 1924	--
" ? membranacea Brnrd.	14	18	R	P	--	--	--
* " pectinipes Pilsbry	31	31	?	P	--	Barnard 1924	--

Balanus algicola Pilsbry	Int.	25	(S),Sh,St,R	C,IA	Typically on hard bottoms. Found on sandy bottoms where <u>Pyura</u> present	Nilsson-Cantell 1939, Barnard 1924	W & E
" maxillaris Gronovius	Int.	27	(S),Sh,R	C	--	--	W & E
* " spongicola Brown	0	164	?	P	--	Barnard 1924	--
" trigonus Darwin	Int.	73	(S),Sh,St,R	A	Typically on hard bottoms but commonly epizootic. In world-wide distribution this sp. recorded as deep as 3,000 m.	Barnard 1924	(W to Oudekraal), E
* Lepas sp.	58	64	fS	P	--	Gilchrist 1898	--
* Scalpellum ornatum (Gray)	18	18	?	P	--	Barnard 1924	--
* " valvulifer Annand	40	40	?	P	--	Barnard 1924	--
<u>TANAIDACEA</u>							
Apseudes n.sp. (FAL.320 G)	17	17	wS	P	--	--	--
Leptochelia sp. (FAL.231 U)	12	50	R	P	Olim <u>L.savignyi</u>	--	--
Tanais philetaerus Stebb	2	24	(S),R	F	Only found on sandy bottoms where <u>Pyura</u> present	--	--

AMPHIPODA

Amaryllis macrophthalma Haswell	Int.	42	wS,coS&fSh,Sh, R,lR	C-A	More typical of hard bottoms	Barnard 1916	W & E
Ampelisca anomala Sars	18	18	S&Sh&lR	P	--	--	--
" brevicornis (Costa)	64	82	cokS,kSh,G	LC	--	--	--
" chiltoni Stebb.	22	78	gnM,S&Sh, kSh&G	F	--	--	--
" excavata Brnrd.	Int.	48	coS&fSh,S&G&R	P	--	Barnard 1925, ~~Barnard~~ 1955	E
Ampelisca spinimanus Chevr.	0	64	L&S,fS,kS, S&Sh,R	C,LA	More typical of soft bottoms. This species is probably synonymous with <u>A.palmata</u>	--	--
Ampithoe falsa Brnrd.	Int.	9	S&R	P	--	--	(E to Still Bay)
" ramondi (Aud.)	Int.	22	L&S,S,Sh,R	C	--	Barnard 1955	W,(E in Inhambane Est.)
Aora typica Kröyer	Int.	42	Sh,R,lR	C	--	Barnard 1916, ~~Barnard~~ 1940	W & E
Byblis anisuropus Stebb.	30	30	S&Sh	P	"A separate specific name may be justified"	Barnard 1955	<u>B.anisuropus</u> extends E
Calliopiella michaelseni Schell.	1	2	R	P	Under Patellid shells	Barnard 1955	(W in Saldanha Bay)

Caprella cicur Mayer	Int.	24	Sh,R	F-C	--	--	E
" equilibra Say.	0	73	Sh,R	C-A	--	--	--
" penantis Leach	Int.	22	R,lR	F	--	--	E
Caprellina longicollis (Nicolet)	Int.	7	R	P	--	--	W & E
Ceradocus capensis Sheard	Int.	46	Sh,R	P	--	--	W & E
Cerapus abditus Templ.	14	27	fS,R	P	Found in Inhambane Est.	Barnard 1955	E
Cheiriphotis megacheles (Giles)	10	17	R,(S),coS&Sh	F	--	Barnard 1955	(W in Saldanha Bay), E
Corophium acherusicum Costa	10	14	coS&Sh,S&R,R	P	--	--	--
" triaenonyx Stebb.	10	19	S,coS&Sh, S&Sh&R	P	--	--	--
Ericthonius braziliensis (Dana)	0	36	S&Sh&St,Sh, S&G&R,R	C	--	Barnard 1955	E
Euonyx conicurus Brnrd.	15	27	fS,S&Sh,S&St&G	P	--	Barnard 1955	--
Eurystheus atlanticus (Stebb.)	8	40	S,coS&fSh, S&Sh&lR,R	F	--	--	--
" holmesi Stebb.	8	9	R	P	--	Barnard 1955	--
" palmoides Brnrd.	7	30	fS,Sn	P	Ovig. female present	Barnard 1955	--
Hippomedon longimanus (Stebb.)	78	78	gnM	P	--	--	--

Hyale saldanha Chilton	Int.	4	R	P	--	Barnard 1916	W & E
Ischyrocerus anguipes Kröyer	Int.	14	S	P	<u>Pyura</u> present on the sandy bottom	Barnard 1916	E
" carinatus Brnrd.	14	18	S,S&Sh&lR	P	Pyura present on the sandy bottom	--	--
" gorgoniae Brnrd.	14	24	R	P	In <u>Lophogorgia flammea</u>	Barnard 1940	--
Jassa falcata (Mont.)	Int.	12	Sh,R	P	--	Barnard 1916	W & E
Laetmatophilus purus Stebb.	2	12	Sh,R	P	--	--	--
* " tridens Brnrd.	20	20	?	P	--	Barnard 1916	--
Lemboides afer Stebb.	26	40	kS,coS&fSh,Sh	P	--	--	--
Lembos hirsutipes Stebb.	2	11	coS&Sh,R	P	--	--	--
* Leucothoe dolichoseras Brnrd.	20	24	?	P	Lives in <u>Capsella rugosa Kükthi</u>	Barnard 1925	--
" richardii Less.	Int.	46	fS,coS&Sh,Sh, R	P-F	--	Barnard 1916, ~~Barnard~~ 1955	(W in Saldanha Bay)
Liljeborgia dubia (Hasw.)	48	48	co~~Ks~~kS&Sh&Sn&St	P	--	--	--
" epistomata Brnrd.	26	82	S	P	--	Barnard 1955	(W in Saldanha Bay)
* " proxima Chevreux	9	9	?	1 specimen	--	Barnard 1916	--

Lysianassa ceratina (Wlkr.)	Int.	40	L&coS,Sh,R, lR	F	--	Barnard 1940	W & E
" variegata (Stimps.)	Int.	46	fS,coS&fSh, Sh,R	C	Attracted to light on water's surface at night	--	W
Macropisthopus stebbingi Brnrd.	Int.	6	S&St&R	P	--	Barnard 1916	E
Maera ? hamigera (Hasw.)	73	73	kSh&G	P	--	--	--
" inaequipes (Costa)	Int.	36	R	P	--	--	W & E
" vagans Brnrd.	Int.	42	R	P	--	--	W
Melita machaera Brnrd.	10	17	coS&Sh,R	P	"Ovigerous female" present	Barnard 1955	--
Microlysias xenokeras Stebb.	5	36	S,Sh	F	--	Barnard 1955	--
Nototropis granulosus Wlkr.	18	18	S&Sh&lR	P	--	Barnard 1955	~~W~~ E
Orchomenella plicata Schell.	Int.	40	coS&fSh	P	--	Barnard 1940	W (E in Knysna Est.)
* Orchomenopsis chilensis (Heller)	Int.	15	?	P	--	Barnard 1925	--
Paradexamine pacifica (Thomson)	0	4	R	P	--	Barnard 1955	--
Paramoera capensis (Dana)	Int.	24	S,Sh,S&Sh&lR, R	A	More typical of hard bottoms. Attracted to light on water's surface at night	Barnard 1916, ~~Barnard~~ 1955	W & E

Paraphoxus oculatus G.O. Sars	26	27	fS	P	--	--	--
Photis uncinata Brnrd.	15	82	fS,Sh,kSh&G, (R)	C	More typical of soft bottoms	--	--
* Podocerus cristatus (G.M. Thomson)	20	20	?	P	--	Barnard 1916	--
" inconspicuus (Stebb.)	0	19	S&Sh&R	P	--	--	--
* " palinuri Brnrd.	20	20	?	P	--	Barnard 1916	--
Polycheria atolli Wlkr.	Int.	40	coS&fSh,R	C	Commensal with several species of Ascidians. Also attracted to light on water's surface at night	Barnard 1955	W & E
Pontharpinia stimpsoni Stebb.	17	82	wS,cokS, S&Sh&G	P	--	--	--
Siphonoecetes dellavallei Stebb.	Int.	36	fS,Sh	P	--	Barnard 1955	W
?Stenothöe assimilis Chevr.	14	17	R	P	--	--	--
* Stomacontion capense Brnrd.	44	44	?	P	--	Barnard 1916	--
Trischizostoma remipes Stebb.	11	12	Sh	P	--	--	--
Tryphosa normalis Brnrd.	12	82	S,kS,kSh&G	F,(LC 50-80 m.)	--	Barnard 1955	(W in Saldanha Bay & Langebaan Lag.)
Tryphosa onconotus Stebb.	12	30	fS,coS&Sh	P	--	--	--

Unciolella foveolata Brnrd.	64	64	cokSh	P	"Ovig. females" present	Barnard 1955	--
Urothoë elegans Bate	12	14	coS&SH	P	Attracted to light on water's surface at night.	Barnard 1955	(W in Saldanha Bay & Langebaan Lag.) E
" grimaldii Chevr.	26	82	kS,S&Sh	P	Found in Saldanha Bay & Langebaan Lag.	Barnard 1955	E, (and N W coast of Africa etc.)
" pinnata Brnrd.	30	30	S&Sh	P	--	Barnard 1955	--
" " " var. femoralis Brnrd.	30	30	S&Sh	P	--	Barnard 1955	--
" pulchella (Costa)	40	73	coS&fSh, kSh&G	P	Found in estuaries of Great Brak R., Knysna, Sundays R. & Port St. Johns	Barnard 1955	E

ISOPODA

Arcturella brevipes Brnrd.	4	40	Sh,S&Sh&lR,R	P	--	Barnard 1920	--
" corniger (Stebb.)	9	24	L&S,S,Sh,R	P	--	Barnard 1955	(E in Inhambane Est.)
" lineata (Stebb.)	Int.	40	R	P,(LC 5-15 m.)	--	Barnard 1920	E
* Arcturopsis hirsutus Brnrd.	20	20	?	P	--	Barnard 1914 a	--

Artopoles capensis Brnrd.	14	17	R	Rare	--	Barnard 1955	--	--
Astacilla bacillus Brnrd.	7	24	S,Sn	P	--	--	--	
Cirolana cranchii Leach	Int.	42	R	P	--	--	W & E	
" hirtipes M.Edw.	12	24	L&coS,coS&Sh	P	--	--	--	
" pilula Brnrd.	42	62	Sh,R	P	--	Barnard 1955	--	
" sulcata Hansen	0	46	coS&Sh,Sh, Sn,R,lR	A	More typical of hard bottoms	--	--	
Cirolana venusticauda Stebb.	Int.	24	coS&Sh,R	F-C	More typical of hard bottoms	--	W & E	
Conilorpheus scutifrons Stebb.	Int.	36	S&R	P.	--	Barnard 1955	E	
* Cymodoce cavicola Brnrd.	42	42	?	P	--	Barnard 1920	--	
" comans Brnrd.	8	40	S,Sn	P	--	Barnard 1914 b	--	
* " excavans Brnrd.	24	42	?	P	--	Barnard 1920	--	
" cf. setulosa (Stebb.)	?Int.	23	L&S,Sh,St,R	C	C.setulosa occurs intertidally	--	C.setulosa extends E	
* " umbonata Brnrd.	91	91	?	P	--	Barnard 1914 b	--	
" unguiculata Brnrd.	0	8	R	P	--	--	--	
" valida (Stebb.)	Int.	24	wS,L&coS,R	P	--	Barnard 1914 b	E	

Cymodocella pustulata Brnrd.	Int.	17	R	F	Found in Saldanha Bay	Barnard 1955	W & E
" sublevis Brnrd.	Int.	14	coS&Sh,R	P	Found in Saldanha Bay	Barnard 1955	W & E
Dynamenella dioxus Brnrd.	Int.	17	coS&Sh,R	P	--	--	W & E
" huttoni (Thomson)	Int.	17	R	P	--	--	W & E
" macrocephala (Krauss)	Int.	2	R	P	Found on Patellids	--	E
Eurydice longicornis (Studer)	0	0	?	P	Found on water's surface at night, attracted to light. Recorded at E.L.W.S.T. in Simon's Bay: also found in Milnerton, Knysna, & Zwartkops estuaries	Barnard 1955	(W at Olifants R. mouth & in Saldanha Bay), E
Exosphaeroma planum Brnrd.	Int.	17	R	P	--	Barnard 1953	W & E
" varicolor Brnrd.	Int.	14	coS&Sh	P	--	--	W (E to Hermanus)
Glyptidotea lichtensteinii (Krauss)	Int.	7	R	P	--	--	W & E
* Gnathia spongicola var. minor Brnrd.	55	55	?	P	--	Barnard 1920	--
Haliophasma foveolata Brnrd.	Int.	36	?(S&Sh)	P	--	Barnard 1955	(E to Still Bay)

Haliophasma pseudocarinata Brnrd.	Int.	88	gnM,S&R	P	--	Barnard 1955	E
Ianiropsis bisbidens Brnrd.	?4	?17	?coS&Sh,?R	P	Some records have been confused with <u>Stenetrium crassimanus</u>	Barnard 1955	--
Idotea ziczac Brnrd.	13	15	S&R	P	--	Barnard 1955	(W in Saldanha Bay)
Isocladus mimetes Brnrd.	12	14	Sh	P	--	Barnard 1955	--
" otion Brnrd.	7	24	S,coS&Sh,Sn	P	--	Barnard 1955	--
Jaeropis curvicornis (Nicolet)	Int.	?17	R	P	Some records have been confused with <u>Stenetrium</u> sp. (FAL.157 V)	~~Barnard 1955~~ --	W --
Janira capensis Brnrd.	Int.	9	S&R	P	--	Barnard 1955	W (E to Still Bay & in Knysna Est.)
Lanocira capensis Brnrd.	Int.	64	R	F,(LC 40-65 m.)	--	Barnard 1914 b, ~~Barnard~~ 1920	--
" gardineri Stebb.	0	1	R	P	--	--	--
Leptanthura laevigata (Stimps.)	7	82	fS,S,kS, S&Sh&G	F	--	--	--
Mesanthura catenula (Stimps.)	Int.	1	R	P	--	Barnard 1955	E
Paranthura punctata (Stimps.)	Int.	14	coS&Sh	P	--	--	W & E

Paridotea fucicola Brnrd.	Int.	6	S&St&R	P	--	Barnard 1955	W & E
Parisocladus perforatus (M.Edw.)	Int.	2	R	P	On Patellids	Barnard 1914 b	W & E
Sphaeramene microtylotos Brnrd.	14	17	R	P	Recorded also from stomach of cormorant	Barnard 1955	--
Stenetrium crassimanus Brnrd.	Int.	?17	(?coS&Sh),R	P	Some records have been confused with *Ianiropsis bisbidens*	Barnard 1955	E
" diazi Brnrd.	Int.	14	R	P	--	Barnard 1955	E
" sp. (FAL.157 V)	?0	?17	R	P	Some records have been confused with *Jaeropsis curvicornis*	--	--
Synidotea hirtipes (M.Edw.)	7	40	S,kS,coS&fSh, Sh,Sn	C, (IA 15-25 m.)	--	--	--
Zuzara furcifer Brnrd.	13	16	S&Sn	P	--	Barnard 1955	(E in Keurbooms R. Est.)

~~ANOMURA~~

~~Anapagurus hendersoni Brnrd.~~	~~9~~	~~82~~	~~I&S,S,Sh,~~	~~C~~			

ANOMURA

Anapagurus hendersoni Brnrd.	9	82	L&S,S,Sh kSh&G,Sn	C	In berry Feb.- Apl., June, Aug, Sept. For the lower half of its range the shells utilised are invariably encrusted with the little anemone <u>Epizoanthus similis</u>	"Challenger" 1895, Barnard 1950	(W to Table Bay)
* Callianassa gilchristi Brnrd.	37	37	?	P	--	Barnard 1950	--
" kraussi Stebb.	Int.	14	S(&R)	P	A typical estuarine species	Stebbing 1902, Barnard 1950, ~~Broch 1939~~	(W in Langebaan Lag.)
Diogenes brevirostris Stimps.	Int.	27	L&S,S,Sn	P	In berry Feb. & June. A typical estuarine species	~~Hickson 1937~~ Barnard 1950	(W in Langebaan Lag), E
" costatus Hend.	Int.	82	S,Sh,kSh&G, (R)	C	In berry Feb., Apl., May, Aug., Sep.	"Challenger" 1895, Barnard 1950, ~~Barnard~~ 1955	(E in Durban Bay & Inhambane Est.)
" extricatus Stebb.	0	30	L&S,S,Sh, Sn,St	C	In berry Aug., Sep., Nov., Found at E.L. W.S.T. in Simon's Bay	Barnard 1950	(E in Knysna Est.)

Eupagurus ? deprofundis Stebb. (FB.792 G)	8	46	coS&Sh,Sh,R	F-C	More typical of hard bottoms. In berry Mar., Aug., Sept.	--	--
" placens Stebb.	17	82	S,kSh&G,(R)	F-C	More typical of soft bottoms. In berry in Sept.	Barnard 1950	(E in Knysna Est.)
* Galathea dispersa Bate	9	114	?	P	--	"Challenger" 1895, Barnard 1950	--
" intermedia Liljeb.	9	77	L&S,S,Sh, coS&fSh	C	In berry Mar., Apl.	"Challenger" 1895, Barnard 1950	--
Paguristes gamianus H.M.Edw.	Int.	27	S&Sh,Sh,R	F-C	More typical of hard bottoms. In berry Sept. & Nov.	--	W & E
Pagurus arrosor (Herbst)	37	168	Sh,kSh&G	P	--	Barnard 1950	--
Porcellana streptocheles Stimps.	Int.	91	S,Sh,Sn, kSh&G,R	A to 50 m.	Very frequent on hard & soft bottoms. In berry Mar., Apl., June, Aug., Nov.	"Challenger" 1895, Stebbing 1904, Barnard 1950	W & E
Upogebia assisi Brnrd.	18	18	S&Sh&lR	P	--	--	--
" capensis (Krauss)	Int.	28	S	P	A typical estuarine species	Stebbing 1902, Barnard 1950, ~~Broch 1939~~	(W in Langebaan Lag.), E

Upogebia (Calliadne) savignyi Strahl.	8	8	R	P	--	Barnard 1955	W

BRACHYURA

Achaeopsis spinulosus Stimps.	9	183	S&R	P	--	"Challenger" 1895, Barnard 1950	--
* Atelecyclus septemdentatus (Mont.)	35	101	?	P	Possibly an introduced species	Barnard 1950	--
Cryptodromiopsis bituberculata (Stebb.)	33	42	R	P	--	Barnard 1950	--
" spongiosa (Stimps.)	Int.	154	S&G&R,R	P	In berry in June	"Challenger" 1895, Barnard 1950	(E to Hermanus)
Dehaanius dentatus (M.Edw.)	Int.	40	S,Sh,Sn,R	C-A	Very frequent on hard & soft bottoms. In berry Feb.-Apr., June-Sept., Nov.	"Challenger" 1895, Barnard 1950	(W in Saldanha Bay), E
* Dromidia aegibotus Brnrd.	31	58	?	P	--	Barnard 1950	--
" dissothrix Brnrd.	11	36	Sh,R	F	In berry June, Aug.-Sept.	--	--
* Dromidiopsis cornuta Brnd.	42	42	?	P	--	Barnard 1950	--
* Eudromidia hendersoni (Stebb.)	34	34	?	P	--	Barnard 1950	--

Eurynome aspera (Penn.)	14	99	S,S&R,R	P	In berry Feb.	Barnard 1950	--
Goneplax angulata (Penn.)	27	168	gnM,fS,Sh	F,(LC 80-90 m.)	Typical of deeper soft bottoms	Barnard 1950	E
Hymenosoma orbiculare Decm.	Int.	73	S,Sh,kSh&G, Sn	C-A	In berry Mar., Aug., Sept. & Nov. A typical estuarine species. <u>H.geometricum Stimps</u>. is regarded as synonymous	"Challenger" 1895, Stebbing 1908, Barnard 1950	W & E
" " " ? var.	18	24	S,S&Sh,Sn	P	"Horned, hairy" variety. No intermediate between this & the normal form has been seen	Barnard 1950, ~~Barnard~~ 1955	--
Inachus dorsettensis (Penn.)	73	73	kSh&G	P	--	--	--
" güntheri (Miers)	10	183	L&S,S,S&Sh,R	C	In berry Apr., June, Aug., Sept.	Barnard 1950	--
Leucisca squalina McLeay	Int.	22	R	P	In berry Aug.	Barnard 1950	E
Macropodia falcifera (Stimps.)	9	97	S,Sh,R	F	In berry Feb., Apr.	"Challenger" 1895, Barnard 1950	--

Macropodia rostrata (L.)	2	27	L&S,S,Sh,R	C	More typical of hard bottoms. In berry Mar., Apr., Sept. & Dec. Possibly an introduced species. In world-wide distribution this sp. found down to 108 m.	Barnard 1950, ~~Barnard~~ 1955	(E in Knysna & Bushman's River Estuaries)
* Mamaia capensis (Ortm.)	29	101	?	P	--	Barnard 1950	E
Mursia cristimanus de Haan	16	329	kS&Sh&G,Sh	F,(LC 35-50m.)	Typical of deep, soft bottoms. In berry Sept.	"Challenger" 1895, Stebbing 1902, Barnard 1950	--
* Nautilocorystes ocellata (Gray)	18	82	?	P	--	Barnard 1950	--
Ovalipes punctatus (de Haan)	Int.	91	S,Sh	P	--	Stebbing 1904, Barnard 1950, ~~Barnard~~ 1955	W, (E in Hermanus Est.)
Parapilumnus pisifer (McLeay)	Int.	33	S,R	P	--	Stebbing 1902, Barnard 1950	W & E
Philyra punctata Bell	Int.	55	L&S,S,Sh,fSn	C,(IA 15-25m.)	Typical soft bottom species. In berry Mar., Aug., Sept., & Nov.	Stebbing 1904, Barnard 1950	(W in Saldanha Bay & Langebaan Lag.)

Pilumnoides perlatus (Poeppig)	Int.	18	R.lR	P	In berry Sept. Possibly an introduced species	Barnard 1950, ~~Barnard~~ 1955	W
* Pilumnus hirsutus Stimps.	0	154	?	P	--	Barnard 1950,1955	(W in Saldanha Bay)
* Pinnotheres dofleini Lenz	0	75	?	P	Associated with <u>Ascidians</u> (<u>Pyura</u> & <u>Phallusia</u>) & <u>Pinna</u>	Barnard 1950	--
Plagusia chabrus (L.)	Int.	37	R	C	Megalopae found from 0-22 m. on S,Sh,Sn,R; fairly common	"Challenger" 1895	W & E
Pseudodromia latens Stimps.	23	100	L&coS,S, S&Sh	P	--	Stebbing 1902, Barnard 1950	(W in Saldanha Bay)
" rotunda (McLeay)	15	37	R	P	--	"Challenger" 1895	--
* Thelxiope barbata (Fabr.)	58	84	?	P	--	Stebbing 1904, Barnard 1950	--
* Xanthias tuberculidens Rathbun	42	183	?	P	--	Barnard 1950	--

MACRURA

Hippolyte kraussiana (Stimps.)	5	15	S,Sh	P probably C	In berry Nov., Dec.	Barnard 1950	(E in Knysna & Bushman's River Estuaries)

Jasus lalandii M.Edw.	0	46	St,R	C	Intertidally in pools & crevices. Frequents rocky crevices underwater	von Bonde 1938, Barnard 1950, Stebbing 1908	W (E to Hermanus)
Macropetasma africanum (Balss)	7	13	S&R,R	P probably C	--	Barnard 1950	(E in St.Lucia Est.)
* Merhippolyte agulhasensis Bate	70	106	?	P	--	Barnard 1950	--
Palaemon pacificus (Stimps.)	0	46	S&R,R	P probably C	Intertidally in pools. A typical estuarine species	Barnard 1950	(W in Saldanha Bay), E
* Palinurus gilchristi Stebb.	55	110	fS	P	--	Stebbing,1902, Barnard 1950, Gilchrist 1898, Stebbing 1908	--
Pontophilus megalocheir (Stebb.)	7	73	S,Sh,Sn, MSh&G	F	In berry Feb.	--	--
Processa austroafricana Brnrd.	17	64	S,Sh	F	In berry Aug.	--	--
" cf. edulis (Risso)	14	27	L&S,S,Sh	F	In berry Sept.	--	--
Solenocera sp. (FAL.240 P)	88	88	gnM	P	--	--	--
Spirontocaris near ctenifera Brnrd.	20	23	S&Sh	P	--	--	--
* ~~Spirontocaris~~ pax Stebb.	37	55	?	P	--	Barnard 1950	--
Synalpheus anisocheir Stebb.	Int.	22	S&R	P	--	Barnard 1950	E

PYCNOGONIDA

Achelia quadridentata (Hodgson)	0	17	R	P	--	Barnard 1954	(W in Table Bay)
Austroraptus thermophilus Brnrd.	4	114	R	P	--	Barnard 1954	E
* Böhmia chelata (Böhm)	0	140	?	P	--	Barnrd 1954	--
Discoarachne brevipes Hock	Int.	55	R, 1R	P	In berry Sept.	Barnard 1954	W & E
Endeis clipeatus (Möbius)	Int.	114	?R	P	--	Barnard 1954	(W to Oudekraal), E
Nymphon comes Flynn	14	146	wM&S&Sh, S, Sh	P-F	--	Barnard 1954	E
* " signatum Möbius	35	120	?	P	--	Barnard 1954	E
Nymphopsis cuspidata (Hodgs.)	Int.	27	S, S&Sh, Sn	F	--	Barnard 1954	W & E
* Pallenopsis intermedia Flynn	37	164	?	P	--	Barnard 1954	E
* Parapallene spinosus (Möbius)	31	120	?	P	--	Barnard 1954	(W to Table Bay), E
Pynogonum pusillum Dohrn	14	17	R	P	--	Barnard 1954	W (Angola). Also in Mediterranean (Naples)

OPHIUROIDEA

Amphioplus integer (Ljungman)	Int.	16	R	P	--	Mortensen 1933	E
Amphipholis squamata (D.Chiaje)	Int.	64	wS, cokS, R	F	Found as deep as 400 m. off Durban	H.L. Clark 1923, Mortensen 1933	W & E
" strata Mortensen	42	55	S, R	P	--	Mortensen 1933	--

* Amphiura angularis Lyman	55	55	?	2 specimens	--	Mortensen 1933	--
" atlantica var. dilatata Lyman	82	270	?(gnM&S)	P	--	H.L. Clark 1923, Mortensen 1933	--
" capensis Ljungman	Int.	46	S&Sh,Sh,Sn,R	F-C	--	H.L. Clark 1923, Mortensen 1933	W & E
" compressa Mortensen	11	55	S,Sh	P	--	Mortensen 1933	--
" incana Lyman	7	64	S,Sh,Sn,(R)	C,(LA 5-25 m.)	Typical of soft bottoms	H.L. Clark 1923, Mortensen 1933, "Challenger" 1895	--
Amphiura simonsi A.M. Clark	27	78	gnM,Sh,fSn	P,(LC 35-50 m.)	--	--	--
Astrocladus euryale (Retzius)	12	64	S,Sh,kS&Sh,R	F-C	With eggs in Sept.	Bell 1905 c, H.L. Clark 1923, Mortensen 1933, Gilchrist 1898, "Challenger" 1895	(E in Knysna Est.)
Dictenophiura anoidea H.L. Clark	36	210	S,Sh,R	F,(LC 35-60 m.)	Frequent on hard or soft bottoms	H.L. Clark 1923, Mortensen 1933	--
Ophiacantha nerthepsila H.L. Clark	31	49	S,Sh,R	P	--	H.L. Clark 1923	--
Ophiactis carnea Ljungman	Int.	73	(coS),Sh,Sn kSh&G,R	A	Typically a hard bottom species	H.L. Clark 1923, Mortensen 1933 "Challenger" 1895	E

Ophiocten amitinum Lyman	40	210	coS,Sh, kSh&G	P,(LC 35-80 m.)	A typical soft bottom species	Mortensen 1933	--
Ophioderma leonis Döderlein	Int.	37	St,R	C	--	H.L. Clark 1923, Mortensen 1933, "Challenger" 1895	(W to Oudekraal; E to Danger Point)
Ophionereis dubia Müll.& Trosch.	Int.	28	coS&Sh,Sh	P	--	--	E
Ophiospila seminuda A.M. Clark	22	64	S&Sh&lR, cokS,S&G&R	P	--	--	--
Ophiothrix triglochis Müll.& Trosch.	Int.	350	S,Sh,kS&Sh, Sn,R	A	Probably more typical of rocks than of soft bottoms	Bell 1905 c, H.L. Clark 1923, Mortensen 1933, "Challenger" 1895	W & E

ASTEROIDEA

* Asterias (Stolasterias) africana (Müll.& Trosch.)	?0	37	?	P	Is this Marthasterias glacialis forma africana ?	"Challenger" 1895	--
Asterina exigua (Lam.)	Int.	11	R	C	--	H.L.Clark 1923, Mortensen 1933	W & E
* Asterina gracilispina H.L.Clark	26	26	?	P	Referred to this species by Mortensen with considerable doubt	Mortensen 1933	--

* Asterina granifera (Gray)	0	42	Sh,R	P	See note below	H.L.Clark 1923, Mortensen 1933	--
* " " (") var. sporacantha H.L.Clark	42	42	R	P	Mortensen thinks this probably identical with <u>Patiria bellula</u>	H.L.Clark 1923, Mortensen 1933	--
Astropecten irregularis var. pontoporaeus Sladen	7	88	S,Sh,kSh&G, (R)	A	Typical of soft bottoms	Bell 1905 b, Mortensen 1933, Gilchrist 1898, "Challenger" 1895	E
* Austrofromia schultzei (Döderlein)	15	16	?	I specimen	--	H.L.Clark 1923, Mortensen 1933	--
Calliaster baccatus Sladen	9	49	R	P	--	Bell 1905 b, Mortensen 1933, "Challenger" 1895	--
* Echinaster reticulatus H.L.Clark	33	46	S	I adult	--	H.L.Clark 1923	--
Henricia ornata (Perrier)	Int.	548	(Sh),St,R	C	--	Bell 1905 b, H.L.Clark 1923, Mortensen 1933, "Challenger" 1895	W & E
Luidia africana Sladen	57	88	gnM,fS,cokS, kSh&G	F,(LC 50-80 m.)	Typical of the deeper soft bottoms	Bell 1905 b, Gilchrist 1898	--

Marthasterias glacialis L. forma rarispina (Perrier)	Int.	77	S,Sh,Sn,R	C,(LA 0-50 m.)	Equally at home on hard & soft bottoms	Bell 1905 b, H.L.Clark 1923, Mortensen 1933	E
* Mediaster capensis H.L.Clark	38	200	fS	2 Adults	--	H.L.Clark 1923	--
Patiria bellula (Sladen)	Int.	55	Sh,R	C	Typically on rocks. Mortensen thinks this probably identical with <u>Asterina granifera</u>	Bell 1905 b, H.L.Clark 1923, Mortensen 1933	W & E
" formosa (Mortensen)	12	55	S,coS&Sh	P	--	Mortensen 1933	--
* Pteraster capensis Gray	37	345	?	P	--	Bell 1905 b, H.L.Clark 1923, Mortensen 1933	--
* Spoladaster brachyactis (H.L. Clark)	42	49	?	1 Specimen	Olim <u>Culcita veneris Perrier</u>	Bell 1905 b	--

<u>ECHINOIDEA</u>

* Brissopsis lyrifera Ag. & Des.	9	345	?	P	--	"Challenger" 1895, Bell 1905 a, H.C.Clark, 1924, Gilchrist 1898	--
* Echinocardium australe Gray	40	230	?	P	--	Bell 1905 a	--

Echinocardium cordatum (Pennant)	7	55	S,Sh	P-F,LC	--	H.L.Clark 1923	(E in Knysna Est.)
Echinolampas crassa (Bell)	22	36	S&Sh(&lR), S&G(&R)	P	--	Bell 1905 a, H.L.Clark 1923	--
Parechinus angulosus (Leske)	Int.	68	(S),Sh,Sn,R	A	Tiny juveniles hidden in growths of weed etc. are often present where adults never are. Probably "Echinus n.sp." in Bell 1905 a is this species	Bell 1905 a, H.L.Clark 1923, "Challenger" 1895	W & E
Spatagobrissus mirabilis H.L.Clark	26	27	fS	P	--	--	--
Spatangus capensis Döderlein	40	87	cokS,Sh, kSh&G	LC	Very characteristic of certain parts of the bay	H.L.Clark 1923, Gilchrist 1898	--

<u>CRINOIDEA</u>

Annametra occidentalis (A.H.Clark)	0	26	wS,kS,S&Sh,R	C,IA	Frequent on hard & soft bottoms	H.L.Clark 1923	(W to Table Bay)
Comanthus wahlbergi (J.Müller)	15	31	L&S,S&Sh,R	C,IA	More typically on hard bottoms	Bell 1908, Gislén 1938, H.L.Clark 1923	--

Tropiometra carinata (Lam.)	Int.	49	L&coS,R	F,LC	Equally at home on hard & soft bottoms	Bell 1908	(W to Oudekraal). Found in Mauritius
* " clarki Gislen	31	31	R	1 Specimen	--	Gislen 1938	--

HOLOTHUROIDEA

Cucumaria insolens Theel	Int.	37	(S&Sh),St,R	A	Typical of hard bottoms; on soft bottoms only found amongst weeds. It is possible that there has been some confusion with C.sykion	Deichman 1948, Cherbonnier 1952, "Challenger"1895	W & E
" stephensoni D.John	Int.	6	St,R	P	--	Deichman 1948	E
" n.sp. (FAL.158 G)	0	3	R	P	Found in cave	--	--
? Epitomapta sp. (FAL.117 Z) [illegible]	23	24	L&coS	P	--	--	--
* Holothuria africana Theel	18	37	?	P	--	H.L.Clark 1923, "Challenger"1895	--
Leptosynapta n.sp. (FAL.117 Q)	23	24	L&coS	P	--	--	--
Pentacta doliolum (Pallas)	Int.	37	fS,Sh,St,R	C-A	More typical of hard bottoms	Deichman 1948, Cherbonnier 1952, H.L.Clark 1923, "Challenger"1895	W & E

Taeniogyrus dayi Cherbonnier	22	30	fS	P	--	--	(W in Langebaan Lag.)
Thyone articulata Vaney	37	38	Sh	P	--	--	(W to Table Bay)
" aurea (Q.& G.)	Int.	14	fS,S,R	P	--	H.L.Clark 1923, Deichman 1948	W
" n.sp. (FAl.14 D)	8	9	R	P	--	--	--
" n.sp. (FAL.161 Y)	0	3	R	P	--	--	--

<u>TUNICATA</u>

Agnesia capensis Millar	22	24	S	P	--	Millar 1953	--
Amaroucium circulatum Hartmeyer	3	48	cokS&Sh&St,R	P	--	Millar 1953	E
" circumvolutum (Sleuiter)	36	36	S&R	P	--	--	--
" erythraeum Michaelsen	Int.	22	St,R	F,probably C	--	--	~~--~~ E
* " fuegiense (Cunningham)	18	37	?	1 Specimen	Olim <u>Atopogaster elongata var. pallida Herdman</u>	"Challenger"1895	--
" retiforme (Herdman)	0	3	R	P	Found in cave	--	--
" variabile Herdman	0	40	coS&fSh,R	P	--	--	--
" unilarviferum Millar	0	19	R	F,probably C	--	Millar 1953	(E in Table Bay)
Ascidia n.sp. "A" (FAL.5 J)	35	35	?	P	--	--	--

Ascidia sydneiensis Stimps.	0	12	Sh,R	P	Also found on ship's hull	Millar 1953	E (Widespread Indo-Pacific species)
Boltenia n.sp. (FAL.212 T)	22	22	S&Sh&lR	P	Found infra-tidally off Port Elizabeth at 27 m. on S&Sh	--	E
Botryllus magnicoecus (Hartmeyer)	Int.	40	coS&fSh,R	F	Found infra-tidally at Saldanha Bay & off Port Elizabeth	Millar 1953	W & E
* Clavelina enormis Herdman	18	37	?	1 Colony	--	"Challenger" 1895	--
" roseola Millar	18	18	S&R	P	--	Millar 1953	--
" steenbrasensis Millar	4	36	R	P	--	Millar 1953	--
Dextrocarpa solitaris Millar	17	28	S&R,Sh	P	--	Millar 1953	--
Didemnum stilense Michaelsen	Int.	50	(S&Sh),R	A	Typical of hard bottoms. Very often epizoic. Very variable in appearance	Millar 1953	(W in Langebaan Lag.), E
Diplosoma listerianum (M.Edw.)	8	17	R	P	Found infra-tidally at Saldanha Bay; & off Port Elizabeth(at $8\frac{1}{2}$-10 m. on mud)	Millar 1953	W (Atlantic & Mediterranean), E

Distaplia capensis Michaelsen	Int.	7	R	P-F	--	--	(E to Still Bay)
" domuncula Michaelsen	20	50	S,S&Sh	P-F	Often cloaking *Pseudodromia latens*	Millar 1953	(E to Walker Bay)
" n.sp. "A" (FAL.216 C)	42	42	R	P	--	--	--
Eudistoma illotum (Sluiter)	4	70	gnS,S&R,R	P	Olim *Polycitor (Distoma) illotus (Sluiter)*	Hartmeyer 1912, Millar 1953	(W in Langebaan Lag.)
" ovatum (Herdman)	0	36	S&R,R	P	--	--	--
" n.sp. "A" (FAL.132 T)	0	2	R	P	--	--	--
Gynandrocarpa domuncula Michaelsen	15	25	R	P	Cloaking *Pseudodromia rotunda*	--	--
* Herdmania momus (Savigny)	18	37	?	1 Specimen	Olim *Cynthia pallida*	"Challenger" 1895	--
Leptoclinides capensis Michaelsen	Int.	24	L&coS	P	--	--	(W in Table Bay infratidal; E to Still Bay)
Lissoclinum n.sp. (FAL.234 T(p.p.))	48	48	cokS&Sh&St	P	--	--	--
Molgula n.sp. "A" (FAL.158 Q)	0	3	R	P	Found in cave	--	--
" n.sp. "B" (FAL.158 R)	0	3	R	P	Found in cave	--	--
" falsensis Millar	0	24	S,R	P	--	Millar 1953	--
* Pachychlaena gigantea Herdman	18	37	?	1 Specimen	--	"Challenger" 1895	--

Polyandrocarpa placenta (Herdman)	18	37	S&R	P	Olim <u>Goodsiria placenta</u>	"Challenger"1895	--
Polycarpa anguinea (Sluiter)	8	9	(S&)R	P	Found at 5-7 m. on rock off Port Elizabeth. Found in Knysna Est.	Millar 1953	E
" sp. (FAL.86 H)	14	17	R	P	--	--	--
Polycitor nitidus (Sluiter)	8	22	S&Sh&lR,R	P	--	--	--
Polyclinum arenosum Sluiter	Int.	24	S&Sh,R	P	--	Millar 1953	E
" isipingense Sluiter	Int.	22	(S&)R,R	P	--	Millar 1953	E
Pseudodistoma n.sp. (FAL.175 F)	0	7	R	P	Found at 5-7 m. on rock off Port Elizabeth	--	E
Pyuroides gen.et sp.nov. "A" (FAL.137 N)	0	4	R	P	--	--	--
Pyura stolonifera (Heller)	Int.	17 (62)	fS,S,R,lR	C,IA	Observed whilst diving to be common on rocks near Roman Rock down to, but not beyond 14 m., and to be common in Fish Hook Bay lying loose on sand at 17 m. (cont'd next p.)	Gilchrist 1898, Millar 1953	W & E

					Dredgings have found this on soft bottoms as deep as 60 m. but these deeper records are suspected to be flotsam washed from the place of origin		
Styela costata (Hartmeyer)	0	64	(L&coS,cokS), Sh,St,R,lR	F, (LC 0-25 m.)	Typically on hard bottoms	Millar 1953	(E in Knysna Est.)
" pupa Heller	Int.	22	S&R	P	--	Millar 1953	(W in Langebaan Lag.), E
Sycozoa sigillinoides Lesson	48	48	cokS~~&~~&Sh&St	P	--	--	--
Synoicum adareanum (Herdman)	18	18	S&R	P	--	--	--
Tridinemnum cerebriforme Hartmeyer	0	48	S&R,coS&fSh, Sh,S&Sh&lR,R	F-C	Found off Port Elizabeth at 5-14 m. on St,R	Millar 1953	(W in Saldanha Bay & Langebaan Lag.), E

CEPHALOCHORDA

Branchiostoma capense Gilchrist	9	73	S,Sh,cokS&Sh (&St),Sn	C (LA 35-50 m.	Most of these undoubtedly escaped through the dredge net	~~Kirkpatrick 1904 b~~ Gilchrist 1904 a	--

PISCES

* Arnoglossus capensis Blgr.	42	42	fS	P	--	Gilchrist 1905, Gilchrist 1902, Gilchrist 1898	--
Chorisochismus dentex Bloch	Int.	46	S,Sh,Sn,R	C	--	Gilchrist 1905, Gilchrist 1904 b	W & E
Coccotropsis gymnoderma (Gilchrist)	9	44	S&Sh,S&R	P	--	Gilchrist 1908	--
Gillias capensis (Gilchrist & Thompson)	11	11	S&R	P	--	--	--
Gobius agulhensis Brnrd.	19	29	S,Sn	P	--	--	--
Gonorhynchus gonorhynchus (L.)	22	40	coS&fSh, S&Sh&lR	P	--	Smith 1949	E (Indo-Pacific)
Gymnobatrachus apiatus (Cuvier)	Int.	46	Sh	P	--	--	--
Heteromycteris capensis Kaup	2	30	L&S,S,Sh,Sn	C,?A	Particularly frequent from 15-25 m. A common estuarine species	Gilchrist 1905, Gilchrist 1902, ~~Kirkpatrick~~ Gilchrist 1904 b	(W in Milnerton Est.), E
Ophthalmolophus agilis (Smith)	Int.	14	S&Sh	P	--	Smith 1949	(E in Knysna Est.)
* Pterosmaris axillaris (Boulenger)	37	37	?	P	--	Gilchrist 1902	--
* Solea fulvomarginata Gilchrist	?0	?8	?	P	"Occasionally seined"	Gilchrist 1905	--
* Synaptura kleini (Bonap.)	?0	?8	?	P	Olim <u>Solea (Pegusia) capensis</u> Gilchrist. "Occasionally seined"	Gilchrist 1904 a	--

Sygnathus acus L.	13	14	S&Sh	P	"Male found in August with yellowish eggs, no embryos"	Gilchrist 1905	(E in Hermanus Est.)
Trigla sp. (juveniles)	7	36	S,Sh	P	--	--	--
Trulla capensis Kaup	1	42	S,Sh	C	--	Gilchrist 1902, Gilchrist 1898	--

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PART II. INTERTIDAL AND SHALLOW INFRATIDAL ROCKS.

INTRODUCTION.

The vast and growing literature on benthic marine ecology divides rather sharply into papers concerning the intertidal region and those dealing with the sea bed from the shallows to great depths. The division follows a difference in accessibility for workers have tended to follow field methods that are familiar to them. Thus, those interested in the intertidal region naturally consider problems that involve direct observation and direct manual work; they see their work and walk amongst it. But those who dredge usually cannot see the sea bed nor approach it personally. The field techniques unfortunately do not overlap but, on the contrary, become increasingly difficult at the lowest tidal levels and in shallow water. The result is a gap in our knowledge and an artificial differentiation between the ecology of the two regions.

Many have been unhappy about this gap and about the resultant disjointedness of ecological work. Filling the gap has depended on special methods and on biologists willing to use them. As long ago as 1844, H. Milne-Edwards used a

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diving suit for personal observation underwater, and several naturalists have done so since, including Gislen (1929 and 1930) who specifically attempted to treat the intertidal and infratidal uniformly. Despite the paucity of work in the shallows, Ekman (1935, revised 1952) grouped the biota of the intertidal region with that extending downwards from it to the edge of the continental shelf and Gislen (1944) adopted the same grouping. Both recognised the biotic continuity despite the gap in knowledge.

Knowledge is now being rapidly increased by use of more suitable methods than conventional diving. Revival of the diving hood by Beebe (1926) has brought an inexpensive method to light. It has been used very successfully by him and by Kitching, Macan and Gilson (1934) and Kitching (1941), for example. Recently a revolutionary improvement in access to the shallows occurred with perfection of the self-contained diving apparatus (pointed out by Drach, 1948a and 1952). Using this method, Drach gives some general biological observations on the shallows (1948b) and on the constitution of Laminarian beds (1949). And in England Forster (1954 and 1955) has published notes on the biota of rocks down to over 25 m..

It is to be hoped that the impetus given to study of the shallows by the self-contained diving apparatus will not result in a third, unrelated body of knowledge but that intertidal ecology will be linked to that of deeper water. In this work in False Bay, particular attention has been paid to the shallows, the ecology of which has been linked with

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So far as intertidal rocks are concerned, South Africa is fortunate in the brilliant survey by Stephenson (1939, 1944, 1947) and colleagues. Below tidal levels there is a fair amount of information from dredging on the shelf but it is scattered and only Ekman has really made any synthesis of it. There has been no work in this country correlating intertidal with infratidal ecology. Since the intertidal is well known, emphasis here is on the infratidal. In this paper the biotas of the rocks of the two regions are compared at one locality and descriptions are given of deeper rocks found elsewhere to a maximum depth of 17 m.. Detailed collections were made of the species at any height above low tide level or depth below it in an effort to determine their depth ranges within narrow limits so that the transition from the intertidal to the infratidal could be analysed by the method of critical levels (Colman 1933). This elucidated the question of the affinities of the "sublittoral fringe" of Stephenson. Quite a few species new to science have resulted incidentally.

It would have been logical to make this comparison at one of the stations described in detail in the Stephenson survey such as St. James, in False Bay, described by Eyre (1939). But St. James is unsuitable for diving due to the

shallowness/.....

shallowness of the water and the amount of surf and consequent water turbidity. The place finally chosen for diving, Oatland Point, differs from St. James in important respects as will be shown later. Unfortunately my intertidal results at Oatland Point cannot be compared with those of Eyre to elucidate these differences because her description of the St. James locality almost certainly includes small pools and crevices and the biota of the different levels of the shore are not distinguished in great detail.

It is necessary to define clearly the terminology used here. In the Stephenson survey series of papers (fully listed in Stephenson 1947) the intertidal region was called the "intertidal" and was sub-divided into horizontal biotic zones. Below the level of Extreme Low Water of Spring Tides (E.L.W.S.) was termed the "sublittoral" (Stephenson 1939) and from E.L.W.S. upwards for a variable extent but roughly speaking to the mean level of Low Water of Spring Tides (M.L.W.S.) was termed the "sublittoral fringe". Later, Stephenson and Stephenson (1949) replaced the word "intertidal" with "littoral" and "sublittoral" with "infralittoral" despite previous criticisms of the debasement of the word "littoral". Similar criticisms of the word "littoral" have been made by Ekman: in 1935 he used it to mean the area from the top of the intertidal region down to the edge of the continental shelf but replaced it by the term "shelf fauna" in 1952. Gislen (1944) uses the term "sanidal", corresponding to Ekman's "shelf fauna", in an effort to avoid the word "littoral". Day, Millard and Harrison (1952) also shun "littoral" and point out that the term "intertidal zone"

for the/.......

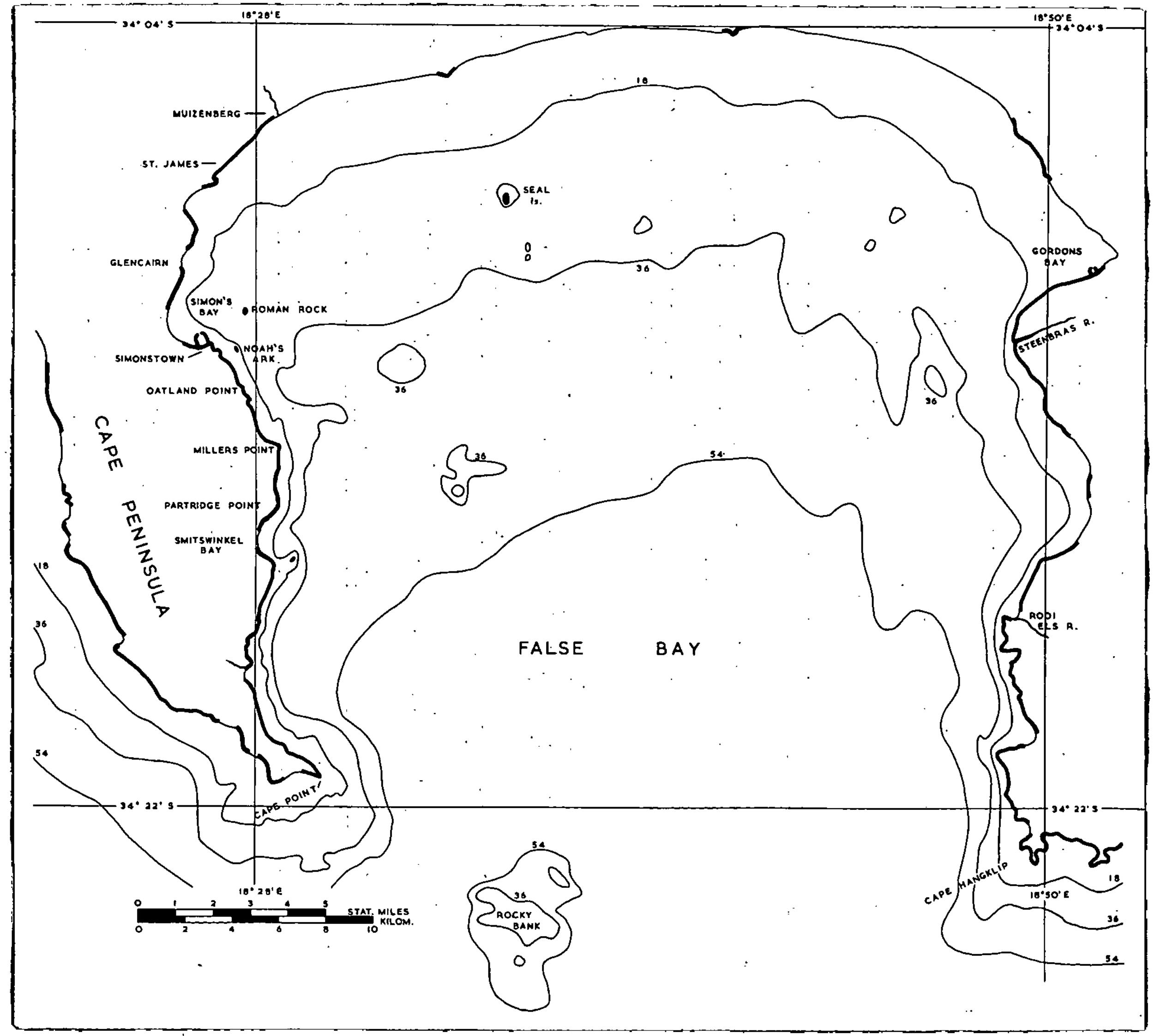
Figure 1.

False Bay.

Based on British Admiralty chart 636.

Sandy shores in thin line, rocky shores in thick line.

Depth in metres: the contours approximate to those at 10, 20 and 30 fathoms.



for the region of the shore between tide marks is widely accepted. They suggest that the fringe of the sea-bed below the intertidal zone be referred to as the "infratidal fringe", this term replacing both "sublittoral fringe" and "infralittoral fringe". The term implies that the region of the sea never bared by tides be called the "infratidal zone" although they do not say this in so many words.

ENVIRONMENTAL NOTES.

A. GEOGRAPHICAL.

False Bay is a well defined bay of the sea roughly square in shape and open to the south, the sides being about 20 miles long (see Fig. 1). The bay is about 12 miles south of Cape Town and is separated from the South Atlantic by the Cape Peninsula which is the westerly limit of the southern coast of Africa. The bay cannot be regarded as having any estuarine characteristics for it is large and has negligible fresh water inflow. No large rivers enter the bay but in winter there are many little mountain streams on the westerly and easterly shores, two of which on the easterly side are dignified with the title of river, the Steenbras River and the Rooi Els River. The mouth of the bay is too large for it to have characteristics of a marine lagoon. False Bay is best regarded as part of the oceanic coastline where there is some shelter from the full effects of swell and storm, particularly in winter.

The place/......

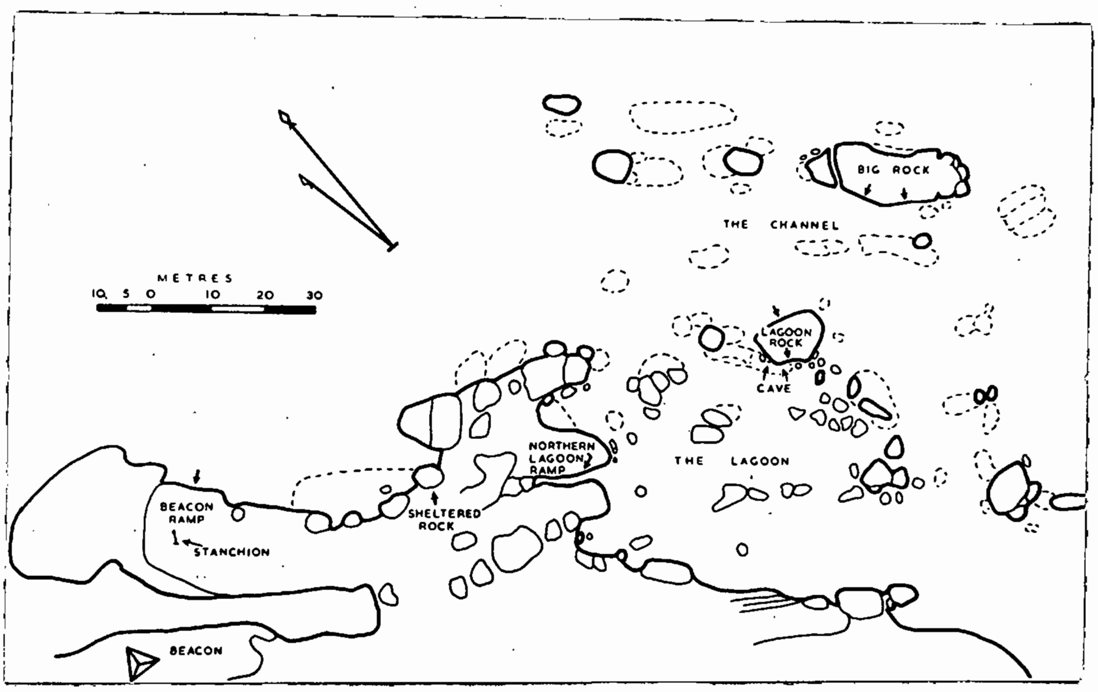


Figure 2. Sketch map of Oatland Point.
Main rock formations below datum are indicated by dashed lines.
Arrows show places of work.

The place selected for most of the work was Oatland Point as being easily accessible by road and the nearest place suitable for diving. Fig. 1 shows that Oatland Point is the nearest place where the bottom slopes appreciably. It provides reasonably deep and clear water and very varied rock faces. The ground slopes to the sea without streams nearby. At the water's edge are granite formations forming almost horizontal pavements and vertical walls. Splits in the large masses may form V-shaped clefts between cubiform slabs. Erosion forms characteristically rounded boulders lying next to, and on top of, one another with ramifying crevices and increased erosion at the bases of the boulders forms small hollows and large caves. The rock formation is similar both above and below water.

Oatland Point continues seaward as many separate large rocks rising abruptly from the bottom. At low tide a distinct, shallow lagoon is formed by a semi-circle of rocks through which the water passes freely only at the north and south. (See sketch map Fig. 2 and Plate I.). The Lagoon is D-shaped, roughly 50 m. long, 40 m. wide and 1-2 m. deep at L.W.S.T. A conspicuous, large rock at the middle of its periphery is named "Lagoon Rock". Most of the rocks in the lagoon are covered at M.H.W.S. but the outer semi-circle remains exposed and gives considerable protection from the swell.

Outside the Lagoon a scattered series of rocks form a discontinuous outer semi-circle. The northern part of the gap between the two semi-circles is named "The Channel" and is about 60 m. long, 30 m. broad and 6 m. deep at L.W.S.T.

Usually/.....

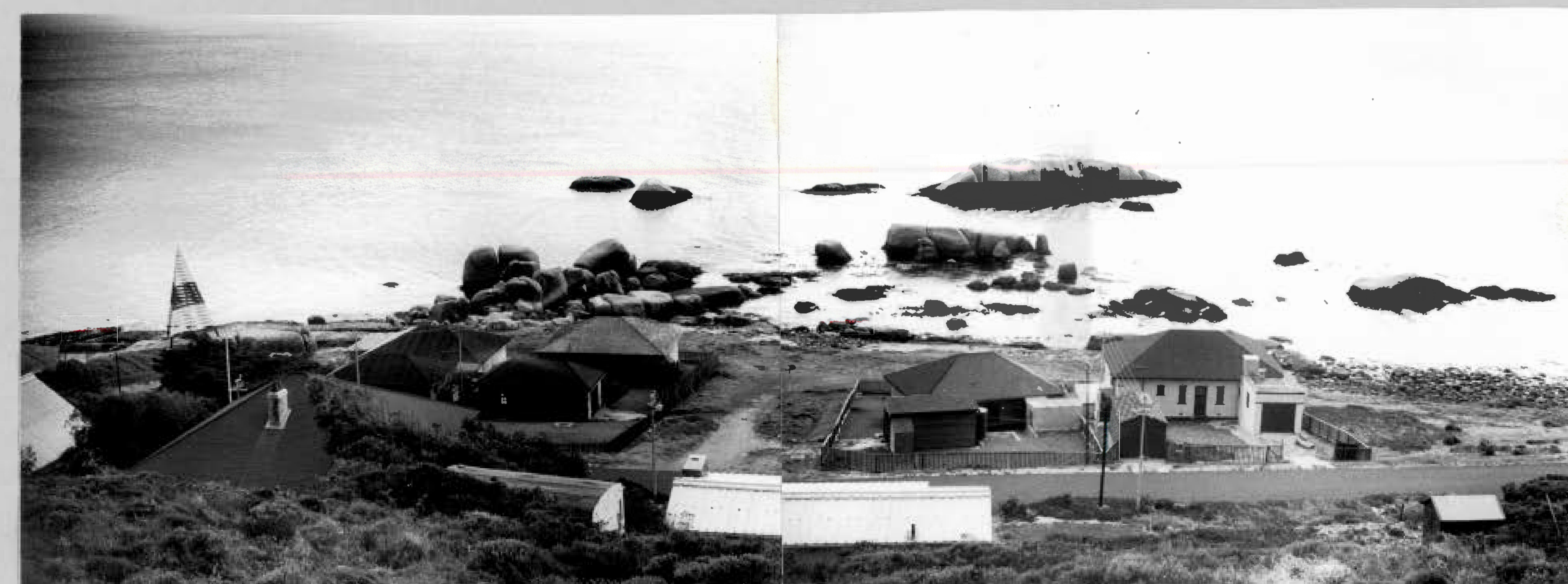


Plate I. Oatland Point at L.W.S.T.

To the left can be seen the
beacon beyond which lies Beacon Ramp.

Usually there are currents through it due to tide and wind. A conspicuous large rock of the outer semi-circle is called "Big Rock"; it lies seaward of Lagoon Rock being separated by the southern end of the Channel. Seaward of the outer semi-circle the bottom is sandy and slopes gently away from a depth of about 8 m..

Diving was not confined to Oatland Point. Deeper rocks were found elsewhere, namely at Roman Rock Lighthouse (see Fig. 1.), at Noah's Ark and the Quay, Gordon's Bay Harbour. Further details of the places at which collections were made will be given with the biological descriptions.

Unfortunately the intertidal and infratidal could not be examined on the same rocks because suitable ones were rare and inaccessible. It was decided that four intertidal transects were desirable to show different degrees of exposure to wave action. Three faces were selected at Oatland Point but one that was very exposed to swell and, at the same time, accessible, could not be found nearer than Froggy Pond which is the nearest point to the north and only 400 m. distant; it is too close to be distinguished in Fig. 1.

B. PHYSICO-CHEMICAL.

According to Ekman (1952) False Bay lies in the "Warm-Temperate Region" but Stephenson (1947), commenting on Ekman's 1935 edition, notes that it is transitional between "Warm-Temperate" and "Cold-Temperate". Stephenson (1944) describes the main components of the intertidal rocky biota of South Africa. He finds there to be three main components, those

of the/......

of the western, southern and eastern coasts, these being correlated chiefly to hydrographic factors. False Bay lies in the region of overlap between Stephenson's western and southern components and the mixed hydrographical conditions of the overlap are further complicated by peculiarities within the bay as will be mentioned below. Stephenson (1944) devotes a section to the Cape Peninsula and states that the whole of his survey arose from a desire to elucidate the problems of the Cape Peninsula itself. He suggests that in the 17 miles from Cape Point to Muizenberg similar changes occur to those from Cape Point to 100 miles eastward of it.

The hydrography of False Bay is undeniably complex and has not been worked out even approximately but full knowledge is not necessary for this paper. It is sufficient to emphasise that from Cape Point to Muizenberg there are remarkable, obvious changes in the intertidal flora and fauna, changes which Stephenson has shown to be correlated to the east along the coastline of southern Africa by marked changes in the characteristics of the water masses, particularly in temperature. In discussing this matter again, Stephenson (1947 Fig. 7) gives the hourly variations in sea temperature at various localities on one particular day and St. James shows the highest temperatures with those at Miller's Point, some 8 miles to the south, about 3°C lower. These data are suggestive but not conclusive. Many personal observations (unpublished) over three years confirm Stephenson's comments on temperature variability and they show that, although there is usually no temperature gradient between Muizenberg and

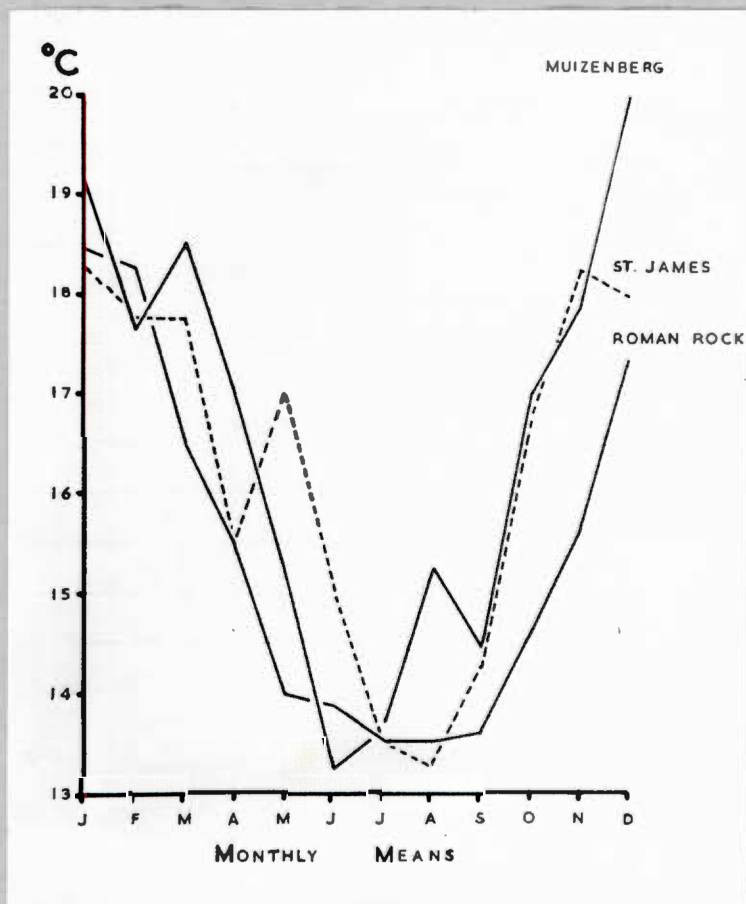


Figure 3. Daytime temperatures of the surface of the sea in the west of False Bay.

Figures for St. James are derived from Marchand 1932 for Muizenberg and Roman Rock from Isaac 1937.

Cape Point when the year as a whole is considered any temperature gradient is from higher temperatures at Muizenberg to lower temperatures to the south and that this is a summer feature. The cause of the gradient is presumably the prevailing south-east wind of summer which causes drift of warm surface water towards Muizenberg. Figures could be produced from available data to prove almost any hypothetical hydrographical arrangement in False Bay but Stephenson's figures for St. James and Miller's Point give likely "typical summer conditions" of water temperature along this coast-line. In winter there is unlikely to be a north - south temperature gradient because the wind blows from the north-west and the effect of sunshine is less.

Some indication of the yearly temperature cycle of surface water in False Bay is given in Fig. 3. The curve for St. James is for 1930 (Marchand 1932); those for Muizenberg and Roman Rock (in Simon's Bay) are derived from Isaac (1937) who does not state over what years the data were averaged. Muizenberg and St. James are nearby and so the differences between their curves are presumably due to the data having been drawn from different years. But it should be valid to compare the curves for Muizenberg and Roman Rock and they show temperatures at Roman Rock to be lower, usually. One cannot say whether this is part of the north-south gradient mentioned or whether it is due to Roman Rock being offshore, with some 17 m. depth of water immediately around it.

So far as the yearly cycle at Oatland Point is concerned the author took numerous temperatures but it was impossible to do so systematically. This fact, with the discovery that

temperatures/...

temperatures in any month could vary greatly from year to year, render the figures unsuitable for comparison with Fig. 3. For example, in March 1953, the mean of four readings was 18.7°C and in March 1954, the mean of five readings was 15.9°C. However, the main features of these records are summarised in Table I for comparison with Marchand's data for St. James in 1930. The average monthly temperature for Oatland Point over two and a quarter years is the same as that for St. James back in 1930 but St. James appeared to have greater extremes.

In September 1953 four stations in False Bay, a few miles offshore, were sampled hydrologically as will be discussed in detail in another paper relative to dredging work. It is sufficient to state here that from 0 to 20 m. depth both temperatures and salinities were found to vary only very slightly with depth. But diving experience showed that vertical temperature gradients were the rule rather than the exception, certainly in summer, and this is backed-up by the records of two occasions when underwater temperatures were taken by manual operation of a normal, reversing thermometer. In November 1953 the surface temperature of the Lagoon, at Oatland Point was 17.4°C and that on the bottom (2 m. below) was 17.2°C. On the same date the temperature of the surface of the Channel was 17.4°C and that on the bottom (6 m. below) was 15.2°C. The wind was fresh south-easterly. As a result of diving, it is suggested that temperatures at 15 m. depth are 2 - 4°C lower than those on the surface: this applies only to the north-west of False Bay, where most diving was done in summer.

Marchand/.....

	Oatland Point 7.6.52 to 29.9.54	St. James 1930			
	Random daytime sea surface temperatures.	Regular daytime sea surface temperatures.	Regular noon sea surface pH values.	Regular noon sea surface salinity.	Regular daytime air (dry) temperatures.
Average of Monthly Means	16.3°C	16.3°C	8.16	35.31‰	18.9°C
Monthly Means: Maximum	-	18.3° (Jan. & Nov.)	8.50 (Feb.)	35.65‰ (Jan.)	24° (Jan.)
Monthly Means: Minimum	-	13.3° (Aug.)	7.75 (July)	35.05‰ (June & July)	14° (July & Aug.)
Extremes recorded: Maximum	20.3° (March 1953)	21.2° (Feb.)	8.55 (Jan.)	36.66‰ (Jan.)	25.4° (Jan.)
Extremes recorded: Minimum	13.3° (May 1953)	11.9° (Aug.)	7.68 (July)	34.99‰ (July)	10.6° (Aug.)

Table I. Conditions at the water's edge on the west coast of False Bay.
(Data for St.James derived from Marchand,1932).

Marchand gives daily figures for the variation in hydrogen ion concentration at St. James in 1930 and a graph of the monthly means which are summarised here in Table I. It will be seen that there is a marked seasonal variation: Marchand couples the high summer pH with dense phytoplankton population and the consequent assimilation of CO2 from the water. It should be noted that there are no dense algal beds at St. James to affect the inshore values markedly.

In January, 1928, Hogben and Zoond (1928) investigated the surface hydrogen ion concentration from about two miles off Partridge Point (see Fig.1) around the Cape Peninsula to Table Bay. They found no statistically significant difference between the pH of waters on either side of the Peninsula although there were two markedly different bodies of water sampled, differing in temperature by over 5°C.. Thus it would seem likely that the bulk of the surface water of False Bay shows little variation in pH. Even so, a gradient from Cape Point to Muizenberg might exist at the water's edge due, not to hydrographical features, but to the presence of great kelp beds in the south and the meagre algal growth in the north. This possibility has not been investigated.

False Bay appears to be very much a mixture of waters derived from various sources and then agitated by the wind, deflected according to topography and warmed by the sun. Marchand points out that for 1930 the salinity curve at St. James closely follows that of sea temperature. Also that the air temperature curve is of the same type as the sea temperature curve but exaggerated, being only just higher in

winter/......

winter but markedly higher in summer. The chief features of these data are entered in Table I for convenience. Hogben and Zoond suggest that, in general, differences in pH, dissolved oxygen and salinity are unimportant as factors governing local distribution of marine species but that temperature is very important.

English!

The conclude the consideration as to possible differences along the west coast of False Bay comment must be made upon wave action and to the nature of the substratum. Swell is usual in the bay and can only enter from the south, diminishing as it progresses northwards and producing rollers and surf over the shelving sea-bed particularly in the north. The coast is not greatly indented and very sheltered localities are rare. Most of this coast is rocky. A centre section, from Simonstown to Smitswinkel Bay (See Fig.1) is of Pre-Cape granite and most of the rest consists of Table Mountain Sandstone with small granite outcrops. The granite characteristically forms islands and chains of rounded, giant rocks such as at Oatland Point whereas the sandstone usually lies in flat terraces as at St. James. Of course, both occur in the jumble of rounded boulders at low tide level.

INTERTIDAL BIOLOGY/.......

INTERTIDAL BIOLOGY.

A. METHODS.

Since the chief characteristic of the intertidal zone is intermittent exposure to air it was decided that pools and crevices should be avoided. Four intertidal sites were chosen with regard to this and to differences in degree of exposure to wave action.

It was decided that biotic levels should be related to absolute levels rather than to tidal ones and for this purpose, a datum had to be chosen from several that could be considered. The datum adopted was that of the South African Railways and Harbours tide gauge in Cape Town harbour; this datum is said to be at "L.W.O.S.T." level (or M.L.W.S.) for Table Bay. The work of Bokenham, Neugebauer and Stephenson (1938) on tidal levels in False Bay is commented upon below but it must be mentioned here that they found M.L.W.S. at Simonstown to be about 3½ inches below the datum of the Cape Town harbour gauge (see Table II). In this series of papers, all heights and depths are measured from datum which is considered to divide the intertidal from the infratidal zone. Unusually low spring tides will expose part of the infratidal zone and this region is termed "the infratidal fringe". These definitions correspond closely to the terms used by Stephenson (1939 etc.). It must be remembered that the terms "datum level" and "M.L.W.S. level" are not quite synonymous in False Bay but the difference is negligible for most purposes.

At each/......

At each site, a position was taken as a bench mark and the levels of conspicuous biotic features were related to it by a method suggested by Professor Day. The method involves two workers, each with an 8 ft. surveyor's ranging rod. The rods are stood vertically on the two points which are to be surveyed and, with the eye close to a convenient height on the one rod, a sight is taken looking past the other rod towards the horizon. This sight is reckoned to be horizontal. A slide is moved along the second rod until its top intersects the line of sight. The difference between the level of the eye of the viewer and that of the top of the slide gives the change in level of the substratum. Where a natural horizon is not available an Abney level provides an artificial one. Levels could be measured to a probable accuracy of ±0.25 inches over distances up to 30 ft.

The bench marks of the transects were surveyed in relation to Trigonometrical Survey bench mark number 436 professionally to an accuracy of ±0.02 ft. I am informed by the Director, Trigonometrical Survey, that "all height values for bench marks in the vicinity of Cape Town are referred to M.S.L. Cape Town" which the S.A.R. and H. authorities in Cape Town inform me is 2.224 English feet above the tide gauge datum. Transect levels have been correspondingly altered to read as from the datum adopted here and converted to the metric scale.

Tidal levels have been calculated for Simonstown by Bokenham et al., on the basis of tide-gauge traces there for 1933-35. Levels have been given (p. 117 of their paper) relative to "Mean Sea Level" which Dr. N.A.H.Millard

(nee/.........

(nee Bokenham) tells me is the same level as that used as reference by the Trigonometrical Survey. These tidal levels are repeated here for convenience (Table II) with conversions to the datum used in this paper and to the metric scale.

	Relative to Trigonometrical Survey datum ("M.S.L.") in feet.	Conversion relative to Cape Town tide gauge datum (M.L.W.S.) in inches.	Conversion relative to Cape Town tide gauge datum (M.L.W.S.) in metres.
E.H.W.S.	3.68	70.85	1.80
M.H.W.S.	2.92	61.73	1.57
M.H.W.N.	0.73	35.46	0.90
M.L.W.N.	-0.38	22.12	0.56
M.L.W.S.	-2.52	- 3.55	-0.09
E.L.W.S.	-3.32	-13.15	-0.33

Table II. Tidal levels at Simonstown. (Based on Bokenham, Neugebauer and Stephenson, 1938).

The definitions of the tidal levels used by Bokenham et al. are worth noting, particularly their comment on the difficulty in determining the levels of extreme neap tides due to the highest low water not falling as low as the lowest high water recorded.

The more exposed a rock is to wave action the greater the difference between the levels of wave upwash and suck-back upon it and this difference may be termed the "wash range". If we compare the wash ranges at the selected intertidal sites we should get an idea of their relative exposure to wave action although, strictly speaking, the

comparison/...

comparison should be made between rocks of identical slope.

Wash ranges were noted on four occasions and are tabulated in Table III.

OATLAND POINT			FROGGY POND
Sheltered Rock	Northern Lagoon Ramp	Beacon Ramp	
Shady, very sheltered	Sheltered	Semi-exposed.	Exposed
0.30 m.	0.46 m.	1.02 m.	1.68 m.
0.38	0.49	0.85	0.99
0.38	(0.28)	1.19	1.55
0.33	(0.17)	0.36	0.70

Table III. Vertical Wash ranges on Four Occasions at the Selected Intertidal Sites. Values in brackets are low because they were obtained at low tide when the site became extra sheltered by emergent rocks.

In three sites exposure to wave action did not depend on tidal level, but one, Northern Lagoon Ramp, gained increased shelter below half tide level due to emergent rocks to seaward. There is progressive increase in wash range from Sheltered Rock to Froggy Pond. Experience suggests that the first line of Table III represents normal conditions. Table III includes a verbal estimation of the exposure to wave action at each site and hereafter the sites will be designated by these descriptions.

It is/......

Plate II. The Shady, Very Sheltered Site, Oatland Point, at L.W.S.T.

The ranging rods are inserted to show the slope of the rock and to give scale; they are marked in feet. The water at the base of the sloping rock is only a few inches deep.

It is felt that about three-quarters of the wash range represents upwash above actual tidal level and one-quarter represents suck-back below it because suck-back is minimised by water cascading from the rock. It may be argued that upwash is more important to the biota than suck-back and that tidal levels are effectively raised by the height of the upwash.

As has been mentioned, sites were chosen that did not have deep crevices or pools. At each site, there were horizontal changes in biota due to local rock formation and so the sites were only examined in detail along vertical transects about 2 m. wide. Detailed field notes were made of the conspicuous species in relation to surveyed levels and collections were taken from all levels for laboratory sorting of small species. The method of examination used by Evans (1947) was not adopted because the areas of the sites were small and because detailed collections were desired.

B. THE BIOTA.

(i) Shady, Very Sheltered Site. ("Sheltered Rock", see Fig.2). and Plate II

Upwash 0.23 m. (9 inches).

The transect faced south but backed upon the sea and so was maximally protected from wave action. Since it was overhanging the transect was always shaded and nearby rocks increased the dimness of illumination.

The rock/......

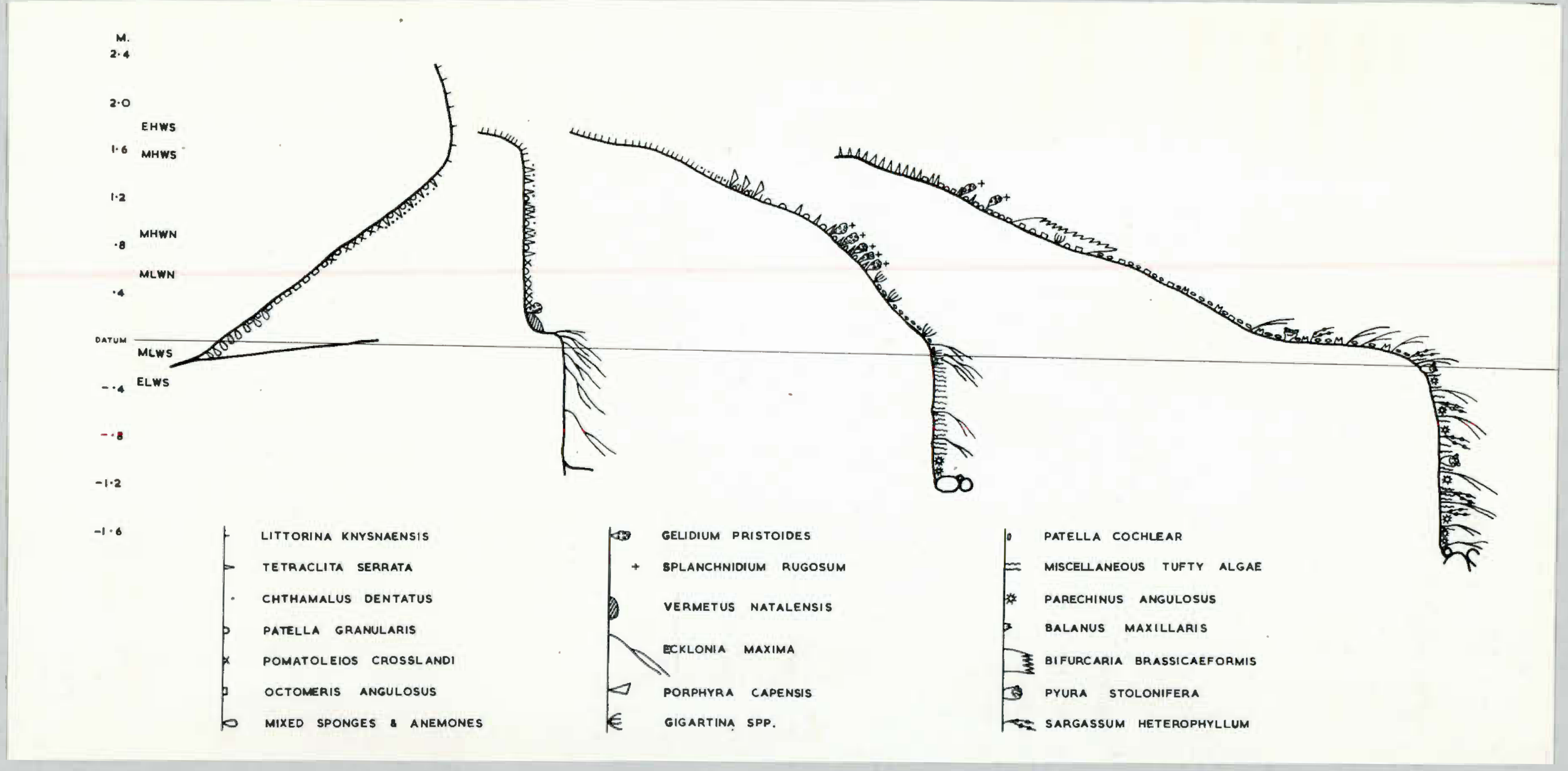


Figure 4. Profiles of the intertidal transects with diagrammatic representation of the chief biota.

From left to right the sites are : Shady, Very Sheltered; Sheltered; Semi-Exposed; Exposed. The vertical scales show true levels.

To avoid confusion *Octomeris* has been omitted from the diagram of the Semi-Exposed site; its range and abundance are approximately that of *Gelidium*.

The rock under consideration rested on a great granite slab just below datum level. The transect lay on the underside of a face sloping at about 40^{o} to the horizontal and running straight from below datum to about 1.6 m. height (i.e. M.H.W.S. level) above which it curved past the vertical (see Fig.4).

The biota was typical of similar situations nearby, although not so crypto-faunistic in nature as smaller and more inaccessible places. The face was brightly coloured at lowest levels with anemones (*Bunodosoma capensis*), with various sponges (e.g. *? Geodia littoralis* CP.426 B and *? Hymeniacedon perlevis* CP.426 C) and with the ascidian *Amaroucium ? erythraeum* (CP.428 B). The soft polyzoon, *Menipea crispa*, was common amongst them and there were fair numbers of *Balanus trigonus* and occasional small *Mytilus crenatus*. The sponges and anemones and *Menipea* were replaced by a dense growth of the barnacle *Octomeris angulosus* which flourished from 0.2 m. height to M.H.W.N. level and, in the lower half of this range, i.e. below M.L.W.N., completely dominated the rock. A dusty looking "*Lithothamnion*" was common on *Octomeris*, particularly in the upper half of the range of the barnacle. Above M.L.W.N. level, the serpulid worm, *Pomatoleios crosslandi*, progressively took more space at the expense of the barnacle and its tubes supported the only soft alga that was present in fair quantity, namely the tiny, red *Pleonosporium harveyanum*. The barnacle *Octomeris* dwindled to extinction above M.H.W.N. level and the upper limit of *Pomatoleios* was at the same level but was very sharply defined. The barnacles *Tetraclita serrata* and, in

lesser/.....

lesser abundance, Chthamalus dentatus started to appear below this conspicuous line but only became very abundant above it where they dominated the rock almost to M.H.W.S. level.

Only a few mobile species were to be found, namely Asterina exigua and Henricia ornata at low levels, Patella granularis and Oxystele variegata among the Tetraclita, and a few Littorina knysnaënsis above all other species. Of these only P.granularis was common. The upper limits of Tetraclita, Chthamalus and P.granularis made a rather well marked line about 0.2 m. below M.H.W.S. level.

Stephenson (1939 etc.) has firmly established terminology for zonation on intertidal rocks in South Africa. On this site the lower limit of Stephenson's Littorina zone is clearly at the upper limits of Tetraclita, Chthamalus and P.granularis (just below M.H.W.S. level). These three species are virtually the only occupants of the upper Balanoid zone. The upper limit of Pomatoleios, just above M.H.W.N. level, provides another clear demarcation line this time between upper and lower Balanoid zones. There is no Cochlear zone and so the lower Balanoid zone here merges imperceptibly at about datum level into Stephenson's "Sublittoral fringe" (the quotation marks are inserted to show that the term is not accepted by this author).

(ii) Sheltered Site. ("Northern Lagoon Ramp"., see Fig.2). and Plate III

Upwash 0.34 m. (1 ft. 1½ in.) above half tide level and much less lower down.

The/.....

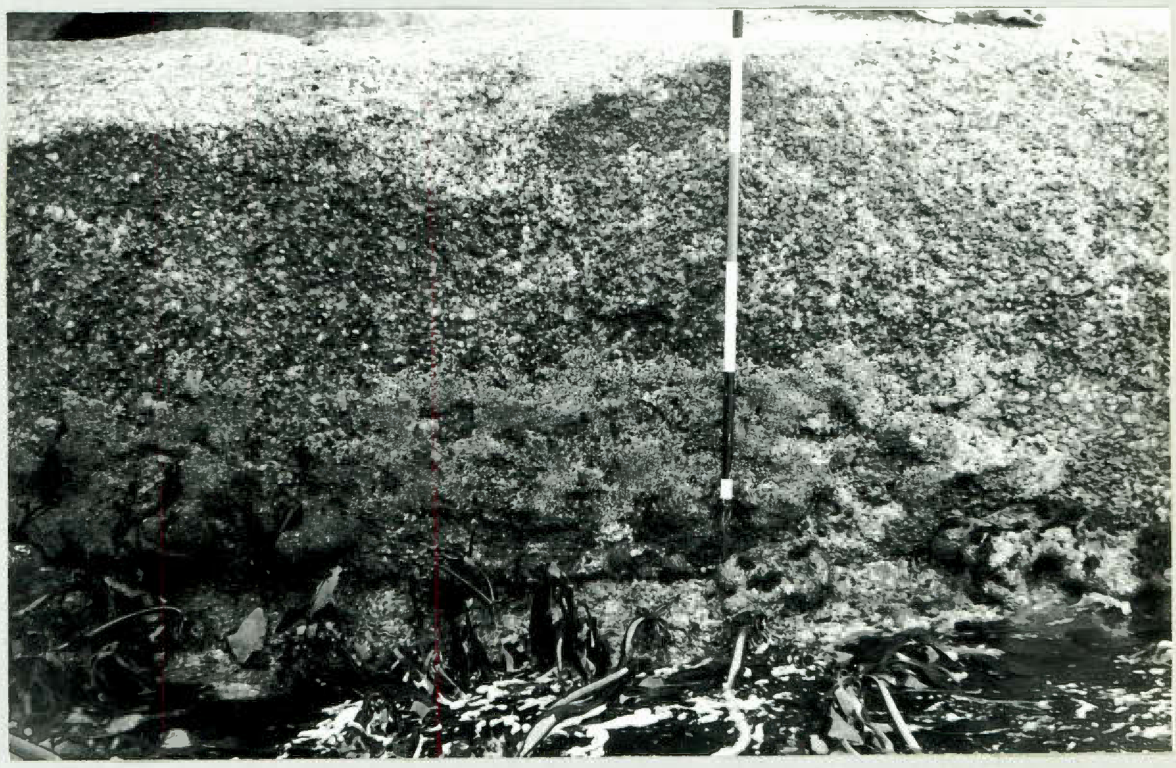


Plate III. The Sheltered Site, Oatland Point, at L.W.S.T.

The ranging rod stands on a narrow step and the transect described lies to the left of the rod; to the right, changes can be seen which are due to increasing wave action. The upper limit of Pomatoleios is clearly seen about half-way up the face but the rather sharp demarcation between Pomatoleios and Vermetus, below it, is not obvious because both are covered by fine "Lithothamnia".

The transect faced SSW so swell or surf did not smack directly on to it but ran across the transect.

The rock face rose vertically from about one metre depth to a step situated ~~about half a metre about~~ a little above datum. The step was about 0.3 m. wide and above it the face rose vertically again to the height of 1.6 m. where it flattened rather sharply (see Fig. 4).

In the infratidal zone the kelp Ecklonia maxima flourished although most of the rock was colonised by a smooth, thick, crusty "Lithothamnion" (CP.392 B) upon which little grew.

Ecklonia and crusty "Lithothamnion" rose a little above datum but the kelp was very small intertidally. There was a sharp transition to a well developed but narrow band of the gastropod, Vermetus corallinaceus, which was replaced by the worm Pomatoleios higher up. The upper limit of Pomatoleios occurred here just above M.L.W.N. level and was also rather sharp; above it the grey barnacle, Tetraclita, dominated the rock to M.H.W.S. level with Chthamalus present in less numbers. Dusty "Lithothamnion" usually colonised both the Vermetus and the Pomatoleios tubes. The tufty alga Gelidium pristoides made a frilly, narrow line at the Vermetus/Pomatoleios overlap and there were a few Iridophycus plants above it.

There were very few mobile species present. Acanthochiton garnoti was rather common amongst the Pomatoleios tubes but small Patella granularis and small Oxystele variegata were commoner there and also higher up among the barnacles. Littorina invaded the highest barnacles from above.

In Stephenson's/....

In Stephenson's terminology the lower limit of the Littorina Zone was just about at M.H.W.S. level, at the upper limits of Tetraclita, Chthamalus and P.granularis. The upper Balanoid Zone gave way to the lower at about M.S.L., the upper limit of Pomatoleios. The Cochlear Zone was absent but was probably represented by the band of Vermetus; below this, was the "Sublittoral fringe" as represented by Ecklonia and the characteristic crusty "Lithothamnion".

(iii) Semi-Exposed Site. ("Beacon Ramp", see Fig.2 and Plate IV).

Upwash 0.76 m. (2 ft. 6 in.)

The transect faced NE and was protected from the direct force of the swell (SE usually) but which nevertheless changed direction to impinge more on this site than might be supposed. The site faced the strong wind-induced chop that prevailed in winter.

Below the transect there was a stony bottom at about 1 m. depth from which the rock face rose vertically to datum and turned sharply to make a slope at about 60° to the horizontal. The slope undulated somewhat but at about 1 m. height definitely became flatter and it flattened progressively ~~about~~ above this until it was about horizontal at 1.8 m. height (See Fig.4).

The two or three decimetres of vertical rock immediately above the bottom were almost devoid of soft algae and bore biota similar to that of the stones of the adjacent bottom, i.e. "Lithothamnion" dominated and there were many Parechinus angulosus. Above this was a dense mat of tufty algae the commonest of which were red Dicurella flabellata, green

Caulerpa/...

Plate IV. The Semi-Exposed Site, Oatland Point, at L.W.S.T.

The figure and ranging rod show where the transect was made. The rod stands at about M.S.L., at the top of the Cochlear zone and below a belt of algae. Nearer the camera, this belt was monopolised by Bifurcaria and nearer still, in the foreground of the picture, it can be seen that the biota of the rock is very much modified by torrents of water draining from a depression in the rock above M.S.L. after every wave.

At the top of the rock to the right, can be seen the inclined iron stanchion that was used as a bench mark for this site. The rock at the very left of the picture is that of the Shady, Very Sheltered Site.

Caulerpa filiformis and olive Dictyota dichotoma. Others were common but varied from one year to another. For instance in September 1954 Laurencia glomerata and Plocamium cornutum were very common but in March 1955 the former was absent at this level, and only a few tufts of the latter were present. Hypnea spicifera and Leathesia difformis were fairly common and Ecklonia, although common a few yards away, was represented by only occasional plants. On this infratidal face all the animals were small, the commonest to the eye being the little pink anemone Corynactis annulata although there was a multitude of polychaetes and amphipods. A few small peach-coloured tunicates (CP.436 A, ? gen. et sp. nov.) were hidden amongst the algae.

In the intertidal zone from M.L.W.S. to M.L.W.N. was dominated by a clearly demarcated zone of the limpet Patella cochlear and its associated "Lithothamnion" and algal gardens and the little serpulid, Spirorbis borealis. This site was richly populated with tufty algae and they particularly favoured the limpet shells. Some, such as Ecklonia, Hypnea spicifera and Bifurcariopsis capensis rose from the intertidal to achieve their greatest growth just above M.L.W.S. Others grew densest around M.L.W.N. e.g. Pterosiphonia cloiophylla and the two tiny but common algae Chylocladia capensis and ? Griffithsia sp. (CP.396 F). Gigartina radula and G. stiriata were peculiar in that they flourished at two levels, i.e. just above M.L.W.S. and at M.L.W.N. with scanty plants in between. Some algae varied seasonally. In September, 1954 Laurencia glomerata was common infratidally and rose as high as M.S.L. but in March 1955 it was less common and was restricted to the range occupied by P. cochlear. And on the former occasion Plocamium cornutum also extended from M.L.W.S. to

M.S.L./....

M.S.L. but it was absent from the transect six months later. Before leaving the lowest levels of the intertidal zone mention must be made of the tufty coralline algae that were numerous just above M.L.W.S. and which decreased in abundance higher up. And it must be pointed out that sessile animals were rare apart from P.cochlear. There were a few small anemones (Bunodosoma) and a few small Mytilus crenatus at and below M.L.W.N. level.

Clearly the lowest half of the intertidal zone is rich in species although most of them are rather small. The distribution of P.cochlear, and its associated "Lithothamnion" ceased abruptly above M.L.W.N. and here,at the middle of the intertidal, was a rich but narrow belt of algae extending from among the limpets at M.L.W.N. to above M.H.W.N. level. The commonest were Gelidium pristoides and Splanchnidium rugosum but Aodes orbitosa was conspicuous a trifle lower down than these. In this algal belt the barnacle Octomeris was common and small Mytilus perna fairly common and both species were confined to it.

From M.H.W.N. to M.H.W.S. the rock was comparatively bare. The grey barnacle Tetraclita dominated the lower half with the small alga Chaetangium ovale thinly interspersed; and the upper half was dominated by the tiny barnacle Chthamalus. In the lower range of Chthamalus there were patches of the alga Porphyra that replaced it.

The distribution of mobile animals on this transect rather depended on the shelter offered by algae. In the infratidal Oxystele sinensis was sparsely dotted about but in the lower

half/.....

half of the intertidal it gathered under algal tufts and was scarcely to be found in the open. Another gastropod commonly found beneath tufts was Cominella cincta. Above M.S.L. O.sinensis was replaced by the smaller O.variegata which, with Patella granularis, rose almost to M.H.W.S. level. P.granularis was found in the open spaces of the algal belt and amongst the Tetraclita above it but was absent above the Tetraclita except where Porphyra was present to shelter it. At the upper limit of Tetraclita a few Littorina were to be seen; they became common above M.H.W.S. and extended upwards to the highest level attained by the rock (2.08 m.).

This site showed all the typical zones as described by Stephenson. There is confusion in demarcating the Littorina from the Balanoid zone because Porphyra, which is typical of the Littorina zone, flourished here lower than the upper limit of Chthamalus. The upper limit of barnacles was rather sharp at M.H.W.S., the upper limit of P.granularis, Stephenson$ alternative boundary line, was 0.1 m. lower and the lower limit of Porphyra was a further 0.2 m. lower.

The upper and lower Balanoid zones meet at the top of the algal belt, at M.H.W.N., and most of the Lower Balanoid zone is here replaced by the Cochlear zone. The Cochlear zone ends at M.L.W.S. and from M.L.W.S. to E.L.W.S. is clearly "Sublittoral fringe" as represented by the algal mat which, as has been mentioned, started at M.L.W.S. and went down well into the infratidal.

iv)Exposed Site/.....

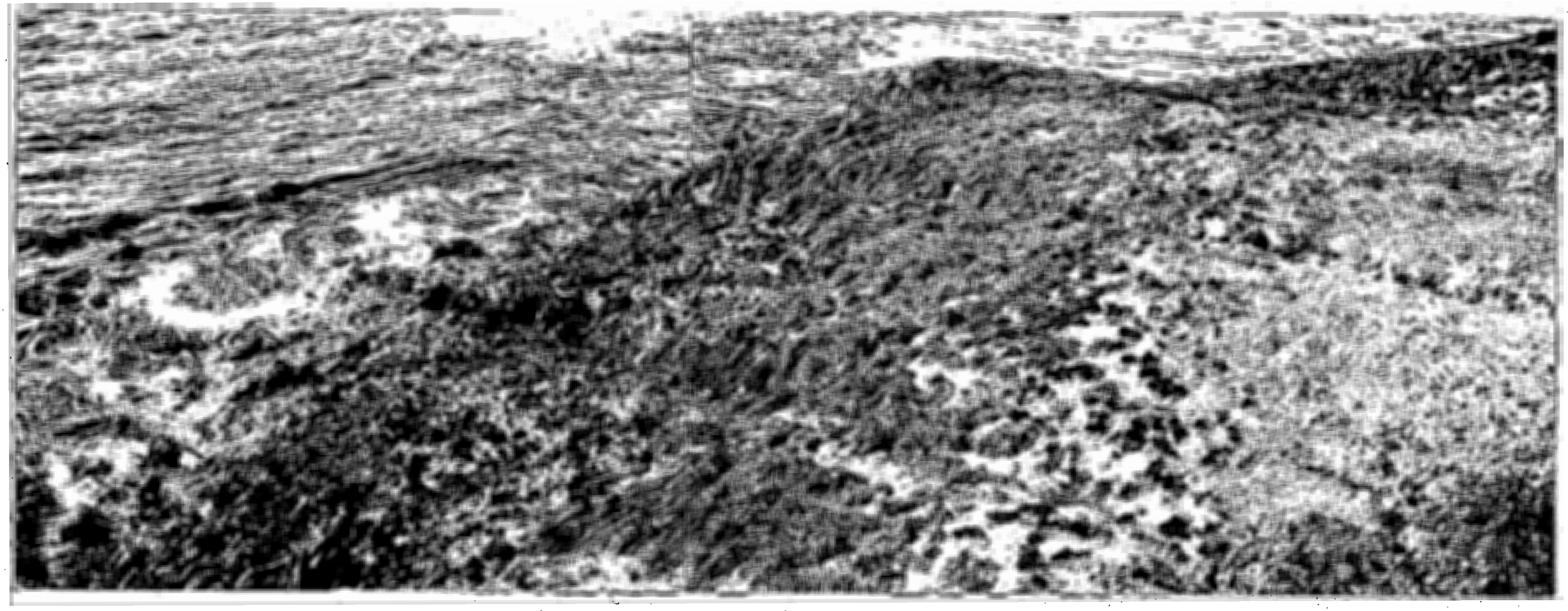


Plate V. The Exposed Site, Froggy Pond, at L.W.S.T.

The photo is taken from a slightly higher, neighbouring rock. The transect lies between the two gullies that run diagonally across the photo. The crest of the site is to the extreme right from which the slope along the transect is fairly constant to the water; actually, an inch or two of cascaded water covers the lowest part of the transect which is almost flat. Barnacles are seen to the right, the rich *Bifurcaria* belt in the middle and small, outlying kelp plants at the bottom of the transect, to the left.

(iv) Exposed Site. (Froggy Pond, southernmost point; see Pl.V).

The southern point of the bay at Froggy Pond was inaccessible; the site selected was the next point south of it.

Upwash 1.26 m. (4 ft. 1½ in.).

The transect faced ESE, almost in the eye of the swell. This point was also exposed to wind chop from the north caused by winter winds.

Below the transect there was a rocky bottom at about 1½ m. depth. From this, the rock rose almost vertically to just above datum where it became almost flat, forming a platform about 1½ m. wide. The face then rose at about 30° to a crest at M.H.W.S. level above which was ignored because of complicated rock shape. (See Fig.4).

The infratidal biota consisted of a motley assortment of species showing no clear or orderly arrangement. The alga Dicurella fragilis was commonest with pale "Lithothamnion", Sargassum heterophyllum, and small Ecklonia plants competing for rock space, with each other, and with small specimens of the giant tunicate Pyura stolonifera. Numerous Oxystele sinensis and Parechinus angulosus were scattered around, the latter favouring niches in the rock.

The lower part of the intertidal zone was occupied by a well developed mosaic of P.cochlear and its associated "Lithothamnion". Their lower boundary was ill-defined and whereas the "Lithothamnion" went down to M.L.W.S. level the limpets stopped about 0.2 m. above it. Pyura and a few algae such as Dicurella fragilis, Sargassum heterophyllum and Ecklonia rose from the infratidal to about M.L.W.N.

A few/....

A few others started at M.L.W.S. and rose to about M.S.L. but were insignificant in quantity (e.g. Hypnea spicifera.). In September 1954 Pocamium corallorhiza and Dicurella flabellata were common at low levels but were absent in March 1955. Tufts of algae were not an important feature of this site but, instead, protection was afforded to many small animals (polychaetes, amphipods and isopods) by numerous small clumps of Balanus maxillaris mixed with large ~~individual clumps of~~ Octomeris barnacles and small Mytilus crenatus.

The P.cochlear mosaic was sharply replaced at M.H.W.N. by Bifurcaria brassicaeformis in a luxuriant belt 0.25 m. broad. In it were a few other algae such as Aodes orbitosa, Gigartina stiriata and Ulva spp., and there were many small Mytilus perna. From the upper limit of Bifurcaria to about M.H.W.S. the rock was dotted with a variety of algae in small numbers; the only ones that were not tiny were Splanchnidium rugosum and Gelidium pristoides. Here, Octomeris was abundant and Tetraclita increasingly abundant among it until at M.H.W.S. the latter dominated the rock at the expense of the former. Since the transect did not extend as high as E.H.W.S. the upper limit of Tetraclita could not be determined.

The ~~next~~ most important mobile species were Patella granularis, Oxystele variegata and Cominella cincta, all with similar distributions throughout the Bifurcaria and barnacle zones, i.e. from M.H.W.N. to M.H.W.S.. No Littorina ~~were~~ was present at the crest of the transect.

The transect did not extend high enough to support a Littorina zone but surrounding rocks suggested the lower limit

of this/....

of this zone to be at E.H.W.S.level or higher. The Upper and Lower Balanoid zones merge just below M.H.W.S., at the upper limit of the assorted algae. The Cochlear zone has a sharp upper limit at M.H.W.N. and merges indistinctly with the top of the "Sublittoral fringe" about 0.3 m. above M.L.W.S.

(v) Comparative Distribution of the Chief Species.

A difficulty that arises in comparing the intertidal sites is that certain very characteristic species move about according to tidal level, sunshine, etc.. It is thought simplest to avoid considering them in the following comparison but the decision is made difficult by the gradation from truly sessile to very mobile. Luckily it is unnecessary "to split hairs" on this count and the following are omitted:.

Amphineura: Acanthochiton garnoti.

Streptoneura: Amblychilepus scutellum, Cominella cincta, Littorina knysnaensis, Oxystele sinensis, O.variegata, Patella granularis, Thais dubia.

Asteroidea: Asterina exigua, Henricia ornata.

It will be noted that although Patella granularis is considered to be mobile, P.cochlear is regarded as a hemi-sessile species. This is justifiable because of the different habits of these two limpets.

The conspicuous sessile and hemi-sessile intertidal species of the sites are listed in Table IV in which their distribution is shown with an indication of their abundance. There is one proviso: species may be conspicuous at one site and present, but of negligible importance, at another: in the latter case they would be regarded in table IV as absent,

e.g.Bunodosoma/...

	Shady, Very Sheltered.	Sheltered.	Semi-Exposed.	Exposed.
<u>Algae</u>				
Aodes orbitosa	-	-	FC	FC
Bifurcaria brassicaeformis	-	-	-	C
Bifurcariopsis capensis	-	-	FC	F
Bryopsis sp. (CP.413 F)	-	-	-	F
Chaetangium ovale	-	-	FC	-
Chylocladia capensis	-	-	FC	F
Ecklonia maxima	-	FC	FC	FC
? Falkenbergia sp. (CP.413 G)	-	-	-	FC
Gelidium pristoides	-	F	C	FC
Gigartina radula	-	-	C	-
Gigartina stiriata	-	-	C	F
? Griffithsia sp. (CP.413 H, CP.396 F)	-	-	C	FC
Hypnea spicifera	-	-	FC	FC
Iridophycus capensis	-	F	-	-
Laurencia glomerata	-	-	FC	-
"Cochlear Lithothamnion"	-	-	A	A
"Crusty Lithothamnion" (CP.392 B)	-	C	-	-
"Dusty Lithothamnion"	A	A	-	-
Plocamium corallorhiza	-	-	-	F
Porphyra capensis	-	-	C	-
Pterosiphonia cloiophylla	-	-	C	-
Sargassum heterophyllum	-	-	-	F
Splanchnidium rugosum	-	-	C	C
<u>Porifera</u>				
? Geodia littoralis (CP.426 B)	C	-	-	-
? Hymeniacedon perlevis (CP.426 C)	C	-	-	-
<u>Polyzoa</u>				
Menipea crispa	C	F	-	-
<u>Actiniaria</u>				
Bunodosoma capensis	C	F	FC	-
<u>Polychaeta</u>				
Pomatoleios crosslandi	A	A	F	-
<u>Streptoneura</u>				
Patella cochlear	-	-	C	C
Vermetus corallinaceus	-	A	-	-
<u>Pelecypoda</u>				
Mytilus crenatus	F	F	FC	C
Mytilus perna	-	-	FC	C
<u>Cirripedia</u>				
<u>Balanus maxillaris</u> ← Omit line	-	-	-	FC
Balanus trigonus	C	-	-	-
Chthamalus dentatus	C	FC	C	-
Octomeris angulosus	A	-	FC	A
Tetraclita serrata	A	A	A	A
<u>Tunicata</u>				
Amaroucium ? erythraeum (CP.428 B)	C	-	-	-
Pyura stolonifera	-	-	-	F
Total	12	12	23	22

<u>Table IV</u>. <u>Distribution and Relative Abundance of Certain Sessile and Hemi-sessile Intertidal Species.</u>

Symbols of relative abundance: A Abundant C Common FC Fairly common F few.

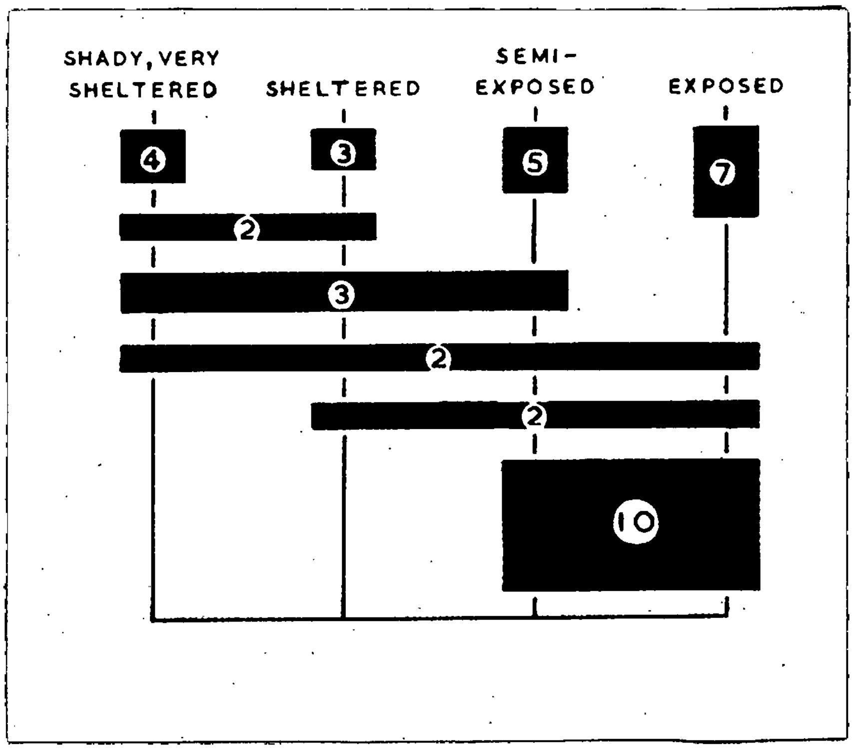


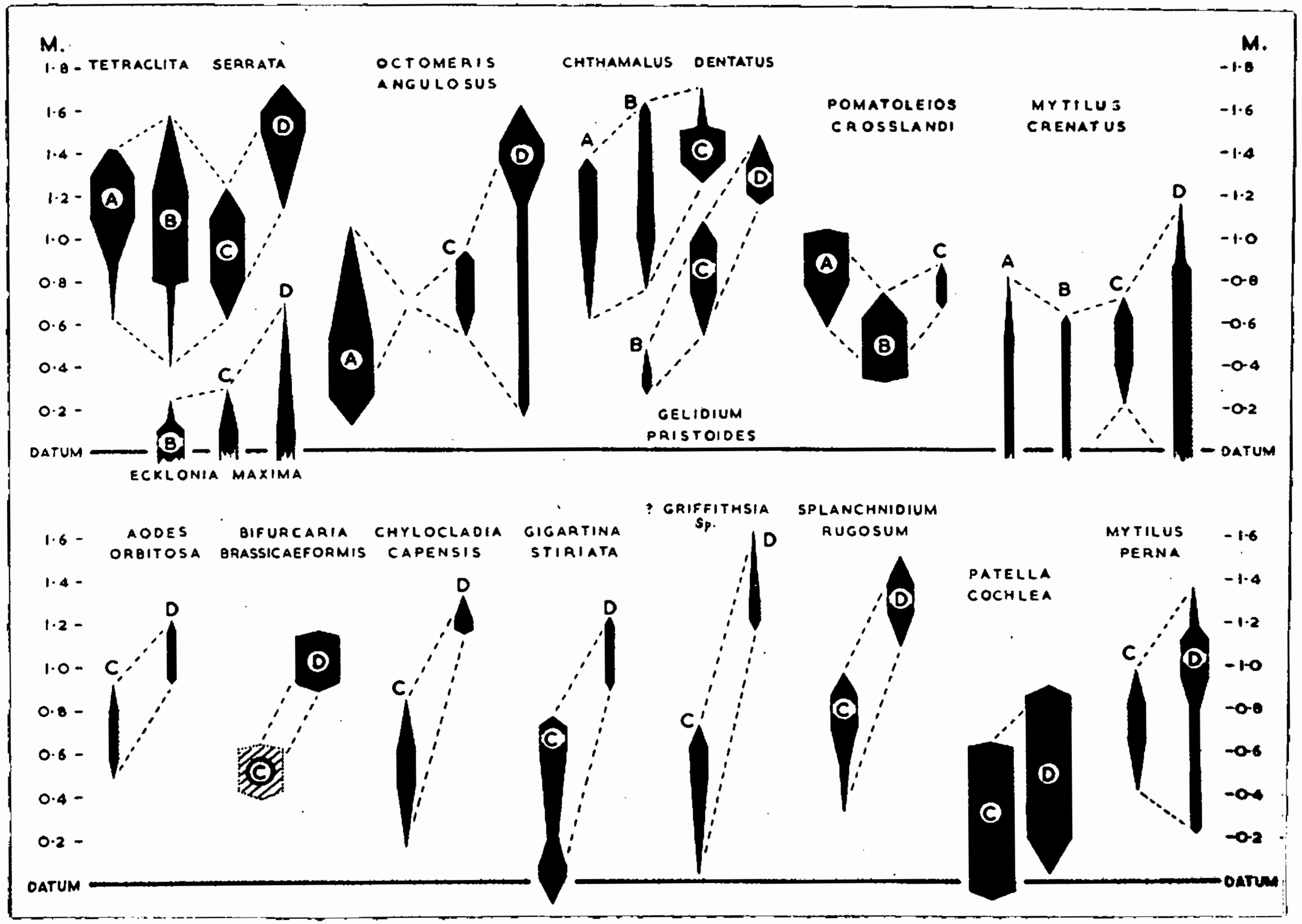
Figure 5. The distribution of certain common sessile and hemi-sessile species between the intertidal sites. The number of species in each group is given.

Figure 6.

Comparison of the vertical ranges and abundance of some common sessile species.

Bifurcaria is represented by hatching at the Semi-exposed site because it was only found just to one side of the actual transect (see Plate IV) .

A Shady, very sheltered site.
B Sheltered site.
C Semi-exposed site.
D Exposed site.



those species present on three or four sites and the bottom half those present only on the Semi-exposed and Exposed sites. Bifurcaria is indicated as being present at the Semi-exposed site; actually it was not present in the transect but it formed a marked patch not two feet away on rock of similar slope and aspect. The widths of the diagrams are intended to give an idea of the relative abundance of each species. The top half of Fig. 6 shows a rise in the upper limits of all species save Tetraclita from the Sheltered to the Exposed sites; and lower limits tend to a similar rise with the exception of Octomeris and Mytilus crenatus (but the latter species is very common infratidally and the high position of its bottom limit at the semi-exposed site is of local importance only). This tendency is usually not continued in the distributions of the same species at the Shady, Very Sheltered site where the added factor of shade is involved. The lower half of Fig. 6 shows very markedly that species always occur at high levels on the more exposed site. The average rise of the centres of distribution of the species of the two exposed sites is 0.47 m. when both the upper and lower halves of Fig. 6 are considered. A point to be noticed is that the actual vertical ranges of these species, and their relative abundance, often remains unaltered.

The distribution of the conspicuous species may be further examined on the lines suggested by Colman (1933) to determine what levels are particularly critical. The foregoing descriptions have commented on the chief infratidal species

at each/.....

Height range (metres)	Number of lower limits.	Number of upper limits	Total number of species.	Difference between total number of species and total number of limits.	True tidal positions (Simonstown).	Effective tidal positions.	Effective tidal levels.
Shady, Very Sheltered Site.	(13 spp.) Upwash 0.23 m. (9 in.)						
2.0 - 1.6	0	0	0	0	EHWS	MHWS	1.57
1.8 - 1.4	0	1	1	0	MHWS		1.37
1.6 - 1.2	0	2	2	0			1.17
1.4 - 1.0	0	5	6	1		MHWN	0.97
1.2 - 0.8	0	5	7	2	MHWN		0.77
1.0 - 0.6	2	2	8	4		MLWN	0.57
0.8 - 0.4	4	2	9	3	MLWN		0.37
0.6 - 0.2	2	5	11	4			0.17
0.4 - 0.0	2	4	9	3		MLWS	-0.03
0.2 --0.2	2	0	9	7	MLWS	ELWS	-0.23
Sheltered Site.	(12 spp.) Upwash 0.34 m (1 ft.1½ in.)						
1.8 - 1.4	0	2	2	0	MHWS		1.26
1.6 - 1.2	0	1	2	1			1.06
1.4 - 1.0	0	0	2	2		MHWN	0.86
1.2 - 0.8	0	0	2	2	MHWN	~~MLWN~~	0.66
1.0 - 0.6	1	3	5	1		MLWN	0.46
0.8 - 0.4	1	5	7	1	MLWN		0.26
0.6 - 0.2	4	6	10	0			0.06
0.4 - 0.0	6	5	11	0		MLWS	-0.14
0.2 - -0.2	3	1	7	3	MLWS	ELWS	-0.34
0.0 - -0.4	1	0	4	3	ELWS		-0.54
-0.2 - -0.6	0	0	4	4	~~ELWS~~		-0.74
-0.4 - -0.8	0	0	4	4			-0.94
Semi-exposed Site.	(26 spp.) Upwash 0.76 m. (2 ft. 6 in.)						
2.2 - 1.8	0	0	0	0			1.24
2.0 - 1.6	0	2	2	0	EHWS	MHWN	1.04
1.8 - 1.4	0	3	3	0	MHWS		0.84
1.6 - 1.2	2	2	4	0		MLWN	0.64
1.4 - 1.0	3	2	5	0			0.44
1.2 - 0.8	1	6	8	1	MHWN		0.24
1.0 - 0.6	1	14	16	1		MLWS	0.04
0.8 - 0.4	5	9	16	2	MLWN	ELWS	-0.16
0.6 - 0.2	7	3	18	8		~~ELWS~~	-0.36
0.4 - 0.0	5	4	15	6			-0.56
0.2 - -0.2	7	4	15	4	MLWS		-0.76
0.0 - -0.4	5	3	13	5	ELWS		-0.96
-0.2 - -0.6	0	0	8	8			-1.16
-0.4 - -0.8	0	0	8	8			-1.36
Exposed Site.	(24 spp.) Upwash 1.26 m. (4 ft. 1½ in).						
2.0 - 1.6	0	4	4	0	EHWS	MLWN	0.54
1.8 - 1.4	0	6	6	0	MHWS		0.34
1.6 - 1.2	0	6	10	4			0.14
1.4 - 1.0	6	7	13	0		MLWS	-0.06
1.2 - 0.8	10	7	18	1	MHWN	ELWS	-0.26
1.0 - 0.6	3	6	12	3			-0.46
0.8 - 0.4	0	5	13	8	MLWN		-0.66

at each site with this in mind so that the possibly critical region of the transition from intertidal to infratidal can be included in this analysis. In addition to the species of Table IV the following infratidally important species, all algae, are considered:-

Caulerpa filiformis, Dictyota dichotoma, ~~D.~~ Dicurella fragilis,
Dicurella flabellata, Leathesia difformis

Table V contains the results of analysis of the four intertidal sites (it corresponds to Colman's Table VII of p. 464). In smoothing his results Colman used intervals of 3 feet with overlaps of 1 foot, whereas here, intervals of 0.4 m. (15.7 inches) are used with overlaps of 0.2 m. (7.8 in). The data of Table V have been graphed against surveyed heights and analysis on the lines suggested by Colman shows that at each site certain levels are critical in regard to the upper and lower limits of distribution of species whilst other levels are not very critical.

The results, amplified by reference to distribution diagrams of the species of each site, are summarised in Fig.7, from which certain inferences may be made. Firstly that the three well illuminated sites show the following patterns from the Sheltered to the Exposed Site. In all three the infratidal region below E.L.W.S., i.e. from -0.3 to about -0.7 m., is not at all critical but from 0.1 m. below datum (M.L.W.S.) to 0.3 m. above it appears to be critical for the lower limits of most species of the lower intertidal zone. At the Semi-exposed site there is, in addition, the suggestion of a critical peak for the upper limits of infratidal species. Higher up, the pattern differs at each site with the critical levels extending higher where exposure to wave action is greater. Increasing

exposure/....

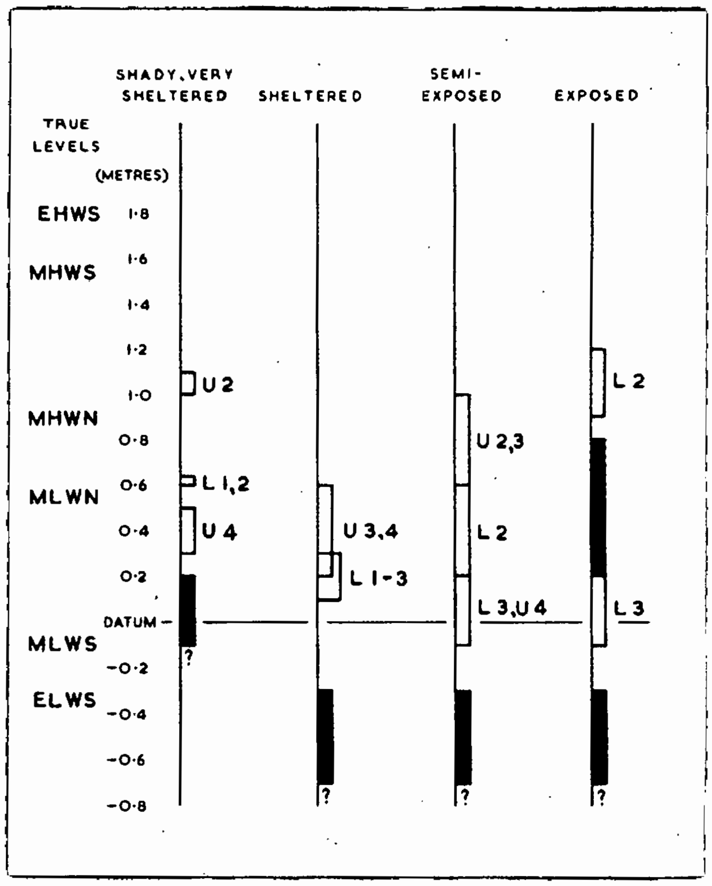


Figure 7. Conspicuously critical levels (open boxes) and non-critical levels (black boxes) relative to datum and true tidal levels.

U Upper limits of distribution.

L Lower " " "

1 Species of highest intertidal levels.

2 " " middle " "

3 " " lowest " "

4 " " the infratidal.

exposure also separates the lower limits of species of the highest, middle and lowest intertidal zones, so much so that at the Exposed site a non-critical area appears between the latter two groups. Secondly, the pattern of critical levels at the Shady, Very Sheltered site is unlike that of the Sheltered site. In the shade the non-critical zone seems to extend above datum level (below -0.1 m. rock shape precludes comparison). Further comments will be made at the conclusion of this section.

Colman suggested that tidal levels are effectively raised by wave splash and applied a correction of 2 feet for Church Reef, near Plymouth in England; and Bokenham, Neugebauer and Stephenson (1938) used a correction of 2.2 feet for four traverses in the St. James region of False Bay. Here, a different allowance must be made for each transect. These allowances have been termed "upwash" and their calculation has been described above ~~(p. 16)~~. They are given in Table V. It will be noted that the difference between the upwash of the two exposed sites is 0.50 m. which is strikingly in agreement with the average rise in level (0.47 m.) of the centres of distribution of many species present at both localities (See Fig. 6 and p. 31).

If the height of any intertidal organism is considered relative to effective tidal levels its effective height is less than its height above datum by the upwash. The same pattern of critical levels is shown at each site but Fig. 8 shows that only at the Shady, Very Sheltered site do all the critical levels exist above effective datum. Wave action

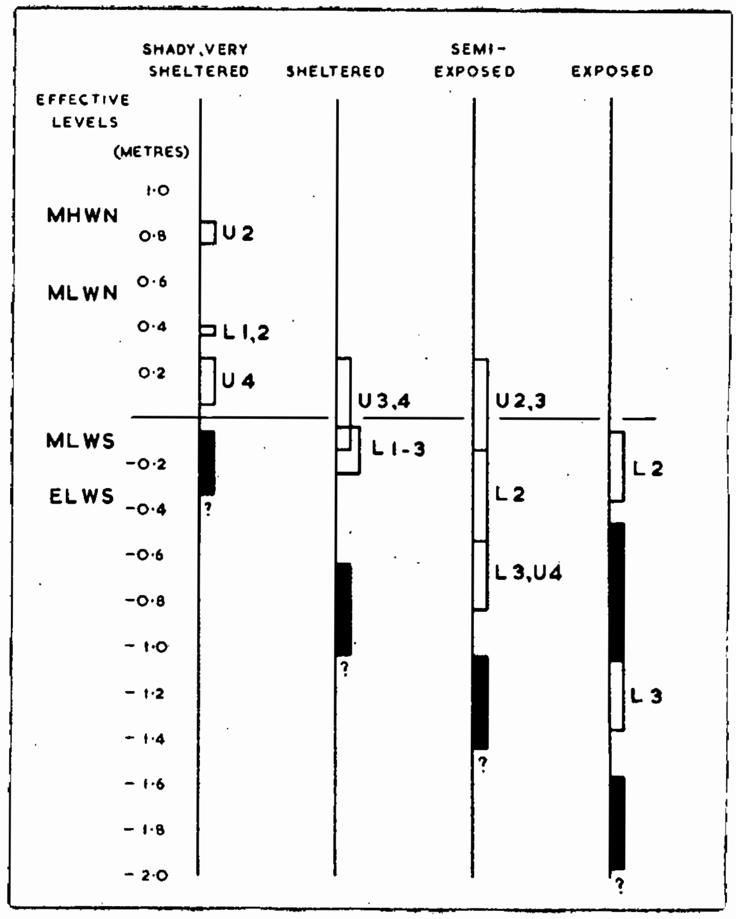


__Figure 8.__ __Conspicuously critical and non-critical levels relative to effective tidal levels.__

Allowance has been made for upwash at each site (as in Table V).

Symbols as in Fig. 7.

moves the critical levels downwards relative to effective levels and spreads them apart vertically.

It is tempting to infer a lot more from figures 7 & 8 than has been said but there are two very sound factors that make for caution. Firstly, this type of analysis treats dominant species exactly on par with lesser ones. An example of the biassed emphasis that may result would point the moral e.g. Fig 7 shows that the critical level for the upper limits of species of the lowest intertidal zone is from 0.6 to 0.8 m. above datum. But the overwhelmingly dominant species of the lowest intertidal is P.cochlear and its upper limit occurs sharply at 0.62 m.. Secondly, the influence of shading and of exposure to wave action could only be neatly demonstrated by this type of analysis if the same species occurred on each site. But they do not and so the critical levels under discussion are not only affected by shade or exposure but by the different tolerances of different species to these factors and to one another. P.cochlear again provides the example for this is only found where wave action is more than moderate and when present it invariably dominates other species, moving their limits up or down as the case may be. (see Fig. 4).

In summary, it may be said that although wave action raises most critical levels up a rock face (Fig.7), it lowers most of them relative to effective levels (Fig.8) and the former effect outweighs the latter because the biota actually occur higher with increasing exposure (Fig.6). Presumably, as argued by Colman, the raising of critical levels is due to wetting by splashing waves. The lowering relative to

effective/...

effective levels is a surprising finding and is not easy to account for save in generalities. Fig. 8 shows that the lower limits of species of the mid-intertidal are to be found around effective E.L.W.S. and the upper limits of species of the lowest intertidal around effective M.L.W.S. But the lower limits of the lowest intertidal species move down markedly with increased wave action, and the upper limits of the infratidal species do the same. It seems that the species of the upper and middle intertidal regions maintain their critical levels relative to effective heights, according to expectation, but that the lowest intertidal species at exposed sites are more tolerant of effectively infratidal conditions and push their lower limits down at the expense of infratidal species. This is almost certainly due to exposed sites supporting species different from those of sheltered sites and not due to changed tolerances of species found on all sites.

Shading appears to raise the critical levels of intertidal species whether relative to true or effective levels; but not to raise the upper limit of infratidal species.

To conclude this discussion on the intertidal sites, we may look at Fig. 4 with an eye to Stephenson's system of zonation. The upper limit of the Balanoid zone clearly rises with increased exposure and the division between Upper and Lower Balanoid zones follows this trend on the illuminated sites. The Cochlear zone raises the lower boundary of the Balanoid zone similarly but, with moderate wave action, it moves the "Sublittoral fringe" downwards although this boundary also rises upon exposure being increased. This zonation shows, as it should, the same features as emerged above. Just as species move up a rock face with increasing

exposure/...

exposure, so do the zonal boundaries; just as some species are replaced by others with increasing exposure, altering the positions of the critical levels, so are the zonal boundaries modified.

Stephenson (1944) discusses the effects of wave action on these zones at some length in respect of the South Coast from Port Elizabeth to Cape Agulhas. Although False Bay is about 80 miles west of Cape Agulhas as the crow flies, Stephenson's remarks hold good. The Exposed site is probably not more than moderately exposed by Stephenson's standards due to its situation in a large bay (but it is fairly heavily exposed by European standards). The zonation at the Exposed site is that shown by Stephenson (1944) slightly to the exposed side of the centre of Plate XIII with modifications due to most of the species being at the westerly ends of their geographical ranges, e.g. G.pristoides, Hypnea, Plocamium corallorhiza, M.perna, P.cochlear and Pomatoleios. On the other hand, Ecklonia is present, although near its easterly limit, and Bifurcaria is a species that flourishes only in this region of overlap of the western and southern biotic components. The "Sublittoral fringe" at the Exposed site supports a mixed algal community, as is frequently the case, rather than a well developed Pyura community but the latter is common nearby.

INFRATIDAL BIOLOGY.

A. METHODS.

The infratidal was first explored here with a diving hood of the type made popular by Beebe (1926) and successfully used by Kitching *et al.* (1934). This was first used in False Bay by Mr. P:W.Jackson who very kindly lent me his apparatus. I found the diving hood to be too clumsy for regular use outside the protection of harbours and so replaced it with a self-contained, compressed-air diving apparatus of the "aqualung" type which has been most satisfactory. Frogman flippers were preferred to weighted boots on the grounds of safety and mobility and a waterproof suit was used when the water was cold. By force of circumstances, all diving was done alone which has nothing to be said in its favour.

The usual equipment carried was as follows; a sheath-knife at the belt, a scraping tool looped to one wrist and a collecting basket to which were attached a depth gauge and a writing tablet with pencil. Notes on these items follow.

Sheath knife --- Useful generally. It should be heavy.

Scraping tool -- (a) "Hand Hoe". This consisted of the metal head of a garden hoe to the back of which was attached a pocket of coarse bolting-silk. Useful for scraping and then catching the floating debris. The heavier the instrument the better because underwater the swimmer can exert little leverage on his instrument. For this reason this tool was usually ineffective on limpets and large ascidians and algae.

(b) Abelone lever. A heavy tyre-lever with sharpened ends: used for the more strongly attached

organisms/...

organisms.

Collecting basket -- An item purchased ready-made. Made of galvanised iron wire of interlocking spiral mesh which permitted collapse when empty. Mesh of about 1 cm. bar. Mouth circular, 13 cm. (5¼ inches) diameter and closed by a spring-actuated flap opening inwards. The mouth was found to be rather small.

Depth gauges -- Plastic manometer-type gauges supplied commercially for underwater sportsmen were found to give trouble. Excellent Bourdon-type pressure gauges are available but expensive. The gauge used was a car's Bourdon-type oil-pressure gauge of range 0 - 45 lbs/sq.inch which was enclosed in a rigid, watertight, glass-fronted case. Through the case there led an extension of the Bourdon tube which opened to the sea through a filter of copper gauze. The filter had to be replaced occasionally since it clogged with salt, sand and debris. The gauge was calibrated in quiet water against a sounding line, and occasionally checked. Readings appear to be accurate to 5%.

Writing tablet -- Talc sheeting affixed to either side of a painted board by drawing pins. Dimensions 12½ x 20 cm. (5 x 7¾ inches). A red wax-pencil was used for writing. Not all wax-pencils are suitable. Wolff's "Chinagraph" made by the Royal Sovereign Pencil Co.,Ltd., has proved excellent. The pencil was sharpened at both ends and bound to prevent the wooden halves from separating. It was attached to the board by nylon line and a fishing swivel and when not in use was secured by a rubber band. Board and pencil floated. Erasure was normally done by rubbing with finger or cloth but the talc was occasionally cleaned with carbon tetrachloride.

Underwater camera -- a 35 mm., compur shutter Voigtlander "Vitessa" camera was encased in a watertight aluminium box through which the following controls could be manipulated: focussing, wind-on and shutter tensioning, shutter release. The box was fitted with sports-type viewfinder and a manually operated exposure counter. Shutter speed and iris diameter had to remain constant once the case was closed but this was seldom found to be a drawback since electronic flash was usually employed. A "Multiblitz" electronic flash outfit was used. The power unit of this was carried in an aluminium box on the chest and the flash head was encased in aluminium and attached to the camera housing. A glass dome was specially made to cover the flash bulb and a special underwater reflector of stainless steel was designed and fitted externally. The electric cables ran loosely through "Tygon" plastic tubing which joined the cases of the camera, power unit and flash head through garden-hose unions. The switch for the flash unit was transferred to a position in the camera box and was switched "On" as the last action before fastening the camera case. The inside of the three cases and of the plastic tubing was pressurised by carbon dioxide contained in a 10 oz. capacity cylinder and admitted through a pressure-reduction valve actuated by external pressure so that the deeper the camera went the more high-pressure carbon dioxide was admitted. When maintaining any given depth supply of gas was cut-off and on ascending excess internal pressure was released by a blow-off valve. Adjustment of the two valves ensured that pressure in the camera case remained about 7 lbs./Sq.inch in excess of the surrounding water pressure and water never penetrated the apparatus. Misting of the lens and window never occurred due

to the/....

to the carbon dioxide quickly expelling the water vapour present in the enclosed air. The flash head and power unit were subject to this pressurisation via the loose-fitting Tygon cables.

Use of the flash gave sharp pictures at the expense of natural lighting. Ilford H.P.3. film was used and experiment showed the underwater flash factor to be 70 with this equipment. The Meritol-Caustic two bath method of development was used to gain contrast without loss of film speed but so far underwater results have always been rather soft. Exposures were usually made at f.8 over distances of 1.3 to 3 m.. In determining range, a ½ m. stick was first attached to the face to be photographed; the size of the stick relative to the frame of the viewfinder enabled the range to be calculated. This photographic outfit produced excellent results in the clear water of the Mediterranean but in the comparatively dirty water of False Bay results have been disappointing. In dirty water, suspended particles scatter the flash beam just as mist scatters the headlamp-beams of a car at night, and with the same confusion to the viewer. Without the flash, lighting is inadequate so that the vicious circle of adequate exposure, camera shake and depth of focus becomes insoluble.

The method of examining a chosen rock or bottom was as follows. The site was reached by swimming if near to shore and by boat if far out. It was given a preliminary survey by aqualung and notes were made underwater; if sufficient air were left some collections were made. As a result, certain areas were later worked in greater detail. To avoid confusion,

the collecting/...

the collecting basket was only used for material from one area at a time. Notes and collections were representative of the superficial biota but it was usually impossible to scrape away encrustations right down to the rock face and elements of this habitat would almost certainly be missed. Since the rock was of granite there was no infauna. Very active animals escaped capture but the largest (eg. Jasus, Plagusia) could easily be noted. The Blennioid fishes and shrimps and prawns could not be identified or caught and so were disregarded. By putting many lumps of debris into the basket an astonishing variety and quantity of small animals were found on laboratory sorting (Amphipods, Isopods, Gastopods, Nematodes, etc.), but Turbellaria and Nudibranchs escaped from the basket during swimming.

In the shallows a short, buoyed "sounding" line, or a bamboo stick of 1 m. length were sometimes used to measure depth but deeper readings were by depth gauge. Readings were later adjusted relative to datum of the Cape Town tide gauge.

B. THE BIOTA

(i) Oatland Point.

Where the infratidal transects rose above low tide level the chief intertidal biota were noted for the sake of completeness and to provide some biological indication of the degree of exposure to wave action. These intertidal notes have not been discussed in the previous section because the levels were not surveyed.

Unfortunately/...

Unfortunately, the intertidal biota did not indicate different exposure to wave action as "typically" as one would like. Surprisingly, none of the sites possessed a mosaic of Patella cochlear which, if present at one or another, would probably be a useful guide. Nor was the biota arranged at any site in a pattern corresponding to one of the surveyed intertidal transects. This is ~~not~~ lamentable but not surprising in view of the possible variations in the biota of apparently identical situations whereas these sites inevitably varied in aspect and slope quite apart from their exposure. However, some fair biological indications were given and they are interpreted below in the light of personal experience and of the remarks of Stephenson (1944). No attempt is made to compare differences in level of species or zones because intertidal levels were measured only very approximately.

a) The "Inside" of Lagoon Rock. (See Plate VI).

The Lagoon side of Lagoon Rock (see Fig.2) will be referred to as the "inside" and the Channel side as the "outside".

The site faced SSW and was not struck directly by the swell. It received further protection from adjacent rocks but, all the same, there were usually turbulent eddies across it due to the surf. The exposure was judged to be in the order of that at the Sheltered intertidal site, possibly rather more sheltered conditions were indicated biologically by the presence in the Lower Balanoid zone of abundant Vermetus, with "Lithothamnion", instead of a P. cochlear mosaic. The dominant barnacle was Tetraclita, mussels were of negligible importance, and there was no Pyura, either in the infratidal fringe or infratidally.

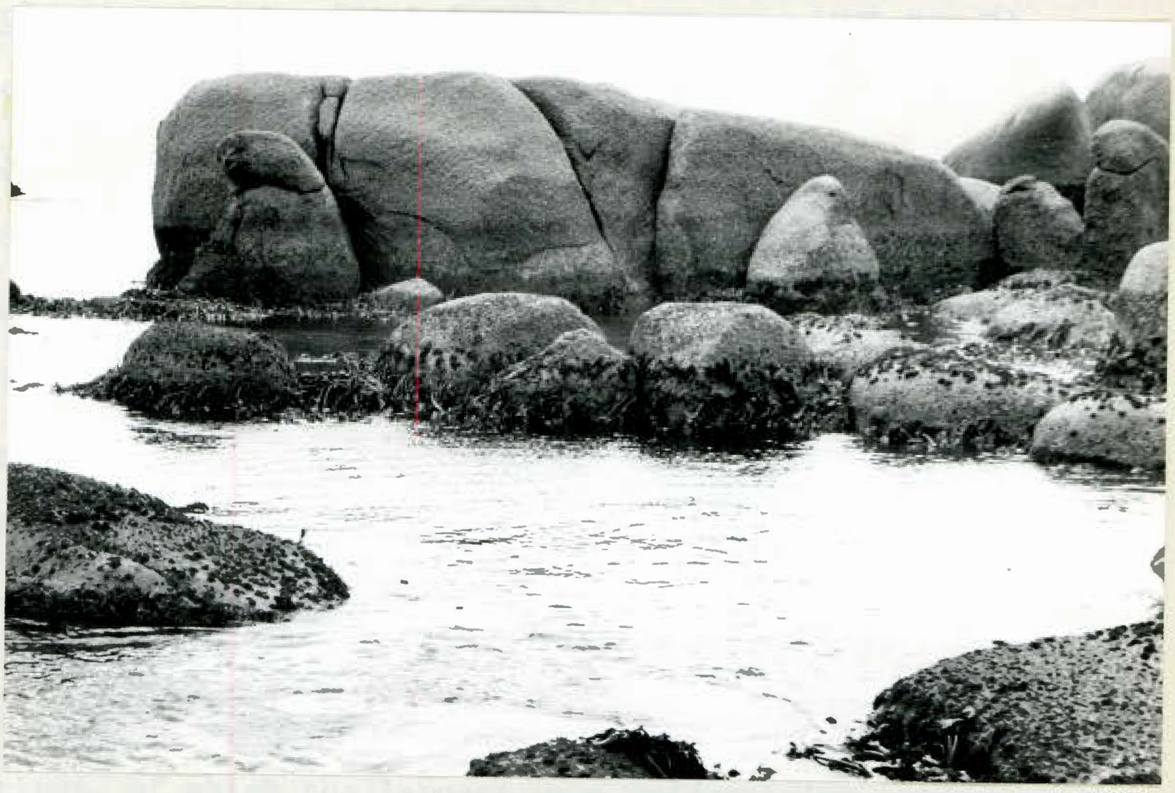


Plate VI. The "Inside" of Lagoon Rock, Oatland Point, at L.W.S.T.

The site was examined on either side of the base of the V in the middle of the rock. The "Shallow Cave" lies beneath the rock to the left of the V. In the top, right-hand corner can be seen the northern end of Big Rock.

characteristic outliers were small, pale orange sea fans (Eunicella ? papillosa, FAL.132 U). To the south the face received additional protection from swell from another rock and there were considerable differences in biota. The infratidal fringe and infratidal were dominated there by a "Lithothamnion" that permitted only a few small Ecklonia plants and which supported scanty epibiota, principally small anemones (Corynactis annulata) and a soft polyzoan (Menipea crispa). Whereas the described transect was like a thick, rich persian carpet, this very sheltered part of the rock was like a polished stone floor. Its sanitary-looking bareness was relieved by groups of brightly coloured sea urchins (Parechinus angulosus) and, indeed, such arrangements of urchins on "Lithothamnion" were characteristic of many shallow rocks in the Lagoon.

b) The "Outside" of Lagoon Rock. (See Plate VII).

The rock faced NNE which made a slight angle away from the prevailing swell so that exposure to wave action was greater at the south-eastern end than at the north-western, but the change was gradual. The south-eastern end is chiefly considered here and its exposure was considered to be of the same order as that of the Exposed intertidal site, although the wave action rather differed in nature at the two places. At the intertidal site the swell changed to rollers and surf just off the rocks and the impact of the surf was considerable. But at Lagoon Rock the swell remained unchanged and there was no true surf to pound the rocks; however, shearing currents of bubbly water tore across the rock faces with the rising and falling water.

Turning/...

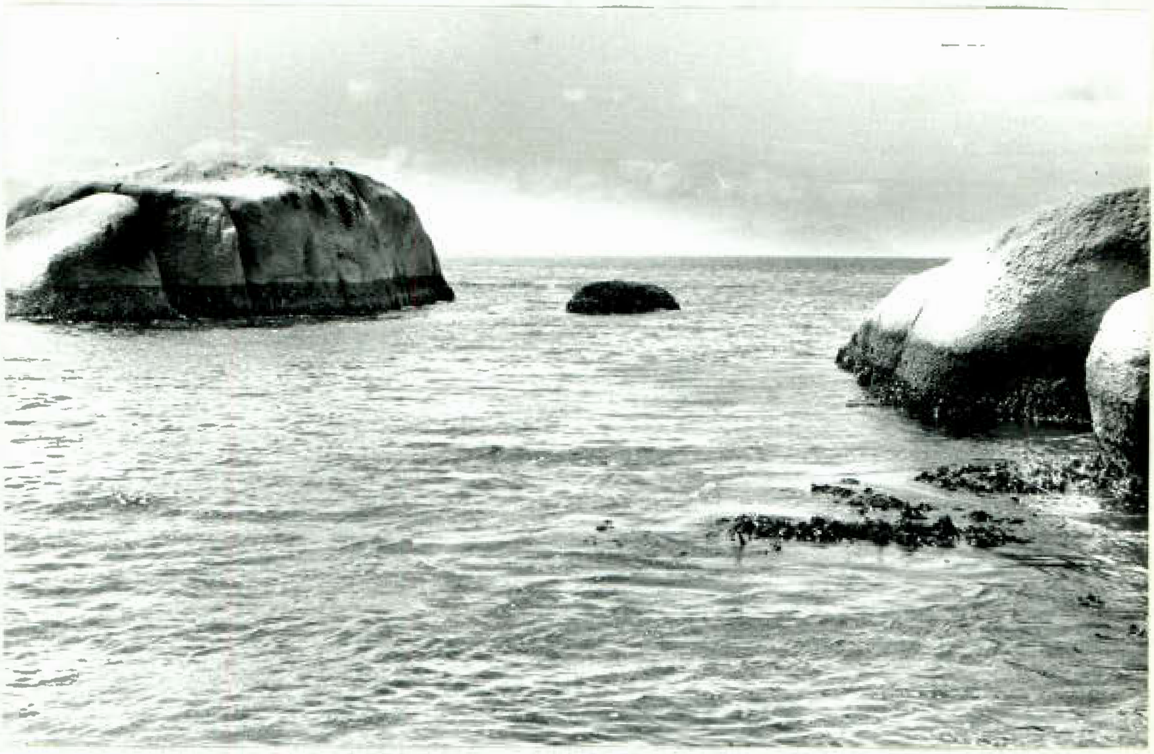


Plate VII. The Channel, Oatland Point, at L.W.S.T.

The "Outside" of Lagoon Rock is well illuminated to the right of the photo and the Channel side of Big Rock is in shade to the left. Barnacles show up darkly on the granite and their upper limit is sharp. The fringe of kelp is clearly visible on all rocks and, on Big Rock, a pale zone is visible above it due to _Balanus algicola_ growing in profusion on _Mytilus crenatus._ The sea is unusually calm.

Turning to biological indications of exposure we may first note the absence of the Cochlear mosaic and say straight away that this may be due to the different nature of the exposure, as just remarked. Be that as it may, the level that one might have expected to be occupied by P. cochlear was dominated instead by the alga Bifurcaria brassicaeformis, a lover of bubbly water, together with Mytilus perna, M.crenatus and the barnacle Octomeris angulosus in large numbers. These corroborate the comment that exposure was considerable.

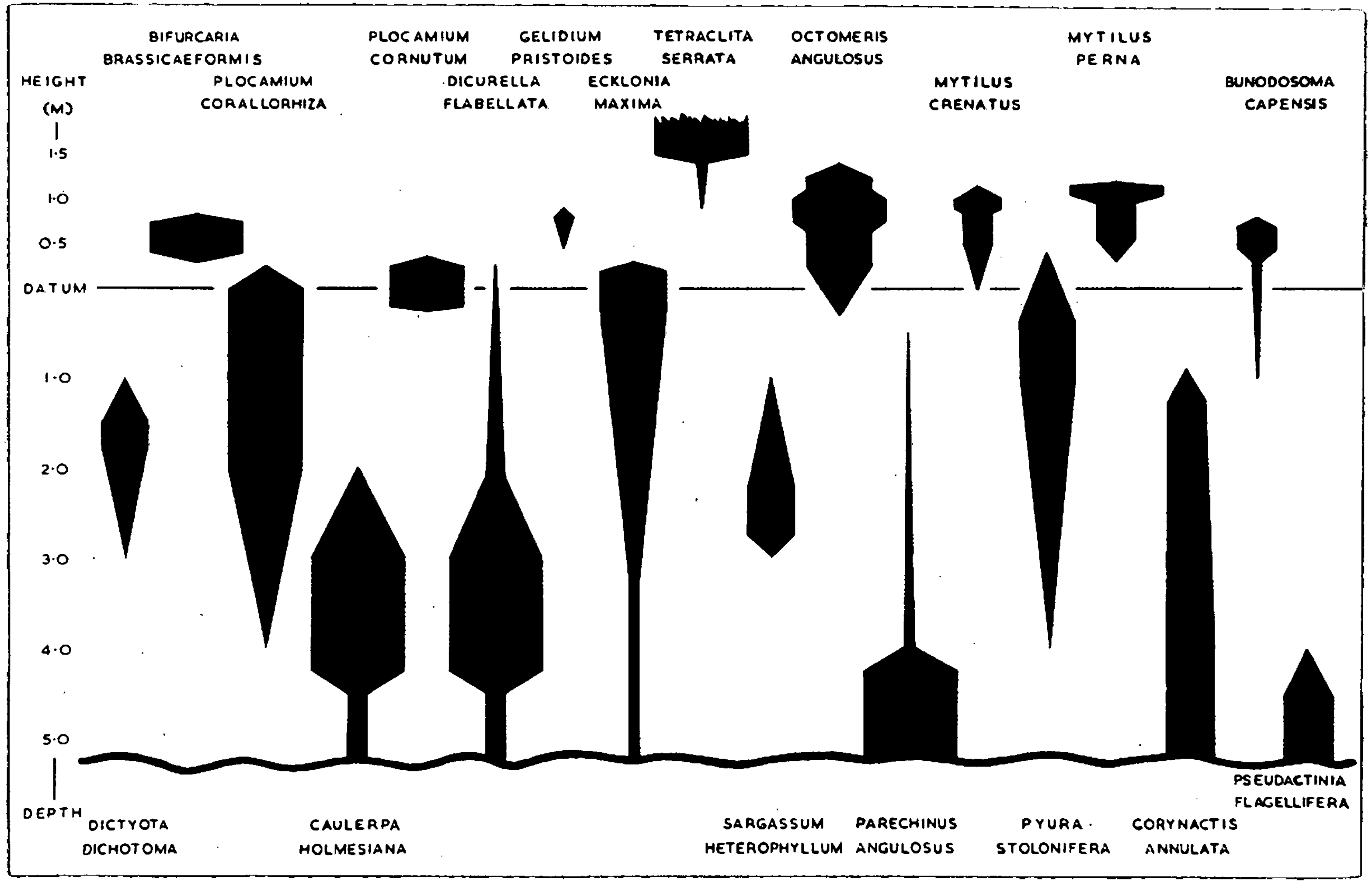
The outside of Lagoon Rock fell almost vertically from above the intertidal to the Channel bottom which was at about 5.3 m. depth here. The only break in the drop was a diagonal step or ledge no more than 0.8 m. wide (the biota of which are omitted from consideration). In plan view the straight part of the face was about 10 m. long and broken only by a narrow cleft from top to bottom near the north-western end.

The situation on the more exposed, or south-eastern, half of the face was as follows. The infratidal fringe rose to about 0.3 m. above datum where were found the upper limits of such important, shallow-water species as the kelp, Ecklonia, the ascidian, Pyura stolonifera, the tufty algae Plocamium corallorhiza and P. cornutum. The rock was dominated infratidally by a carpet of mixed algae, a patchwork of reds, browns and greens that hid a profusion of small animal life. Although Pyura was fairly common here the animal was small and either solitary or in little colonies of three or four; it tailed-off before reaching the bottom (See Fig. 9). Ecklonia was more abundant than Pyura but although it formed a thick fringe

around/...

Figure 9.

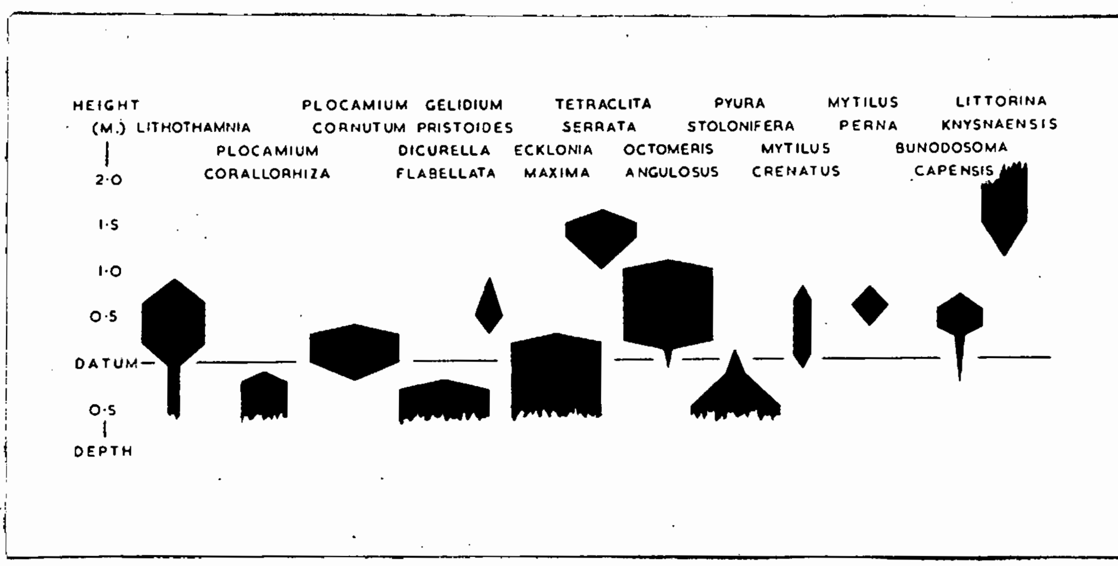
The "outside" of Lagoon Rock, at the more exposed end: diagram of the vertical distribution and abundance of conspicuous species.



around the rock - like a monk's fringe of hair below his tonsure - the plants became tiny and scanty below 2 m. depth. In fact, the chief coloniser of the top 2 m. was the feathery, red *P. corallorhiza* which, half-way down the infratidal face, was invaded by fair quantities of the brown algae, *Dictyota dichotoma* and *Sargassum heterophyllum*. Further down all these were replaced by the red *Dicurella flabellata* and green *Caulerpa holmesiana.* The lowest metre of rock supported, as was often the case, a community typical of the adjacent stony bottom. Here, the rock was very bare-looking except for scattered sea-urchins (*Parechinus*) and large anemones (*Pseudactinia flagellifera*) but actually the rock was covered with "*Lithothamnion*" and there were many tiny anemones (*Corynactis annulata*) and barnacles (*Balanus spp.*) upon it.

The north-western end of the face was less exposed, as has been mentioned, and intertidally this was reflected by an absence of *Bifurcaria*, decrease in the abundance of mussels and descent in level of *Tetraclita* (See fig.10.). It seemed that the upper 2 m. or so of the infratidal also reflected this change of exposure. Here *Ecklonia* and *Pyura* were more luxuriant and especially so in the shelter of the vertical cleft. But the main difference was that *P. corallorhiza* was rather ousted by *D. flabellata* which dominated the algal carpet from E.L.W.S. almost to the bottom.

This site was examined in March 1953 and checked in April 1955 and the pattern was similar on both occasions. Detailed differences were the abundance of fluffy reddish and greenish epiphytes (such as *Falkenbergia rufolanosa*) on the first date and their scarcity on the second; and the replacement of

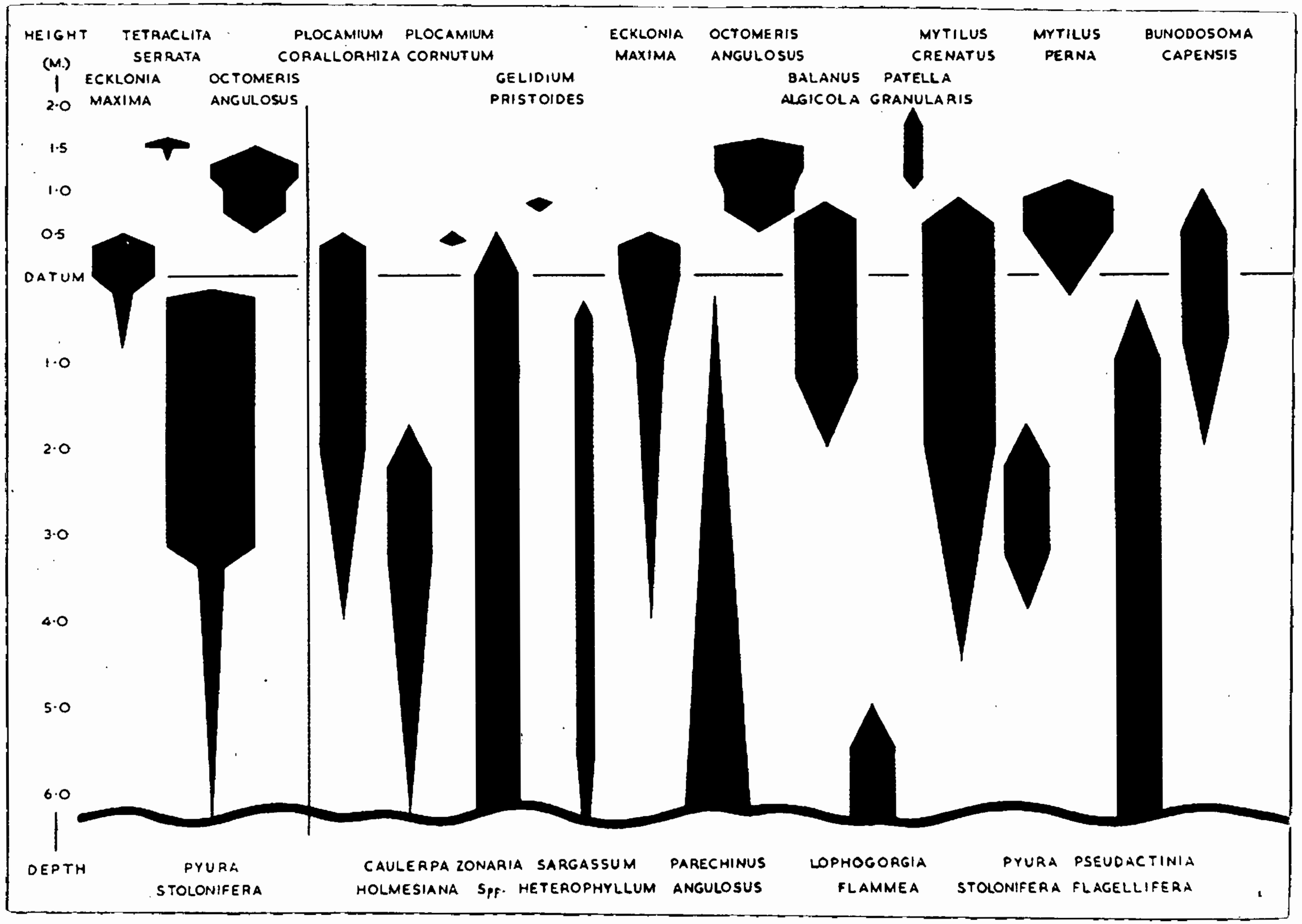


<u>Figure 10.</u> <u>The "outside" of Lagoon Rock, at the more sheltered end: diagram of the vertical distribution and abundance of conspicuous species around datum level.</u>

Figure 11.

The Channel side of Big Rock : diagram of the vertical distribution and abundance of conspicuous species.

To the left of the diagram the main differences to be found at the north-western end are indicated.



this applies when the tests are full-sized and closely packed and then *Pyura* is the overwhelmingly dominant species of the rock. The phrase loosely includes many species that are commonly associated with *Pyura* in this growth form (cf. usage of Eyre, 1939, who lists some of the subordinate associated species). The other is "Scattered *Pyura*" which refers to scattered, usually small individuals in clumps of a dozen or so; in this form, *Pyura* is a subordinate member of a community dominated by other species and the ascidian is accompanied by very few of the species characteristic of its "community" form.

The more exposed, or south-eastern, part of the rock will be described first and then differences in the direction of greater shelter will be noted.

Spring tides always exposed a fringe of *Ecklonia* which was rather luxuriant and large down to E.L.W.S. but rapidly diminished in size and importance lower down. This fringe of kelp occupied rather precisely the extent of the infratidal fringe. As at Lagoon Rock, across the Channel, *Plocamium corallorhiza* was common among the holdfasts but here it was subordinate in importance to a dense sheet of mussels, overgrown by barnacles, that extended downwards from the intertidal (see Fig.11). It was by no means easy to discern the limits of the various species but the one largest in size was *Mytilus perna* which was abundant at the top of the fringe but scarcely penetrated below it, so far as could be seen. It became increasingly invaded by medium-sized *M.crenatus* below M.L.W.N. level and this was the dominant species of the rock face down to about 2 m. depth. Intertidally *M. perna* was covered by

Octomeris/....

Octomeris but from the infratidal fringe downwards the important barnacle was Balanus algicola which covered the mussels in such abundance as almost to obscure them.

It has been mentioned that Ecklonia became insignificant below the infratidal fringe and the other species that is usually so important in this habitat, Pyura, was only found here in its "scattered" form half-way down the face of the rock.

The general impression of the infratidal biota was of a great variety of rather small species, particularly algae, polyzoa, hydroids, anemones and ascidians, but, unfortunately, most of the algae seemed to show seasonal fluctuations. Zonaria ? interrupta (FAL.309 A) might have been the most constant for it was a major constituent of the biota all over the rock both in May 1953 and April 1955. On the former date Sargassum heterophyllum and Caulerpa holmesiana were of importance over the ranges shown in Fig. 11, but both were inconspicuous in April 1955 and instead Plocamium ? membranaceum (FAL.153 J) and a fine red algal fluff of the Falkenbergia type were common. Soft, tufty polyzoa such as Bugula dentata, Menipea crispa, M. triseriata and Onchoporella bombycina abounded here and were commoner than rigid polyzoa. Most hydroids were small but were very abundant, especially Aglaophenia parvula, Kirchenpaueria pinnata, Sertularella arbuscula and Plumularia setacea. The most conspicuous anemones were the two large species, Bunodosoma capensis, at upper levels, and Pseudactinia flagellifera, lower down and there were many bright green clusters of the small Anthothoe stimpsoni; the little pink Corynactis annulata was ubiquitous. Eleven species of ascidian were found here apart from scattered Pyura. The commonest was undoubtedly the encrusting Didemnum stilense and, next to this, Amaroucium

erythraeum;/..

were really quite common although the mussels were tiny. Difficulty in removing the tests made examination of the hidden species difficult but Bunodosoma, Pseudactinia, Parechinus, Marthasterias glacialis and Cominella papyracea were much in evidence.

d) Shallow Cave. (See Fig. 2 and Plate VI).

A fairly extensive cave was found beneath Lagoon Rock. It really consisted of the gaps between several adjacent rocks and its irregular, ramifying crevices were too narrow to permit much penetration by a diver. The essential features of the accessible parts of this complicated cave appeared to be as follows. That there was a reasonable amount of indirect illumination and that the several openings, distributed at various depths, permitted fairly strong currents through it. Most of the bottom of the cave was at about $2\frac{1}{2}$ m. depth and consisted of clean, coarse shelly sand. In one place the top of the cave opened on to the northern end of a face already considered, the "Inside" of Lagoon Rock.

Four groups of animals dominated the biota, sponges, polyzoa, ascidians and hydroids and it is most unfortunate that identification of the first two groups has been so fragmentary. It is impossible to comment adequately on the many species of sponges and polyzoa but the lack of comment must not convey an underestimate of their importance in the cryptofauna. Some common soft polyzoa that were identified were Onchoporella bombycina, Menipea ornata, M. crispa and Bugula robusta; the pretty hard, pink Retepora near tessellata (FAL.154 L) was also common. The ascidians were similar in size to the sponges and polyzoa. There was a thick carpet of the sandy-looking Amaroucium retiforme. On a horizontal ledge/..

ledge at about ELWS level Pseudodistoma africanum, Distaplia capensis and two new species of Molgula (FAL.158 Q,R) were common; but Pyura was virtually absent, being found only at high levels in the entrance. Although hydroids were extremely numerous and varied (some twenty species were found) they were usually epizootic in nature excepting Sertularella arbuscula (particularly common underneath rocks) and Halecium beanii.

Algae were definitely unimportant but several were to be found in small numbers in the best lit places. Near the surface, for example, were sparsely distributed small red algae, chiefly Dicurella spp. and Plocamium spp., and a little jointed coralline, ? Jania sp. (FAL.153 E) whilst at the lower entrances to the cave Caulerpa holmesiana was quite common. Ecklonia was virtually absent.

Some species of other taxonomical groups managed to be abundant among the profusion already indicated. For example the crinoid, Comanthus wahlbergi which, like Sertularella arbuscula, particularly favoured the undersides of ledges, and the anemones Pseudactinia and Corynactis were everywhere although the former only grew large near the sandy bottom. The little sea-fan Eunicella sp. (FAL.154 G) was a characteristic species of the cryptofauna although it was not really abundant. Three tubiculous polychaetes formed locally dense populations, viz. Phyllochaetopterus socialis, Filograna implexa forma salmacina and Potamilla reniformis. There were also many small polychaetes, small molluscs, isopods, amphipods and three species of Balanus. Two brittle-stars were commonly found beneath the rich growth of fauna, namely Ophiactis carnea and Ophiothrix triglochis.

Some/....

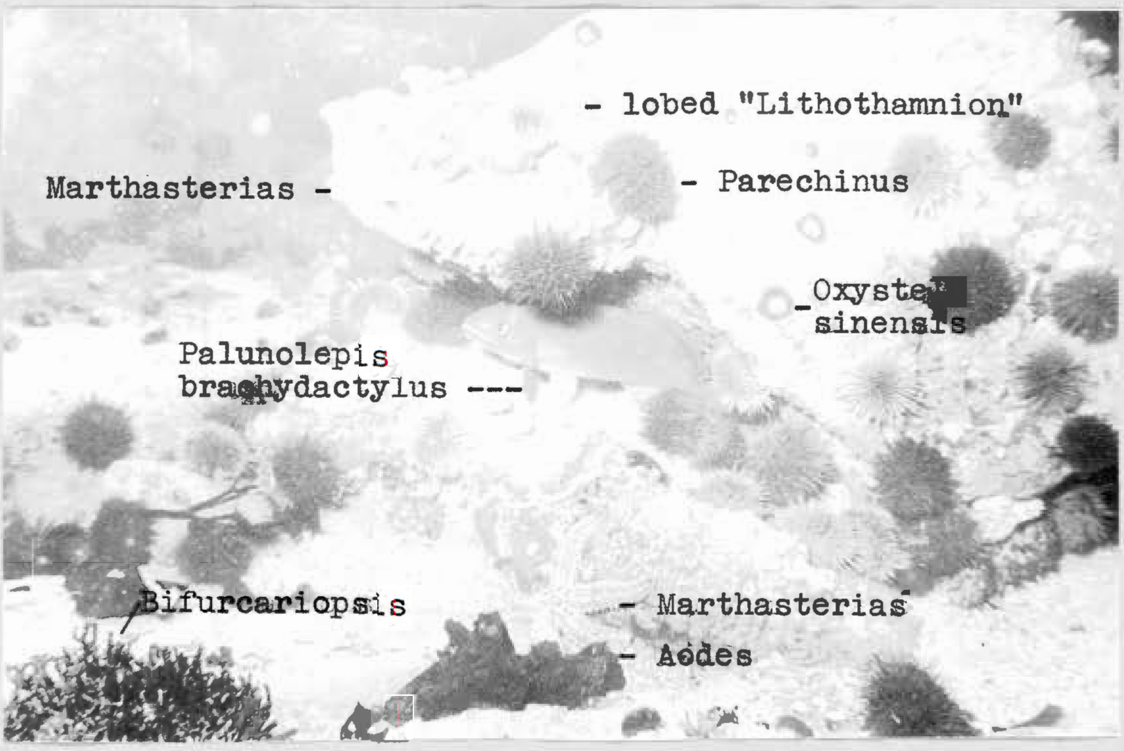
Some idea can be gained of the great variety of life here from the relatively few species mentioned above. No area of rock was free of a rich, thick growth of fauna and the conspicuous species hid a profusion of smaller ones and bore numerous epizoa. Over one hundred and fifty species were listed in the small confines of this cave despite its shallow depth range. The irregular ramifications of the cave did not lend themselves to exhibiting vertical zonation of the biota but, except for the sparse algae, no such zonation was noticed. Unfortunately, it was not possible to follow changes correlated with progressively decreasing illumination for dark corners were inaccessible.

The cave was inhabited by many fish, especially *Diplodus sargus*, *D. trifasciatus*, *Coracinus capensis*, *Gymnocrotaphus curvidens* and *Palunolepis brachydactylus* but most of these have been driven away by the activities of spear-fishermen. Similarly the ranks of crawfish, *Jasus lalandii*, have been sadly thinned by man, probably far more so than by the occasional octopus (*Polypus granulatus*) that has been observed to chase them.

e) The Lagoon Bottom. (See Plates VIII & IX).

The topography of the Lagoon is shown in Fig. 2 from which it can be seen that the main openings in its periphery are at the south and the north. Since the prevailing swell is from the south-east the Lagoon is well protected particularly at low tide when many shallow peripheral rocks become exposed. The southern opening itself received considerable protection

from a/....



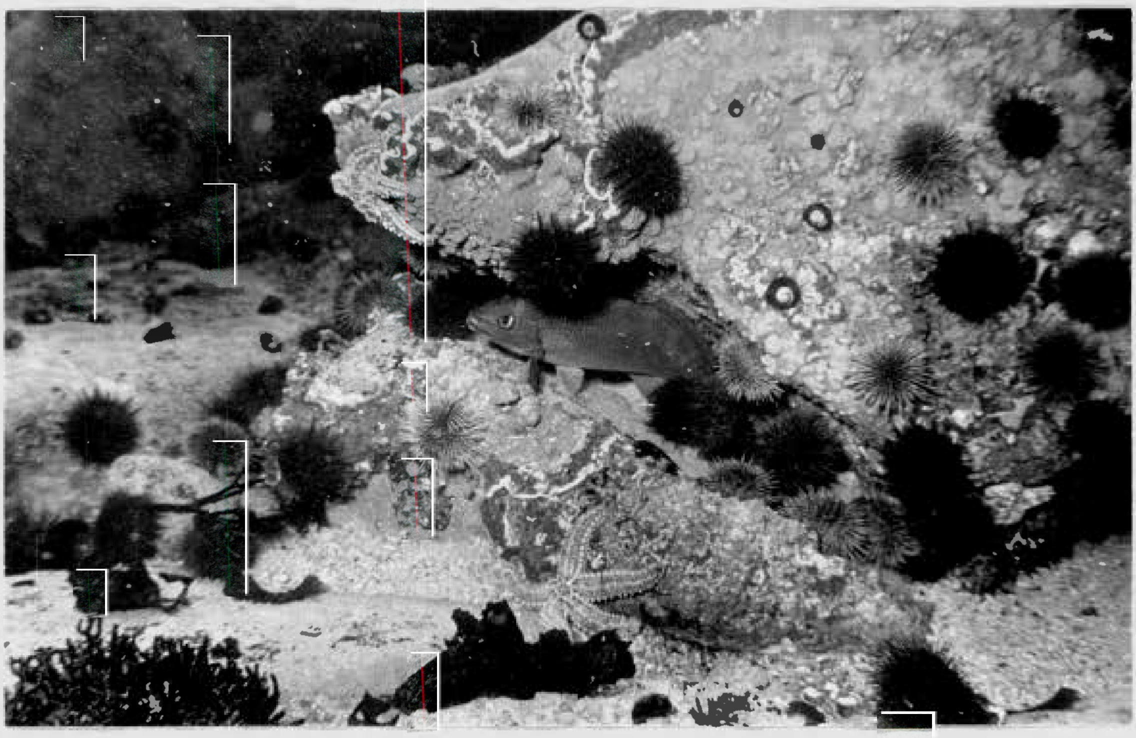


Plate VIII. The Lagoon Bottom.

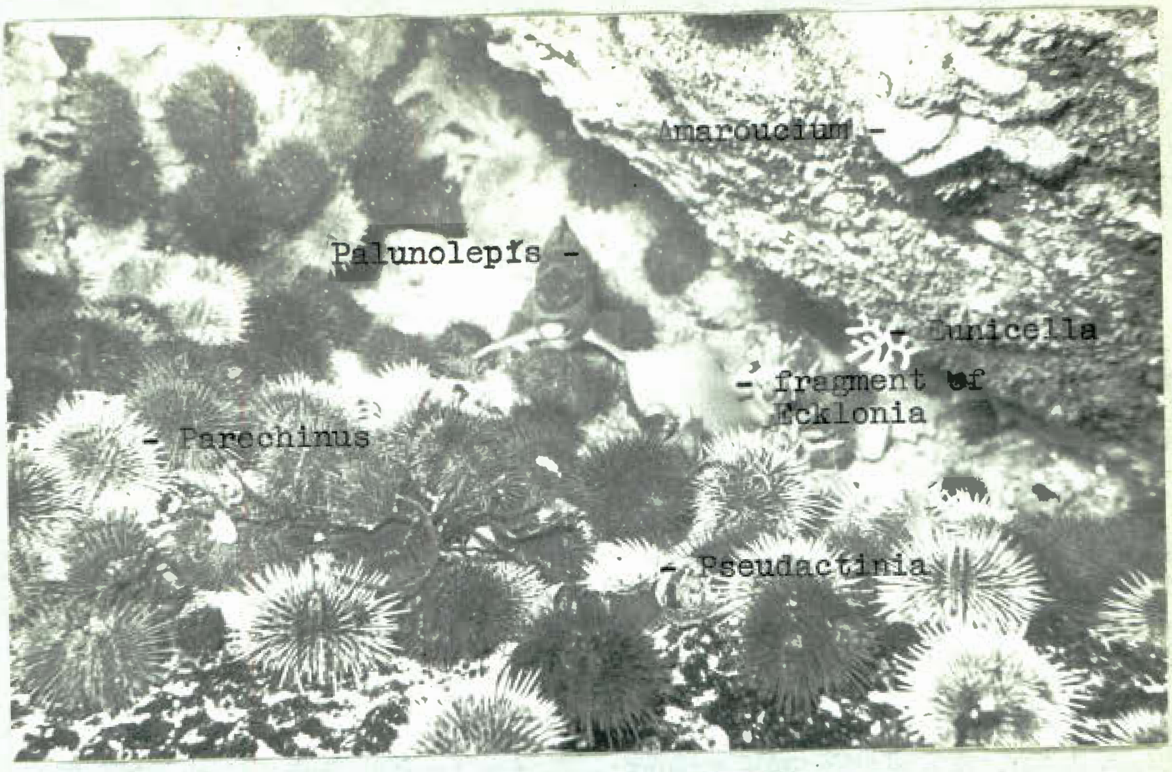
A very characteristic scene.

from a group of rocks to seaward but if a heavy swell is running, waves have time to reform and to enter the opening obliquely. Surf frequently spills into the Lagoon over the south-eastern rocks and small waves come in through the northern opening but large waves seldom pass across the Lagoon. Due to the direction of the prevalent swell there is often a weak current of water entering the southern opening and a stronger one going out of the northern one but much depends on conditions of tide and wind.

The landward margin of the Lagoon consists of granite blocks and slopes with many rounded, sandstone boulders piled up intertidally and in the shallows. The large rocks of the Lagoon are of granite; the bottom consists chiefly of rounded sandstone boulders and stone with gravel and some patches of coarse, shelly sand. The distribution of these deposits correlates with that of water movements for the sand is almost confined to the south-east where it is deposited from the dying surf. Most of the bottom lies at about 1 to 2 m. depth, the deepest places being over the sandy patches.

The following observations were made of the rocks and stones of the Lagoon bottom, avoiding deep cracks between them. The biota was extremely characteristic due to the domination of "Lithothamnia" which covered over three-quarters of the available rock. There appeared to be two main types: a thick, pink one that was lobed at the edges (FAL.182 D) and a filmy-thin, lilac-coloured type (FAL.182 C). The former seemed to be commoner on vertical faces down to 1 m. and

probably/...



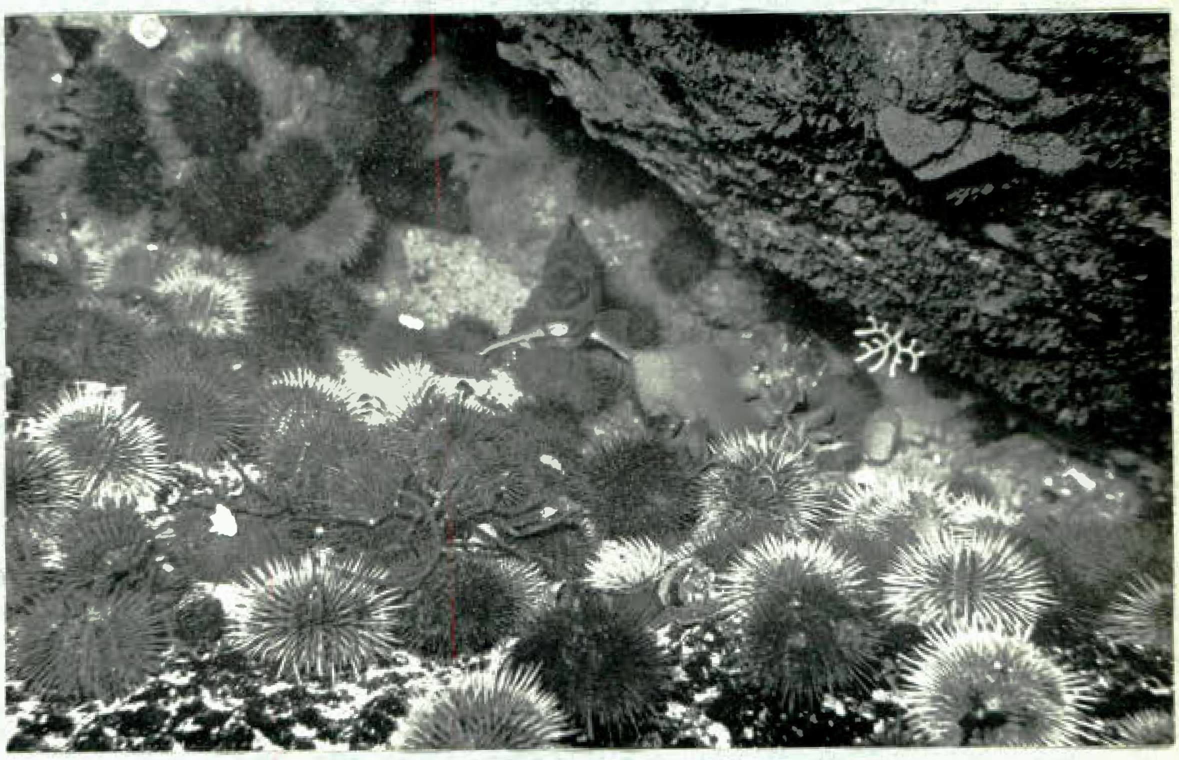


Plate IX. The Lagoon Bottom.

A Butterfish (Palunolepis) in a crevice. The underside of the rock to the right shows characteristic semi-cryptofauna. The rock in the foreground is covered chiefly by "Ralfsia"-type algae beneath the sea-urchins.

probably was identical with the one (CP.592 B) at the bottom of the Sheltered intertidal site (see p. 20). Many of the shallow rocks had bare-looking, slimy areas of a red-brown colouration that suggested the presence of a coating of Myxomycetes. Encrustations of brown algae of the Ralfsia type were common and the remaining rock surface was colonised by various tufty algae, limpets and anemones. Epibiota were very sparse on the "Lithothamnia", on the slimy brown patches and on the ? Ralfsia and so the bottom looked very bare because of the great area that these algae covered.

In regard to sessile species, especially the tufty algae, it was difficult to determine whether they grew upon the "Lithothamnia" or were primary colonisers of the rock. Jointed corrallines such as Amphiroa spp. and Arthrocardia app. were quite common and soft algae such as Aodes orbitosa, Dictyota dichotoma, Bifurcariopsis capensis, Sargassum heterophyllum and Zonaria interrupta. Ecklonia was limited to the immediate vicinity of large, upstanding rocks, growing at their bases and on their vertical faces. Limpets were very common, namely Patella miniata and P. barbara, which, with P. tabularis, were found in the ratio of 14 : 9 : 2 (in a count of 25 random specimens). Identification of these was impossible without dislodging them because the shells were heavily epiphytised with jointed corallines or, less commonly, with tiny algae such as Chylocladia capensis, Champnia compressa, Leathesia difformis etc.. A whole host of small animals such as polychaetes (Platynereis dumerilii was particularly common)

molluscs/...

molluscs and ophiuroids found shelter impartially amongst these epiphytes and in similar ones on the rocks. The anemones Pseudactinia and Anthothoe were fairly conspicuous although not very abundant. They favoured vertical faces, especially near the bottom.

There were various mobile species found on the rocks and, particularly, in the shallow crevices between them. Parechinus and the little gastropod Oxystele sinensis were especially characteristic. Other common ones were the gastropods Turbo sarmaticus, T. cidaris, Cominella papyracea and Argobuccinum argus and the starfishes Henricia ornata, Patiria bellula and Asterina exigua.

Although the sandstone and granite seemed to be impervious to infauna, the thick, lobed "Lithothamnion" was penetrated by many polychaetes and it enveloped several species such as the little bivalve Saxicava. It was very often not actually attached to the rock but separated from it over areas of at least several square decimetres and this sheltered, gloomy space contained a rich cryptofauna of polyzoa, polychaeta, pelecypoda, amphipoda and ascidians. The shells of the patellids and of Turbo sarmaticus were bored by the polychaete, Polydora capensis.

It remains to mention two very characteristic species of the bottom which were not conspicuous to the eye. Hidden beneath the jumbled stones there were clusters of the elegant, black brittle star Ophioderma leonis; and, half-buried in little pockets of sand among the stones there were many blackish holothurians, Cucumaria stephensoni.

The Channel Bottom/...

Plate X. The Edge of the Channel.

In the top, right-hand quarter of the photo a rock rises vertically from the bottom and supports a motley scrub of short algae and a conspicuous plant of Aodes. In the angle at the base of the rock is a large Pseudactinia. In the centre of the photo there is a stand of Caulerpa filiformis next to which, and towards the camera, is a growth of C. holmesiana. The photo was taken at the edge of the Channel, at about 4 m. depth, and is typical of the transitional region between the bottoms of the Lagoon and Channel.

f) The Channel Bottom. (See Plate X).

The Channel separated the seaward group of rocks at Oatland Point from the landward by 25 m. or more (see Fig.2). It lay in line with the prevailing swell which became progressively reduced towards the north-west because the Channel widened there. Diving was done in a moderate swell which was found to produce no strong motion at the bottom, at 5 - 6½ m. below datum.

The bottom varied in nature. About half of it, chiefly to the north-west, was of clean, shelly sand and the rest consisted of stones and rocks around a pronounced but discontinuous median reef. It was difficult to make a hard and fast distinction between the "typical" bottom and the rocks jutting up from it but collecting was confined to stones and low rocks and avoided larger rocks and the reef. Overhangs and dark crevices were also avoided so that notes should refer only to typical, open, flat-bottom biota.

The chief impression of the rocks was that they were colonised by small patches of various algae. "Lithothamnion" was common (FAL.147 Z) but it was the tufty algae that were conspicuous, chiefly the browns, Sargassum heterophyllum, and Dictyota dichotoma and the red Aodes orbitosa. Green patches of Caulerpa holmesiana and C. filiformis were quite common and, where present, completely dominated the biota thereabouts. Other green algae were Codium duthieae and C. stevensiae which were common enough but never dominant species. Reddish algae of the Gymnogongrus type were fairly common and the fine, woolly Falkenbergia rufolanosa formed a thick, pinkish,

epiphytic/...

epiphytic fluff in places. Various other algae were present in lesser degree, including jointed corallines of which the commonest was Arthrocardia ? attenuata (FAL.147 V). Ecklonia was virtually absent since it was only represented by tiny juveniles.

Animals were inconspicuous amongst all these algae. The commonest sessile species included many coelenterates viz. the anemones Pseudactinia, Anthothoe and Corynactis, the hydroid Plumularia setacea, Alcyonium ? fallax (FAL.148 F) and the scarlet sea-fan Lophorgorgia flammea which did not grow large here. Three barnacles were common, Balanus algicola, B. trigonus and B. maxillaris of which the first two were dominant in places but never the last.

Many hemi-sessile species were to be found among the stones and in small crevices. The most conspicuous was Parechinus but many gastropods were scarcely less so, eg. the large Turbo sarmaticus, Argobuccinum argus and Cominella papyracea; and also Cucumaria insolens and Ophiothrix triglochis. As in the Lagoon, Ophioderma leonis gathered under stones and Cucumaria stephensoni in sandy pockets. The only large, very mobile animals were the crawfish, Jasus lalandii, and the octopus, Polypus granulatus.

ii) Noah's Ark.

A brief visit was made to this interesting rock and a collection was made from a small part of its vertical northern face from 11 m. down to the bottom at 14 m.

This part of the face was completely colonised by a rather monotonous short growth lacking large or flamboyant species.

Surprisingly/..

Surprisingly, the little pink anemone *Corynactis* was almost of greatest importance for here it was larger in size than at Oatland Point (it also lacked its typical white margin). These anemones were partly hidden by a lot of the hydroid *Aglaophenia parvula* amongst which small *Mytilus crenatus* were common but, of course, well hidden. There were occasional, large *Pseudactinia*. Many lumps of large, derelict *Balanus maxillaris* shells suggested that this barnacle had once been plentiful. Colourful large starfishes, *Marthasterias glacialis*, roamed all over the rock.

iii) Roman Rock Lighthouse.

Several visits were paid to this locality in an attempt to find the deepest rocks and the collections and notes were made of three areas. Since the biota of these areas was by no means similar each will be described separately. As in the foregoing accounts, only the large and important species will be mentioned.

a) 35 m. WNW of Lighthouse.

The vertical, sloping and horizontal surfaces of a group of low rocks at 12 to 14 m. depth were examined but dark crevices and overhangs were avoided. There was no obvious difference in the ~~biota~~ to be correlated with the angle or aspect of the faces.

The most distinctive feature of the area was a dense "doormat" of small *Mytilus crenatus* anchored upon old, dead *Balanus* shells. Upon this mat short hydroids, were common in particular *Aglaophenia parvula*. Quite apart from this mat

hydroids/...

hydroids of many species were widespread, other common ones being *Nemertesia cymodocea*, *Sertularella arbuscula* and *Antenella africana*; Some were heavily epiphytised by a red, very finely branching alga (*Ceramium sp.* FAL.278 B). In general, algae were not rare but they were inconspicuous. *Dicurella ? flabellata* (FAL.274 B), *Plocamium ? membranaceum* (FAL.268 A) and *Gigartina sp.* (FAL.278 D,E) were to be seen if searched for and also little jointed corallines. Patches of *Anthothoe* and *Corynactis* were common and other coelenterates were *Lophogorgia* and orange *? Gorgonia albicans* (FAL.279 A). A beige sponge (FAL.274 X) was conspicuous and there was one patch of the tubes of *Phyllochaetopterus socialis* covering about half a square metre in which there were numerous isopods (Eg. *Exosphaeroma planum* and *Cirolana sulcata*) and tiny gastropods. Two huge oysters, *Ostrea atherstonei*, were a pleasant discovery. Large, hard polyzoa of the *Chapperia* type were present but uncommon. Three notable absentees were *Ecklonia*, *Pyura* and *Pseudactinia*. Several mobile species were common, particularly the starfishes *Marthasterias* and *Henricia* the two cucumbers *Cucumaria insolens* and *? Pentacta sp.* (FAL.272 B), and *Argobuccinum argus*.

b) 90 m. ESE of Lighthouse.

Observations and collections were made of the sloping surfaces of huge, rounded granite rocks between 12 and 17 m. depth. The almost vertical and almost horizontal surfaces had much the same organisms but overhangs and dark crevices were avoided.

The primary coating of the rock seemed to be dead *Balanus*

shells/...

shells, certainly in many places, but no sheets of living Balanus were to be found. A mat of small Mytilus crenatus commonly grew on this as occurred at the site just described, 35 m. WNW of the lighthouse. Although several square metres of rock might be dominated by the mussel, it was so sand-sprinkled as to be inconspicuous. The other biota presented a very "tussocky" appearance because of many gorgonians such as Lophogorgia and ? Gorgonia albicans (FAL.268 S), and because of big alcyonacea such as the brown, cauliflower-like ? Capsella rugosa (FAL.268 U) and ? Heteroxenia capensis (FAL.268 V). Further examination added to the impression of abundant coelenterates for there were colourful anemones of several sorts everywhere(including the ubiquitous species, Corynactis and Pseudactinia) and many hydroids were common eg. Nemertesia cymodocea, Sertularella arbuscula and Thuiaria articulata (of which the first two were usually epizootic on the sea fans). Cup-corals of the Balanophyllia type were also quite common.

The above coelenterates comprised the chief sessile species and the hemi-sessile and mobile species were drawn from another group, the echinoderms. Several were very common such as Marthasterias, small in size, and crinoids; the orangey arms of Tropiometra carinata and Annametra occidentalis flared from the rock in great clusters. Cock-robin holothurians, Cucumaria insolens, and purple ones ? Pentacta (FAL.272 B) were as numerous but more hidden. Several Astrocladus euryale were seen, two of them climbing a Lophogorgia, and the additional presence of occasional starfishes, Patiria bellula and small Parechinus suggested that the echinoderms were ~~about~~ almost as important as the coelenterates. The gastropod Argobuccinum argus was also very common here.

Throughout/..

Throughout this depth range there were no tendencies to vertical zonation but it is interesting to record that the deepest patches of Pyura community hereabouts were at 12 m.. There was an absence of such typical fringe species as Ecklonia and the gastropods Turbo sarmaticus, Oxystele sinensis and Haliotis midae. The rarity of algae should be emphasised for only one small, red species, Plocamium ? membranaceum (FAL.268 A), was found and it was very sparse.

c) 75 m. SE of Lighthouse.

A rock face fell vertically from about 8 m. to 15 m. depth at which it rested on a sloping rock that disappeared beneath shelly-sand at 17 m.

At 14 to 15 m. the chief coloniser was Balanus trigonus, with Corynactis almost as common. Other important features were big, beige, encrusting sponges (FAL.274 X), a purple Chapperia-type polyzoon, and great bunches of hydroids, principally Sertularella arbuscula and Nemertesia cymodocea with epizootic species. Gorgonians and alcyonaceans were present, but not in large numbers; Pseudactinia was common and vermilion Balanophyllia-type corals fairly common. There were a few crinoids, all of which seemed to be orange Comanthus wahlbergi, and three species of starfish, viz. Marthasterias, Henricia and Patiria. There were no holothurians and no mat of Mytilus crenatus ~~and~~ although occasional, small specimens were present. Argobuccinum was common. In regard to algae, there were only sparse Plocamium ? membranaceum and sparse Dicurella ? flabellata (FAL.274 B).

It was interesting to find Pyura in community form at the

top/...

top of the rock face, i.e. at about 8 m., below which occasional, scattered *Pyura* extended as deep as 14 m..

(iv) The Quay, Gordon's Bay Harbour.

The vertical face of the quay consisted of rough-faced stone blocks with deep, narrow crevices between them. The face was examined from 0 to 3 m. depth.

The quay, in conjunction with the rest of the upper end of this little harbour, was very sheltered and all the biota, rocks and harbour fittings were coated in fine silt for tidal currents here were very gentle. In March 1953, the most conspicuous feature was a growth of fine, fluffy, reddish and greenish algae (FAL.137 T,U) which covered almost everything, including living sea fans. It has not been possible to check this face at another season to determine whether these algae were seasonal such as the fluffy *Falkenbergia* that was abundant outside Lagoon Rock, at Oatland Point, during the same month.

The biota looked very drab because of the fluff and the silt. Even the scarlet *Lophogorgia flammea*, which was common though small, did little to brighten-up the masonry. Fanworms such as *Sabellastarte longa* and the polychaete *Audouinia australis* found homes between the blocks and their protruding tentacles looked less dusty than anything else. The only other sessile species were the tunicates *Styela costata* and a *Pyura* - type species (FAL.137 N); the former often supported little barnacles, *Balanus trigonus*, and the hydroid *Plumularia setacea*. On the other hand, quite a few mobile species were seen, from the largish crab *Plagusia chabrus* to small polychaetes and amphipods. *Parechinus* was rather common, and the big starfish *Marthasterias*, and there were a few gastropods such as *Melatoma*

sinuata,/...

sinuata, *Cominella cincta*, *Argobuccinum argus* and *Aplysia juliana*.

(v) Comparison of the Infratidal Sites.

The infratidal sites may be grouped according to environmental conditions to see whether generalisations are possible. These generalisations can only be made regarding the localities visited and will certainly require modification for places in the north and in the south of False Bay, if only because of the changed abundance of *Ecklonia*.

a) Shallow, Vertical Faces.

Oatland Point, Inside and Outside Lagoon Rock, and the Channel Side of Big Rock. Depth range 0 - 6 m..

Two facts are outstanding: that the rock surface is completely colonised and that there is a very great variety of species. Except where *Pyura* community takes over the rock or, less commonly, where *Mytilus* does so, ~~the biota is dominated by~~ algae, particularly by tufty, non-corallines. The common species are not banded into zones, as occurs intertidally, but it is clear that vertical gradients in distribution exist, even within this small depth range. Such gradients are shown in two ways: by changed abundance of individual species with depth, eg. *Ecklonia*, which is most abundant around datum level and becomes scarcer deeper down; and by species actually occupying different levels in succession eg. *M. crenatus* in and below the infratidal fringe, and *Lophogorgia* only deeper than 5 m..

The biota also change in a horizontal direction where the exposure to wave action changes. Again the abundance of individual species is affected and their presence - or absence.

For example/...

For example, a sheltered face may be colonised by Caulerpa holmesiana; a rather exposed one by Plocamium corallorhiza in upper levels and by C. holmesiana lower down; a more exposed one by Pyura in the shallows and C. holmesiana lower down; and one with submaximal exposure by Mytilus in the shallows and C. holmesiana lower down. This illustrates the fact that shallow levels are more affected by exposure than deeper and in fact, one can go further and venture to say that below 2 m. depth the biota scarcely reacts to different degrees of exposure.

This is the most appropriate place to emphasise that the appearance of infratidal rocks in False Bay depends largely on two species, both giants of that habitat in size and importance, namely Ecklonia and Pyura. At Oatland Point Ecklonia is in conditions representing the end of its geographical range and consequently it is restricted in abundance and reacts sensitively to environmental pressures. It thrives where there is shelter and a lot of bubbly water, for instance, in crevices to leeward of rocks around which the swell breaks. But where exposure is great it is, surprisingly, most abundant around datum level: it appears to require the well-aerated water there more than it shuns the turbulence but this is probably an oversimple deduction. In addition, the abundance of Ecklonia depends greatly on that of Pyura. Pyura is in almost optimal climatic conditions and where there is strong exposure and a lot of "soda water" it usually ousts Ecklonia and everything else except its special friends and hangers-on. These comments only apply to the region around Oatland Point. Further south, near

Cape/....

Cape Point and across the bay near Cape Hangklip, Ecklonia competes with Pyura on at least equal terms down to 3 m. and has no rival below that to about 10 m. depth.

b) Shallow, Vertical Face in Sheltered Water.

Gordon's Bay quay. Depth range 0 - 3 m..

By no means all the rock is colonised, unless by microscopical algae, and there is no great variety of species. The rock and biota are covered by silt and look very drab. There are no tufty algae, and, apart from epiphytes, the sessile species are all animals eg. hydroids, sea-fans, fanworms, barnacles and ascidians which do not show zonation. Such a combination of species was not found elsewhere.

This type of site is not known well enough for further generalisation and the one examined, at Gordon's Bay, is too far from the other stations for elaborate comparison since hydrological differences probably confuse those due only to shelter. Time did not permit the completion of work that was planned for other harbours.

c) Shallow Cave.

Oatland Point, beneath Lagoon Rock. Depth range - 0-2½ m.. Plenty of indirect light.

The rock is completely colonised and a great variety of species are present in profuse abundance. Certain groups of animals are characteristic and are dominant ~~the biota between them,~~ namely the porifera, polyzoa, coelenterata and ascidiacea. Distribution is patchy and does not show vertical zonation. Algae are absent from the cave proper and Pyura is also absent doubtless because of the low illumination and lack of very

turbulent/...

turbulent water respectively.

d) Shallow Rocky Bottoms.

Oatland Point, the Lagoon and Channel Bottoms. Depth range 1 - 6½ m..

The rock seems to be completely colonised except where it lies next to sand which commonly scours all life from a basal strip of a few inches height. The biota appears to change rather sharply at about 3 m. depth.

Down to 3 m. the rocks and stones are dominated by bare-looking expanses of "Lithothamnia" and, to a much less degree, by Ralfsia-type encrusting algae and probably by Myxomycetes. Epibiota are very rare in comparison to rocks free of these algal encrustations and consist of tufty algae (including many jointed corallines) and limpets in about equal proportions, but the limpet shells provide further substratum for algae. Because of the bare appearance of the bottom the mobile animals, sea-urchins, gastropods and starfishes, strike the eye more than elsewhere and the combination of colours is very pretty. In the crevices between the large rocks there is plenty of kelp but it does not grow on the open stony bottom. There is no Pyura.

Stony bottoms at 4 - 6 m. lack the abundance of encrusting algal forms and support instead rich patches of tufty, soft algae, all of which also occur sporadically in the shallows. However, Ecklonia is virtually absent (except in the south of False Bay) and other conspicuous absentees are the limpets and Pyura.

e)/.....

e) Moderately Deep Rocks.

Noah's Ark; Roman Rock at three sites. Depth range 11 - 17 m..

The rock is completely colonised and there are very many different species. There are two dominant groups, coelenterates and echinoderms, but the commonest species of these are not the same as those that are typically found in a shallow cave. Hydroids, alcyonaceans, gorgonians, holothurians and asteroids are particularly common. Distribution is patchy and there is no vertical zonation or gradient; neither does it depend upon the slope of the rock, nor its aspect. A feature of these faces appears to be the presence of mats of small *Mytilus crenatus*. The mussels are usually attached to abundant dead *Balanus* shells although sheets of living *Balanus* are rare. Algae, including *Ecklonia*, are virtually absent and there is no *Pyura*.

Several interesting points result from comparing the above groups. Except for the very sheltered site which is very silty, all infratidal rocks are completely colonised, without a square centimetre remaining bare (unless scoured by sand). It is striking that a great variety of species colonise the rock except where silt acts as a drastic presence-or-absence factor, and except where "*Lithothamnion*" occupies a great deal of space, as on very shallow rocky bottoms.

The abundant or dominant species of one group are usually not abundant in another, or even present at all. This merely proves what is to be expected, that different species flourish under different conditions. In general, algae dominate well-illuminated rocks down to 7 m. but plants give way to animals

between/...

between 7 and 10 m. for below this depth algae are virtually absent. Naturally enough, algae are ousted from caves, however shallow.

One can say that there is no sharp vertical zonation comparable to that in the intertidal zone yet it is quite clear that the biota changes with depth even within the small range considered here. For instance, the biota at 2 m. bears little resemblance to that at 6 m. and none to that at 12 m. (although, of course, certain species occur throughout). It has been mentioned that the biota of the shallowest metre or so varies tremendously according to exposure: in other words, it varies horizontally around a rock. But this tendency rapidly ceases with increasing depth: even at 2 m. the influence of exposure on the biota is markedly less pronounced and at 6 m. it is hard to discern. The influence of slope also decreases with depth for in the shallows the biota of vertical faces differs from that of horizontal, whilst at 12 m. there is no difference.

CONCLUSIONS.

It is now possible to compare the arrangement of life on intertidal rocks and on rocks below tidal levels at one locality. It appears that the work that was done is certainly useful, but perhaps inevitably, it shows that much more must be done to dot the "i"s., and cross the "t"s of our interpretation of the influences at work.

The most useful conclusions drawn from this work are given below but no attempt is made to discuss exhaustively all

environmental/....

environmental influences on an animal because their general principles are well appreciated nowadays (eg. see Gislen 1929 and 1930).

A. THE EFFECTS OF EMERGENCE.

Undoubtedly the most important distinction between the intertidal and infratidal zones is that the former is periodically exposed to air. In False Bay the chief hazards of a marine creature that is left bare by the water are desiccation and overheating and only species that can withstand these conditions can survive. Thus emergence exerts a drastic selective effect on species in the intertidal and does not affect infratidal species at all.

Different levels of the intertidal become exposed to the air, or "emerged", for different periods of time. Bokenham et al. (1938) have calculated the percentage emergence at Simonstown, which is a mile or two north of Oatland Point, and have obtained a sigmoid curve that is shown in their text-figure 8 relative to tidal levels. The curve shows that the rate of change of percentage emergence is greatest at about the levels of M.H.W.S. and M.L.W.S. and pretty constant throughout the central metre of the intertidal, on either side of M.S.L.. Thus, descending a sheltered rock, marine conditions become important rather suddenly at about M.H.W.S. level, increasingly important at a steady rate lower down, throughout the middle of the intertidal zone, and then, suddenly, more important still at about M.L.W.S. level below which emergence virtually ceases. Because of the great rate of change around M.L.W.S. it is interesting to compare the percentage emergence at our datum (not that of Bokenham et al. which is about 10 inches lower down) with that at M.L.W.S., the figures being about 3% and ½% respectively (personal communication from Dr. N.A.H.Millard, nee Bokenham).

Apart from desiccation and heating, which are by far the most important aspects of emergence, there is one that may be important in regard to wave action. When steep rocks are left uncovered by the tide algae hang under the influence of gravity but submerged plants are almost unaffected, or even buoyant.

The importance of emergence is shown by the fact that where it is great, as at the top of the intertidal zone, much of the rock is bare and only a few species are to be found. On the other hand, the lowest intertidal rocks are 100% colonised and support a great variety of life. Clearly, the sharp zonation of the intertidal region is due to the effects of emergence acting over so small a vertical range. There is no infratidal environmental feature of comparable importance.

Emergence may be effectively decreased at any level by the upwash of waves, especially on exposed rocks. This will be discussed later. It is likely that tufty algae effectively reduce the emergence of small species in their shelter so that they are found at higher levels than on open rock, but this work has not found confirmatory evidence.

B. THE EFFECTS OF LIGHT.

The decrease in illumination as one passes underwater is surprisingly small: the shallowest metre or two is almost as well lit at noon as the intertidal zone. Earlier and later in the day more light is reflected from the surface and less passes through it. Although there is no sudden decrease in

illumination/...

illumination at the surface it is true that the intertidal is fully lit whilst the infratidal never is, a progressive, and differential absorption occurring with every metre's depth. There is no local work on light absorption in sea water but Grein's work (1913) in the Mediterranean may be comparable if one remembers that False Bay water never approaches the clarity of the water in which he worked.

Sudden drops in illumination - far greater than that at the water's surface - are found both intertidally and in the shallows due to shading. This may be due to rock formation or to a canopy of algae, eg. Ecklonia. Even in the open air shading may be enough to suppress the presence of algae as was found at the Shady, Very Sheltered intertidal site; and underwater the effect is pronounced as was shown by the shallow cave where algae were absent.

It seems likely that the levels where the greatest changes in the biota occur, the critical levels, are also affected by shade for they appeared to be higher on the shaded intertidal site. Since algae were unimportant there, this raising of critical levels must be due to decreased heating and decreased desiccation.

The loss of light with depth is accompanied by a decrease in algae. Thus, algal distribution on well-lighted, intertidal rocks is not governed by illumination, for there is ample light, but below about 10 m. depth lack of light enables animals to compete successfully for space.

It is tempting, but unwise, to attempt to explain the different biota of shallow flat, sloping and vertical rocks in terms of illumination. Detailed work is necessary to do this and other factors such as exposure to turbulence and sedimentation are likely to be more important.

C. THE EFFECTS OF TURBULENCE.

Of the many aspects of turbulence the one that is chiefly regarded here is the direct, mechanical effect of water movement on biota. This, too, has many aspects for it can be fast or slow, have various horizontal and vertical directions, be constant, variable or oscillatory and if it changes in nature it can change quickly or slowly. The phrase "wave-action" has been used to cover this sort of turbulence in the intertidal zone. The whole of the intertidal zone is exposed to wave action but infratidal water movements are much less violent and are different in nature.

Wave action plays above and below the water's surface and different levels of the intertidal rocks are subjected to wave action in turn as tides rise and fall. Naturally, a rock is more often pounded between neap tide levels than between those of spring tides; the amount of wave action to which any level is subjected is not related to the emergence curve. The effect of the crest of the wave is exaggerated when surf flows up a rock because of its momentum and the effect of the trough is always minimised because of cascading water. This matter has been raised earlier in calculating the extent of the upwash and suck-back of waves breaking on the intertidal. The suck-back of a wave hides from view the fact that cascading water descends well below the surface, certainly for 2 m. or more when the swell is fairly strong.

Colman/....

Colman (1933), amongst others, has remarked that wave action effectively raises tidal levels so far as living organisms are concerned. Certainly, this work has shown that the centres of distribution of many species rise where exposure is greater (Fig.6); and there is a remarkable correlation between the height of this rise and the roughly calculated estimate of wave upwash (see p. 34). The intertidal work also shows, as has been discussed under that head, that increased exposure affects the height and arrangement of the critical levels as well as those of the actual species. Increased exposure spreads the critical levels apart and it raises them relative to surveyed heights (or predicted tidal levels). In the middle and upper intertidal regions the critical levels stay at about the same effective tidal levels but the lowest intertidal species spread relatively lower, into what is effectively the infratidal, and appear to push down correspondingly the top limits of infratidal species. This is probably due to the descent of cascading water into the infratidal and is probably a result of its turbulence, or velocity, acting directly (rather than via other effects, eg. aeration).

It is clear from a glance at a broken coastline that increased wave action at exposed places has caused certain species to flourish there whilst others flourish in sheltered places. In other words, turbulence affects the presence or absence, and abundance of species and this is clearly shown by the intertidal work here. Since False Bay has a swell that always comes from the south the exposure of a rock depends largely upon its aspect and so different sides of a rock support different species at the same level. Turbulence, therefore, cuts across the picture of vertical zonation and causes horizontal differentiation, or patchiness.

Infratidally there is no turbulence of the same magnitude as is found intertidally although cascading water descends violently for 2 or 3 m. below a rock face when a strong swell runs. Other infratidal currents are gentle in comparison, negligible in this context, and turbulence consists of oscillatory movements as the waves pass overhead. In other words, the water does not rush around madly but rocks gently to and fro. The difference between rushing and rocking water is that between surf and uncrested swell. The frogman knows well that the first will throw him on to a reef and drag him across it. But, even in a fair swell, he can lie a few inches off a vertical rock and will only be lightly tapped against it - the impact is cushioned, presumably by reflection of the swell from the rock. Surely the different natures of these forms of turbulence affect the species on the rock ? There is also the effect of gravity to consider. Above water level it not only adds to the force of pounding waves and to the rush of cascading water but algae have to contend with their own weight suddenly, as waves withdraw. Below the surface the effect of gravity is nullified.

The/....

The infratidal biota match these changes in turbulence closely. It has been shown that where exposure to wave action is considerable the important biota of the lower inter-tidal region extend downwards for a metre or two below datum (see Fig. 11) which corresponds with the depth to which cascading water descends. Beneath this depth, about 2 m., turbulence suddenly become low and it decreases rapidly and steadily with further depth. Under conditions of moderate swell algae were found to stream quite strongly at 6 m. depth but there were no very obvious correlations of distribution with aspect to suggest that turbulence influenced them. At 12 m. the rocking of the water was very gentle and appeared to have absolutely no effect on the distribution of the fauna. The horizontal patchiness of species due to different exposure thus disappears with depth but it is recalled that deep rocks showed patchiness, still, which could not be attributed to wave action, or illumination or to any obvious environmental feature.

Two other aspects of turbulence need mention. In the shallows, rocks that lie next to sand are often abraded by it around their bases. This only occurs where there is strong turbulence; it is a frequent sight on rocks that lie next to a beach, where water is constantly sloshing about and carrying sand with it, but it is not a feature of even very shallow bottoms where surf is absent.

Where turbulence is very low silt is deposited from dirty water. This occurred at one of the examined sites, the quay at Gordon's Bay Harbour, and quite obviously the silt had a great effect on the biota there, decreasing its abundance and eliminating many species. These effects were seen in the shallows; none of the deeper diving sites showed silt so

presumably/...

matched/...

Pilumnoides perlatus (Poeppig)	Int.	18	R.lR	P	In berry Sept. Possibly an introduced species	Barnard 1950, ~~Barnard~~ 1955	W
* Pilumnus hirsutus Stimps.	0	154	?	P	--	Barnard 1950/1955	(W in Saldanha Bay)
* Pinnotheres dofleini Lenz	0	75	?	P	Associated with Ascidians (Pyura & Phallusia) & Pinna)	Barnard 1950	--
Plagusia chabrus (L.)	Int.	37	R	C	Megalopae found from 0-22 m. on S,Sh,Sn,R; fairly common	"Challenger" 1895	W & E
Pseudodromia latens Stimps.	23	100	L&coS,S, S&Sh	P	--	Stebbing 1902, Barnard 1950	(W in Saldanha Bay)
" rotunda (McLeay)	15	37	R	P	--	"Challenger" 1895	--
* Thelxiope barbata (Fabr.)	58	84	?	P	--	Stebbing 1904, Barnard 1950	--
* Xanthias tuberculidens Rathbun	42	183	?	P	--	Barnard 1950	--

MACRURA

Hippolyte kraussiana (Stimps.)	5	15	S,Sh	P probably C	In berry Nov., Dec.	Barnard 1950	(E in Knysna & Bushman's River Estuaries)

matched by changes in the biota. This does not quite complete the picture and so it is worthwhile finally to look at changes that occur in the biota and attempt to explain them in terms of the environment.

The intertidal zone, proper, is very narrow, only 1.66 m. (5.44 ft.) between the mean high and low levels of spring tides, but the vertical zonation hits the eye. Quite obviously, this is a result of emergence. The highest sessile species, the barnacles, are only found below M.H.W.S. on a sheltered rock and this is the height at which submergence becomes suddenly important. The other sharp boundaries in the intertidal, those between Upper/Lower Balanoid, and Lower Balanoid/Cochlear zones, are not easy to account for precisely, but presumably are the result of balance between emergence and inter-specific competition.

As Stephenson has noted there is a striking change in the biota at the lowest levels of the intertidal zone, viz. in the infratidal fringe. Stephenson (1939, p. 512 etc.) does not define the upper limit of the fringe except rather vaguely in terms of biota and this is certainly a good idea because the upper limit varies in level as well as in constituent species. In this paper the fringe is more sharply defined (p. 14) as the part of the infratidal region (i.e. below our datum) that is exposed by unusually low Spring tides (E.L.W.S.). Fig. 4 shows how the upper boundary, biologically speaking, fluctuates around datum, usually above it. It is unnecessary to bog-down in definitions to understand what is happening. Emergence decreases suddenly around datum level and become negligible below it and this, clearly, is what causes the biological change. The analysis of critical levels corroborates the importance of the upper boundary of the fringe for the most consistently

critical/...

critical level was around datum. It is interesting that the lower boundary of the fringe is not clearly defined biologically but it is suggested by the finding that the most consistently uncritical level occurred from E.L.W.S. downwards.

Clearly, the species of the infratidal fringe are infratidal in nature since they are only present where emergence is negligible. There is no sharp lower limit to the infratidal fringe on a scale comparable to the intertidal zonation so we may say that the fringe is not a zone in itself and that its upper boundary is the biological boundary between the inter- and infratidal regions. Actually, the fringe is dominated by species (eg. Algae, Pyura) that quickly diminish deeper down so that more extensive infratidal work may differentiate a zone called the infratidal fringe. Certainly, its vertical range would be much greater than that of the whole intertidal zone.

Before leaving the intertidal region comment must be made on the effect of wave action on the biotic levels. This work has shown how species are moved up a rock by the upwash of waves, a well-known phenomenon. It has also been shown that where exposure is very great the dominant, lowest intertidal species extend very much lower to dominate the fringe and the topmost metre or two of the infratidal (Fig. 11). These species do not entirely supplant typical fringe species, such as Ecklonia, and their upper limits are higher than those of the typical fringe species. They are certainly intertidal in nature. Their upper limit is determined by emergence but their downward extension corresponds very markedly with the influence of cascading water. Certainly these species, mussels and barnacles, oust most others where the water pours in torrents; and so, where exposure is sub-maximal, sessile intertidal

species/...

species invade the infratidal fringe in force and penetrate to well below E.L.W.S. level.

Emergence dies at about M.L.W.S. level on a moderately exposed rock and below this the vertical changes in the biota are gradual. The infratidal work has not been analysed by the method of critical levels for several reasons, chiefly because the transects have not covered a great enough depth range, and because the precise limits are known of too few species. The obvious changes, or critical levels, can be spotted from the distribution diagrams by eye without requiring an elaborate analysis which would imply in this case, a bogus precision.

A glance at Figs. 9 and 11 shows that, so far as exposed rocks are concerned, the depth of 1 - 2 m. is important as the lower limit of many intertidal species and the upper limit of infratidal species which dislike turbulence (note that they will rise above datum in very sheltered places). This level corresponds with the lower limit of influence of cascading water here. Lower down, at 4 - 5 m. are the lower limits of many species that are very characteristic of the fringe and the upper limit of one species that, on the contrary, is certainly not a typical species of the fringe. The change at this level is possibly due to the decrease of turbulence to negligible importance as a limiting factor: it is likely that lesser depths are subjected to cascading when the swell is very heavy. But the deduction of critical levels from only one or two transects of small depth range, such as these, is unsatisfactory: one knows that species which here go no deeper than, say, 4 m. are found on other rocks at 12 m. (eg. Pyura).

Comparison/...

and are less patchy. Stephenson (1939, p. 506) remarks that, intertidally, "horizontal differentiation appears to affect the lower zones more markedly than the upper". Patchiness is certainly great to 17 m. depth, as might be expected from the total colonisation of the rocks, but it is undoubtedly greatest in the shallows where changes in turbulence etc., are more pronounced.

It is felt that there is probably an intrinsic patchiness everywhere due to inter-specific competition and the vagaries of mortality and spat-fall but that in the shallows, say at less than 6 m., patchiness is increased by the different environmental factors.

It is interesting to compare very briefly this work in False Bay with that of certain people elsewhere.

The analysis of intertidal critical levels can be compared with the work of Colman (1933), and of Evans (1947) at Plymouth, and of Knox (1953) in New Zealand. In their analyses Colman and Evans considered twenty-two species and Knox thirty-four and so the analyses of the Exposed and Semi-Exposed transects should be comparable to their's on that score. For the other two False Bay transects, the number of important species is probably too low for a good analysis. In the following discussion, the Shady, Very Sheltered site is disregarded because of the complication of shading.

At the outset the problem arises whether true (predicted) tidal levels should be considered (as was done by Evans and by Knox) or whether allowance should be made for wave upwash, giving "effective" levels (vide Colman). The argument for using effective levels is persuasive. Fig. 6 shows the rise of

species/...

species with increasing upwash and Fig. 8 shows that allowance for upwash adjusts the critical levels to about the same effective heights so far as the highest ones are concerned. But this does not hold at all for the lowest critical levels, as has been mentioned, and Fig. 8 also shows that wave action affects the pattern of critical levels markedly. This last point contrasts with the data of Evans who shows that the arrangement of the critical levels at five localities at Plymouth (his Fig.14) is very similar despite their exposure ranging from "Very exposed" to "Very sheltered" (his Table I). Since for False Bay, the effect of wave action is not simply to raise everything up a rock and, since it is difficult to work with mental pictures of effective levels for different sites, it is suggested that it might be best to work relative to true levels always, provided an estimate of upwash be also stated. Although Knox works with true levels it seems that they are also effective levels because he discounts the effect of wave action by his choice of locality and in his field observations.

It is interesting to find Knox in agreement with Evans as to the most critical levels (M.L.W.N. to M.L.W.S. and E.H.W.N. to M.H.W.S.) and the least critical level (around M.S.L.) when their localities are so widely separated. Colman's results are very similar when his wash-allowance has been discounted. On the other hand, the critical and uncritical levels of the False Bay intertidal show no agreement with these. A feature of the False Bay transects is the uncritical zone from true E.L.W.S. level to about 0.5 m. deeper which was too deep for consideration by the other workers.

It might be supposed that the percentage emergence curve, which varies according to the tidal characteristics of

different/...

different localities, would be linked with the critical biological levels. Knox finds this to be so for he finds the most critical levels to occur where the greatest rates of change of emergence are found. On the other hand, neither Colman nor Evans finds such a correlation. The analysis of False Bay work shows no critical level to correspond with the upper inflection of the curve but the level of the lower inflection is consistently critical. It is recalled that the upper inflection, at M.H.W.S., appears to be important biologically even although this does not appear from the analysis - it is the upper limit of barnacles.

It is felt that the concept of critical biological levels is very useful but that the method of application of the concept requires investigation on mathematical and interpretive grounds. Several serious drawbacks of the analysis, as it stands, have been mentioned above. It is also apparent that the degree of "critical-ness" should be mathematically defined for there is a danger of every level of the intertidal being described as notably critical or notably uncritical without nondescript levels being recognised. Colman noted three critical zones and one uncritical zone for an extreme spring tidal range of about 19 ft. at Plymouth, and later Evans recognised five critical zones and one uncritical for the same place. Knox, dealing with an extreme spring range of about 9½ ft., describes six critical zones and one uncritical zone. The extreme spring range in False Bay is 7 ft. and it would have been surprising to find so many critical levels.

The datum chosen for this work in False Bay is 0.09 m. (3.55 inches) above M.L.W.S. and it is worthwhile to discuss its suitability as the dividing line, by definition, between the

intertidal/...

intertidal and infratidal regions. Of course, strictly speaking, the intertidal region extends to E.L.W.S. which is 0.33 m. (13.15 inches) below datum. This datum is nearly enough in agreement with the datum levels chosen by Colman and by Evans ("Chart Datum", which is about 0.2 ft. below M.L.W.S.) and by Knox ("Chart Datum", which is at 0.4 ft. above M.L.W.S.) However, the analysis for critical levels shows that datum level, or just above it, is the most consistently critical level on the shore. Hereabouts are found the lower limits of many intertidal species and the upper limits of many infratidal species. The upper limit of the infratidal fringe is either at datum, or above it and it has been concluded above, (p. 78.) that the upper boundary of the fringe is the biological boundary between the inter- and infratidal regions. Therefore, although the datum may be odd and the terminology poor, it definitely gives the truest picture of the biological changes. It will be noted that the infratidal fringe is the topmost edge of the infratidal region, as defined here; whereas according to Stephenson's terminology (1939, p. 512) it is the lowest part of the intertidal region.

Regarding the infratidal biota there is little work of this type for comparison. Recently Forster (1954 and 1955) has given notes on localities on the English Channel and although the author has no experience of the infratidal there Forster's descriptions sound surprisingly familiar in the light of knowledge of False Bay. It is remarkable that the biotic pattern appears to be similar infratidally in the Plymouth-area and in False Bay; and most of the species that Forster mentions are matched by similar ones in False Bay, often of the same genus - indeed the alga Dictyota dichotoma is present both at East Blackstone, off Dartmouth, and in False Bay, and covers a similar depth range. Forster's descriptions also reveal the presence of vertical distribution gradients in place of sharp vertical zonation and they make it clear that distribution is extremely patchy (at any rate for E. Blackstone between 6 and 18 m.).

Algae obviously dominate the shallows at all Forster's localities and he finds the change to dominance by animals at about 25 m. in the clear water at Stoke Point and apparently at about 8 m. in the turbid and sheltered waters at E. Blackstone. It will be recalled that algae were conspicuous at Oatland Point on the Channel bottom at 6 m. but virtually absent near Roman Rock at 11 m., both localities having a water clarity of about the order of that at Stoke Point. Of course, close comparison is not possible because of the dominance of the kelp _Laminaria_ in the Plymouth area and the merely "fairly common" abundance of the kelp _Ecklonia_ in the Oatland Point/Roman Rock area. A kelp profoundly affects the biota of the rocks beneath because of its size (commented upon by Kitching, 1941) and the shallows in the Plymouth area are obviously covered in kelp forest, whereas at Oatland Point the kelp is short and never forms a forest. In the south of False Bay great forests of _Ecklonia_ are to be found where they profoundly affect the biota, as may be imagined. These _Ecklonia_ forests have been observed to extend certainly as deep as 10 m. and probably to 15 m., which is on par with Forster's lower limit of _Laminaria_ at 17 m.. But dredging operations suggest that it is unlikely that algae extend in numbers deeper than 15 m. in False Bay whereas Forster comments on algae being common as deep as 25 m.. It is rather a surprising detail to find algae extending deeper in the Plymouth area (latitude about 50¼°N) than in False Bay (latitude

about/...

about 34¼°S) when water clarity is of the same order. It is interesting that Forster lists coelenterates and polyzoa as the commonest of the animal groups just below the algal belt, both at Stoke Point and at E. Blackstone. Both groups have been noted as very important and characteristic in the cave at Oatland Point and coelenterates were particularly important on open bottoms deeper than 11 m..

Kitching, Macan and Gilson (1934) also studied the infratidal region on the south Devonshire coast, working down to 3 m. depth below M.L.W.S. level. They found that open, sloping rock faces were dominated by algae, chiefly by Laminaria forest which agrees with Forster's later results. They found overhanging slopes to support an entirely different association, one in which Laminaria was virtually absent and which was dominated instead by the ascidian Distomus and the sponge Halichondria, with other sponges and many hydroids. This association rather recalls the biota of the cave at Oatland Point. They discuss the importance of the slope of a rock and stress the associated factors of illumination, of settling potential for spores and of silt deposition. They suggest that freedom from silt deposition is particularly responsible for many of the peculiarities of the Distomus-Halichondria association, in particular for the importance of sponges, coelenterates and ascidians. This is interesting but no similar suggestion is advanced for these groups of animals in False Bay. It is felt, rather, that these groups are among the commonest in the shallow infratidal and so are most likely to colonise a rock-face not dominated by algae. They make the interesting observation that the lack of large, brown algae (eg. kelp) from this association is not due to insufficient illumination but to other factors, possibly the inability of their spores to settle.

They/...

They also note that barnacles are rapid colonisers of bare rock, but that they are rapidly overgrown later and they comment on the common occurrence of barnacles in the intertidal and at the base of gullies where strong scouring probably occurred. It will be remembered that dead barnacle shells were a common feature of the rocks at Noah's Ark and at two of the Roman Rock sites while live *Balanus* were common at the third Roman Rock site but it is most improbable that scouring is a common occurrence at any of these places.

Kitching (1941) finds that on the west coast of Scotland the shallow infratidal is, again, dominated by laminarian forest down to at least 15 m.. The species there are different from those off Plymouth, in general, and of course, there are detailed differences in zonation. It is particularly interesting to find from his account that the algae of the infratidal fringe differ from those of the truly infratidal zone. Kitching emphasises the sharp drop in illumination from the infratidal fringe to within the *Laminaria* forest just below it due to shading by the kelp. These points together suggest that the infratidal fringe there possesses a character unlike the true infratidal which is strikingly different ~~to~~ from the situation in False Bay. In an endeavour to explain this difference, it is worth recording that Kitching states (p. 335) : "At the upper margin of the sublittoral region, exposed to air at low water of spring tides, there is a characteristic 'sublittoral fringe' ". This and relevant sentences elsewhere rather imply that the upper margin of the infratidal fringe is a little above M.L.W.S. level and possibly detailed work on tidal levels will show that Kitching's "sublittoral fringe" corresponds to the lowest level of the intertidal zone by the definitions used here. For instance, Kitching's Fig. 1 shows that of the species around datum level (presumably M.L.W.S.) five extend upwards from datum, four extend downwards from datum and only two others really overlap on either side of datum. In other words, so far as his Fig. 1 is concerned, datum seems to divide the intertidal from the infratidal very well and his datum seems pretty much the same as this datum.

Although Kitching deals with a kelp forest his conclusions are similar to those made of False Bay in that the "zonation" (vertical distribution gradients) of the infratidal region depends upon wave action and illumination. Kitching reaches this conclusion after pointing out the uniformity in the illumination, and in the constitution of the undergrowth of the forest, over a vertical range of at least 12 m.. Kitching also discussed briefly the vertical succession in English waters of green, brown and then red algae, and it is worth mentioning that this sequence is not found in False Bay. Algae of all three groups are mixed at almost any level here and reds occur abundantly in the intertidal and shallow infratidal whether the illumination is modified by kelp or not.

It is clear that the infratidal localities in England that have been mentioned show many features in common with the infratidal of False Bay. Further diving in different latitudes would be extremely interesting.

It seems that interpretation in terms of vertical zonation must be abandoned for shallow infratidal work and, instead, it is suggested that the best method of consideration would be in terms of communities (as for soft bottoms) and their intergradation vertically and horizontally. There is a great need for autoecological work and for experiments to determine precisely the tolerances of various species to the different features of

illumination/...

					Dredgings have found this on soft bottoms as deep as 60 m. but these deeper records are suspected to be flotsam washed from the place of origin		
Styela costata (Hartmeyer)	0	64	(L&coS,cokS), Sh,St,R,lR	F, (LC 0-25 m.)	Typically on hard bottoms	Millar 1953	(E in Knysna Est.)
" pupa Heller	Int.	22	S&R	P	--	Millar 1953	(W in Langebaan Lag.), E
Sycozoa sigillinoides Lesson	48	48	cokS&~~S~~&Sh&St	P	--	--	--
Synoicum adareanum (Herdman)	18	18	S&R	P	--	--	--
Tridinemnum cerebriforme Hartmeyer	0	48	S&R,coS&fSh, Sh,S&Sh&lR,R	F-C	Found off Port Elizabeth at 5-14 m. on St,R	Millar 1953	(W in Saldanha Bay & Langebaan Lag.), E
CEPHALOCHORDA							
Branchiostoma capense Gilchrist	9	73	S,Sh,cokS&Sh (&St),Sn	C (LA 35-50 m.	Most of these undoubtedly escaped through the dredge net	~~Kirkpatrick 1904 b~~ Gilchrist 1904 a	--

It is suggested that the selected datum (or M.L.W.S., which is 3½ inches below it) is very suitable as the boundary by definition between the intertidal and infratidal regions. The biological boundary is clearly at the upper limit of the species of the infratidal fringe.

It is recommended that work on intertidal zonation should be reported upon relative to actual (or predicted) tidal levels, not "effective" levels, provided that estimates of wave upwash be given. Infratidal work should be examined in terms of communities and their modification under the stress of different environmental features rather than in simple terms of vertical zonation.

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APPENDIX: Additional Underwater Photographs.

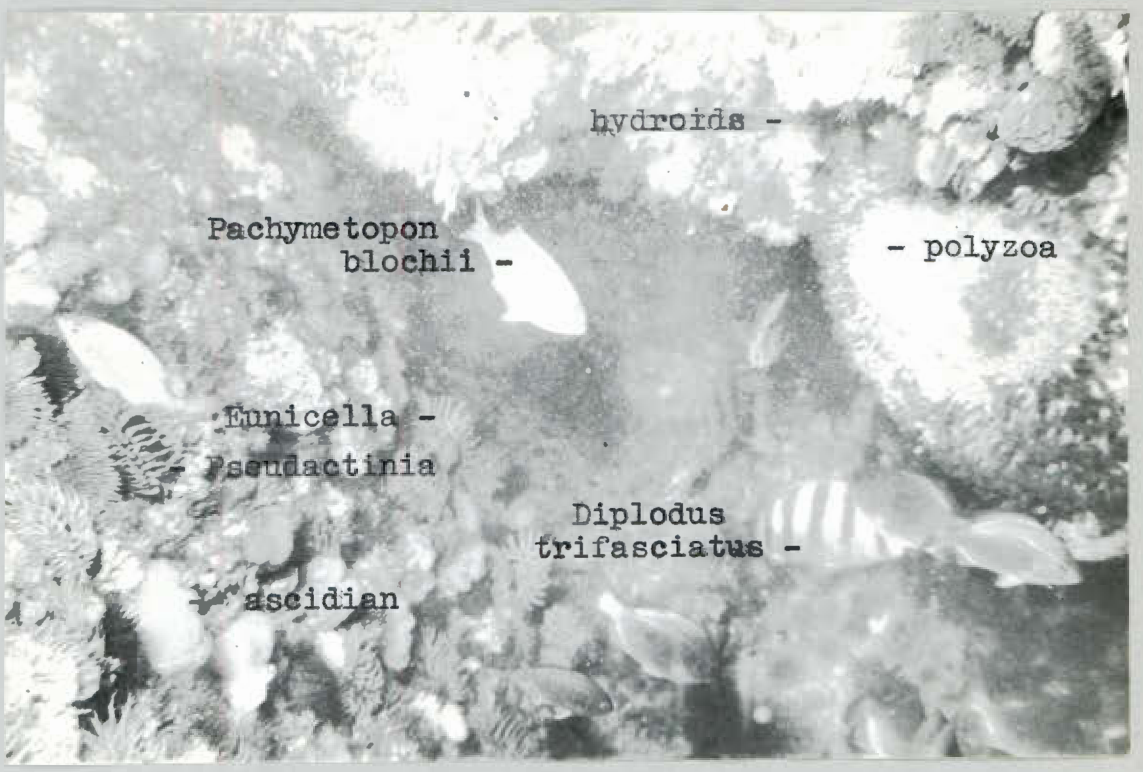


Plate XI. At 4 m. depth within a Cave, Oatland Point.

The cave was dimly lighted; a darker recess is shown in the background of the picture. The cave is situated on the north-eastern side of the Channel under the conical rock that can be seen in Plate I.

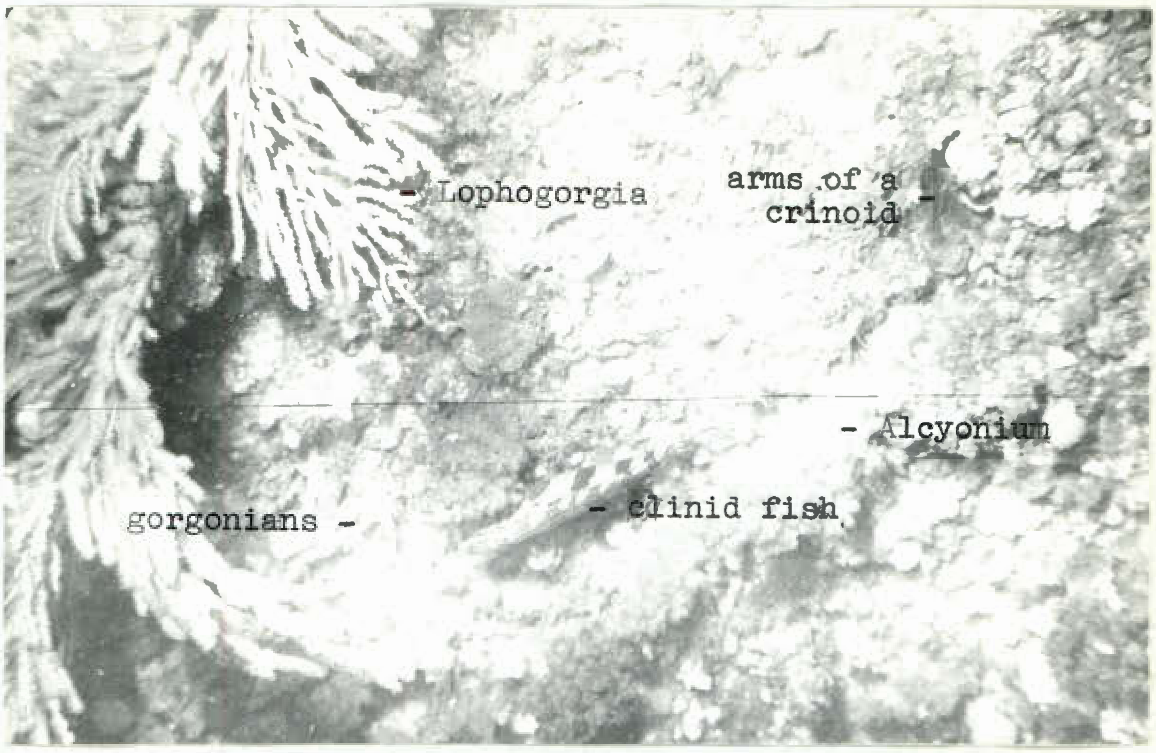
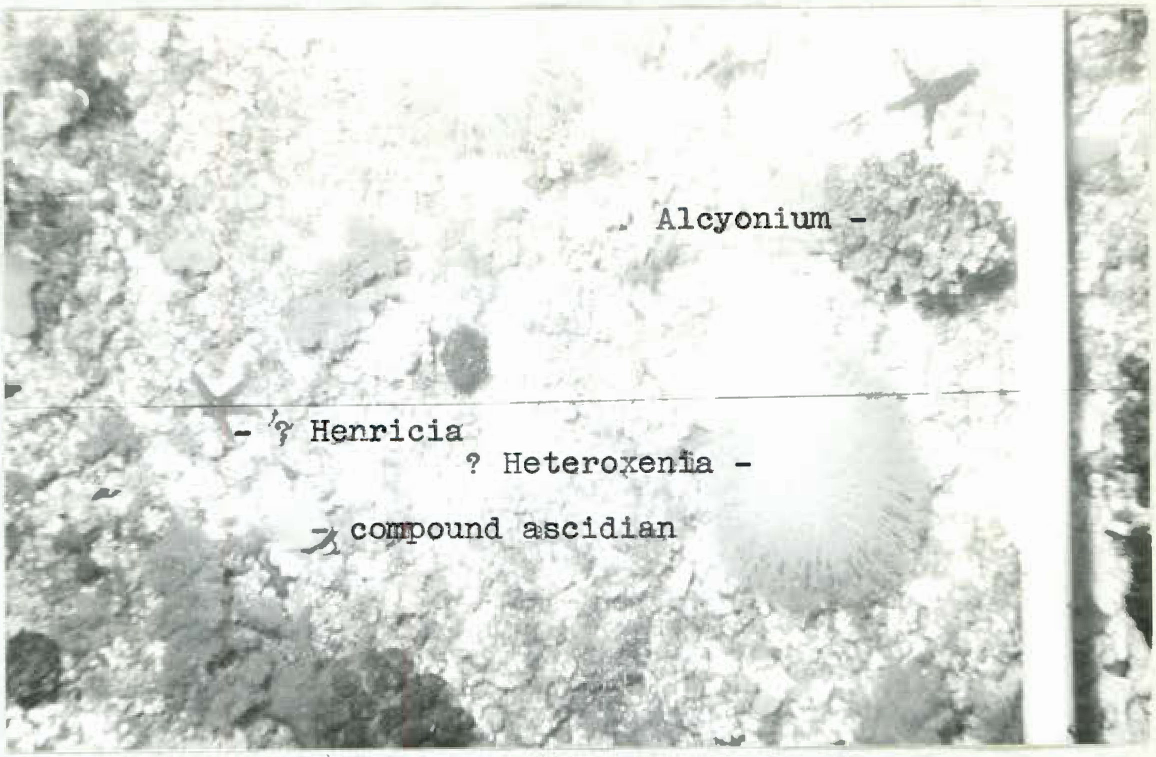


Plate XII. A Cave wall at 2 m. depth.

The cave is the same as that of Plate XI. The wall overhangs at about 75° to the horizontal and is rather dimly lighted. The black line across the photo is due to a scratch caused by a defect in the camera.



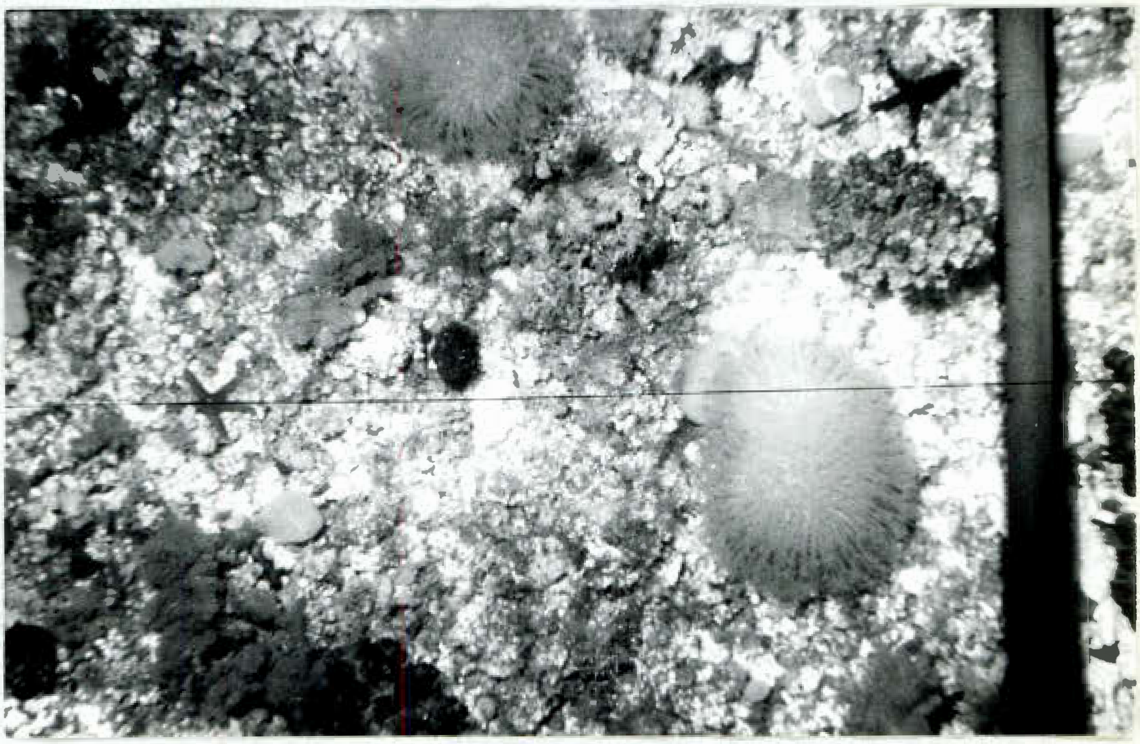


Plate XIII. A Cave wall at 2 m. depth.

This photograph was taken next to that of Plate XII. The focus-stick is seen in this photo; it is marked in decimetres and the markings can just be seen at its left margin. The height of the photograph corresponds to 45 cm. on the rock.

Plate XIV. Abelones amongst kelp, Miller's Point.

The camera looks down through a small clearing in a bed of Ecklonia and spotlights at least four Haliotis midae. They are sitting on top of a rock at 1 or 2 m. depth. The shells are heavily epiphtysed; the mantles of the animals show below the shells. Abelones are often as abundant as this over many square yards of rock and they support a lively industry.

Paper 4

"THE RESULTS OF DREDGING."

THE BENTHIC ECOLOGY OF FALSE BAY.

Part III. THE RESULTS OF DREDGING.

Introduction.

The results of this survey have been split into three parts for reporting. Part I gave the list of identified species as a basis for the later two descriptive papers. Part II reported upon diving observations of shallow rocks in conjunction with the biota of nearby intertidal rocks. This final paper summarises the dredging results and includes relevant observations made by diving. In addition it rounds-off the series by putting together deductions from all three parts in a discussion of the biotic trends in False Bay.

Many expeditions have visited the Cape of Good Hope and many authors mention species as coming from that region. Actually the term has varied widely in meaning so that many references are now vague as to precise locality. An early and reliable collection was that of the "Challenger" in 1873 which worked quite extensively in "Simon's Bay". Soon afterwards a Government Biologist was appointed in the Cape, Dr Gilchrist, under whose able guidance investigation of the shallow sea bed bordering South Africa proceeded by leaps and bounds, the first papers appearing in 1902. Thereafter systematic papers were numerous until about 1930 after which the investigations of the Governmental department became increasingly preoccupied with fishery matters. Unfortunately there was no ecological synthesis of Gilchrist's collections after the harvest of taxonomy.

In 1931 the emphasis shifted from examination of the continental shelf to the intertidal zone with the beginning of the exemplary survey directed by Professor T.A. Stephenson. His field work ended in 1940 and the final report appeared in 1947 although he comments that much material remains to be dealt with.

It was logical for Professor J.H. Day, an associate of Stephenson and a later successor of the Chair, to extend the project inland, up the estuaries, and seaward to the shallow infratidal. In the latter case it was hoped to gain a more detailed picture of local conditions than could be gleaned from Gilchrist's tremendously widespread investigations. Dredgings in False Bay were started in 1946 by Professor Day and his associates in the Department of Zoology of the University of Cape Town. At the start of 1951 the author was charged with the work and two years later direct observation of the infratidal became possible by means of aqualung diving.

The object of this initial survey by dredging was to determine what species are present in False Bay and how they are distributed. It was hoped that the distribution could be correlated with the type of bottom leading to the recognition of faunistic areas or "grounds". Although this hope has not been completely realised some faunistic groupings have become apparent and these are definitely associated with certain types of soft bottom. In addition a preliminary discussion of bathymetrical distribution is now possible,

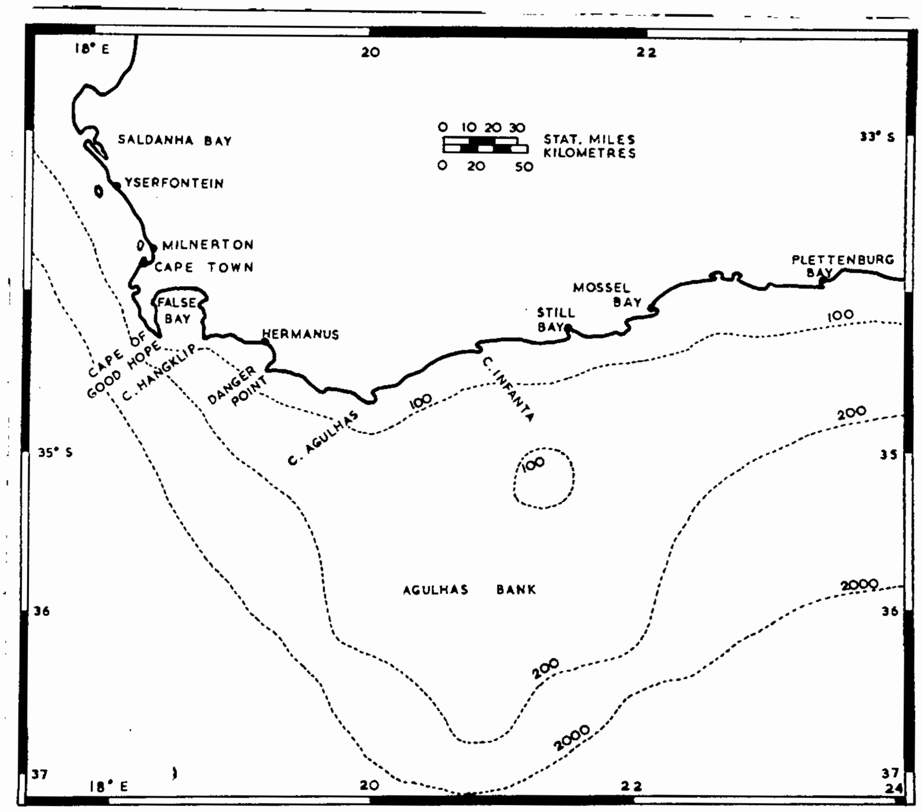


Figure 1. False Bay in relation to the Agulhas Bank.

Depths in metres.

the bay fauna being compared on the one hand with the intertidal biota and on the other with fauna recorded from greater depths outside False Bay. But much remains to be done. False Bay is a very large area and many more dredgings must be made before the whole of the bay can be divided into grounds.

In addition to the many acknowledgements made in Part I of this series thanks are due here to Dr. A.J.Clowes, Principal Professional Officer in the Division of Fisheries, for generous advice that has done much to mould the discussion on local hydrology.

This introduction must close with the reminder that the terminology used will be as defined in Parts I and II. Briefly, datum level divides the intertidal from the infratidal zone, the region below datum which is exposed by extreme spring tides being the infratidal fringe. Datum happens to be about 3½ inches above M.L.W.S. level in False Bay.

Locality and Hydrology.

As shown in Fig. 1. the Agulhas Bank is formed by an expansion of the continental shelf. The 100 m. contour is close inshore and most of the bank lies between 100 and 200 m.. Beyond the 200 m. contour the depth increases rapidly and a precipitous drop starts at about 400 m..

False Bay is situated at the north-western end of the Agulhas Bank, some 12 miles south of Cape Town. It is square in shape and the sides are about 20 miles long. The bed of the bay is shaped like a shovel, sloping gently from north to south and having steep sides. The greatest depth is about 90 m. at the open southern side but in the mouth on the western side is a shoal called Rocky Bank

(see/...

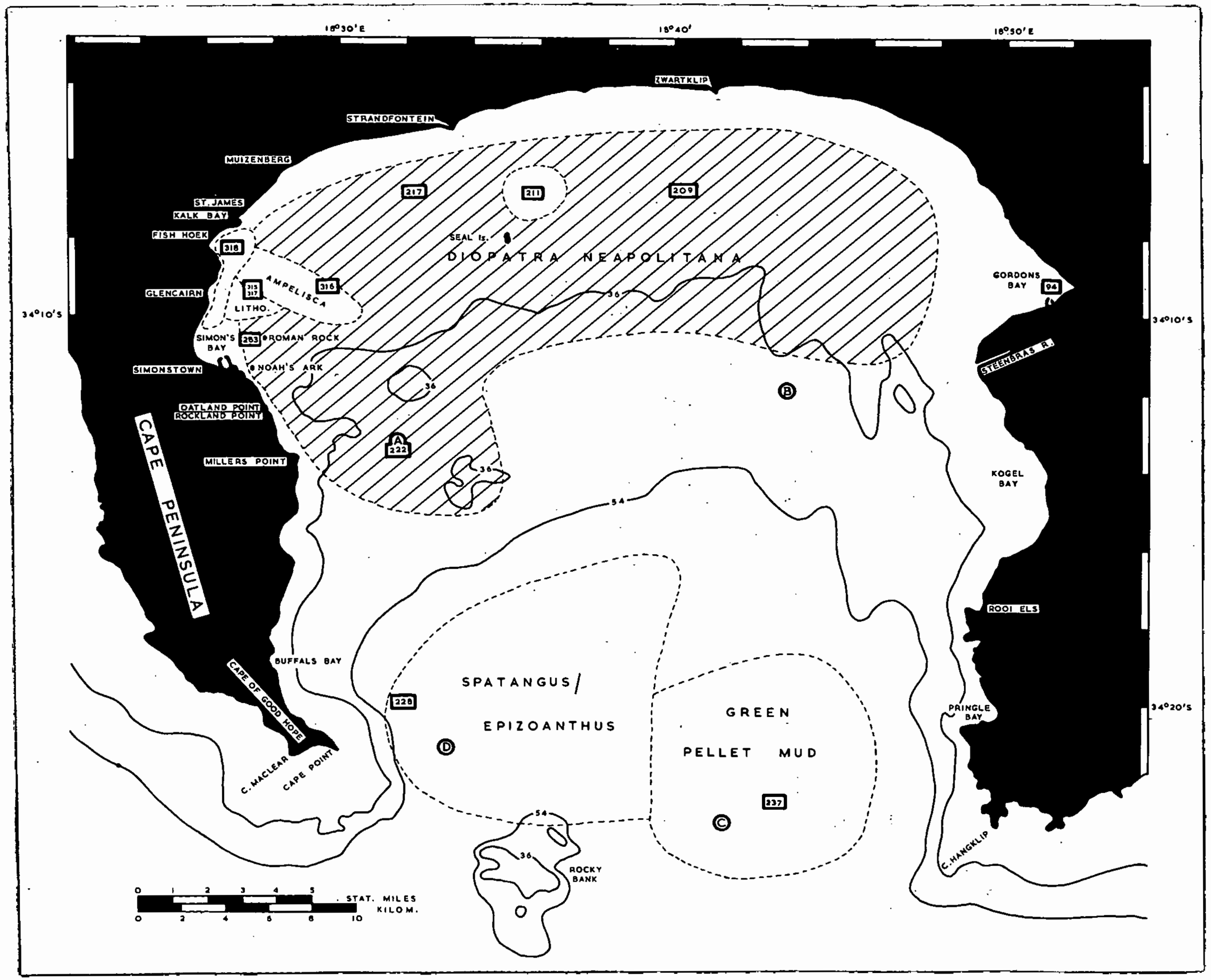


Figure 2.

False Bay, showing six of the seven grounds suggested, the hydrological stations (A - D) and the positions where substratum samples were taken (in boxes).

Contours in metres.

Based on British Admiralty chart 636.

(see Fig. 2) that rises to about 30 m. depth.

The distribution of the area of the bay in relation to depth is important for later consideration of the adequacy of field sampling. For this purpose the southern limit of the bay is defined as the line joining Cape Point and Cape Hangklip. British Admiralty chart 636 was used to draw contours at 10 m. intervals and the areas between adjacent contours were measured. The area of the bay was found to be 428 sq. statute miles and the percentages lying between successive contours are shown in Table 1.

Range in metres	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
Area %	8	9	14·5	14·5	16·5	15	11·5	7	3·5
No. of Stations	25	27	25	11	4	3	4	3	2

Table I. The percentages of the total area found between 10 m. contours and the number of stations made in each range.

The hydrology of the area is interesting but complicated. In the deep water south of the Agulhas Bank there is a conflict between the warm Agulhas (Mozambique) current coming down from the north-east and meeting the cold water of the South Atlantic that comes from the west and which later forms the Benguela current flowing northwards along the western coast of South Africa (see Clowes 1950). This is well shown, for example, by a figure of the offshore isotherms at a depth of 50 m. (in October) compiled by

Stephenson/...

Stephenson (1939, Fig.3) from data of Dietrich. The major currents tend to sweep along the outside of the continental shelf and currents which actually flow over the bank are not usually strong. In discussin-g this region Isaac (1937) neatly summarises extant hydrological work as follows : "The region between Cape Agulhas and the south end of the Cape Peninsula is not directly within the sphere of influence of either the Agulhas or Benguela current, but .... branches of the Agulhas Current escape into it. Also, from time to time, as a result of wind action, colder and warmer water masses invade the region. Furthermore, there is a seasonal effect, since the Agulhas Current flows more strongly and extends further west in the summer and the Benguela Current extends further east in the winter." Apparently the last statement remains controversial.

False Bay, a backwater on the shifting frontier of these currents, is influenced by both in a confused way and additional peculiarities are imposed by local topography and by heating over the shallows. Some comments on its hydrology, chiefly of the surface, have been made in Part II. Deeper hydrological work seems limited to that of Marchand (1932) who describes a section across the bay from Miller's Point to Steenbras River Mouth. The field work was done from 29 November to 2nd December 1930, when the wind was chiefly medium to strong south-easterly so that typical summer conditions probably prevailed despite the early date. The report is very useful but there is doubt whether the section diagrams and the deduced current pattern can be accepted since the data were collected over thirteen days. The protracted fieldwork may explain the anomalous "pocket of cold water" noted on the western side of the bay (even approximate sigma-t values show an apparent instability there that would be impossible in practise). Calculation of a sigma-t diagram from the sections given shows that the water/...

water is anything but homogeneous. This may reflect true conditions or be due to changes having occurred during fieldwork.

There is direct evidence of surface circulation for Marchand (I955) and Clowes (unpublished) have recently investigated surface currents by means of drift cards. In late September and early December, I953, which of course is summertime, surface currents appeared to flow to the north-west. The prevailing winds of summer are called "South-Easters" but yachtsmen in False Bay consider them to be nearer to southerly. If they are right, then, deflection due to Corioli's force would cause surface water to drift to the north-west. Two interesting exceptions to the above drift must be noted. Cards dropped 7 miles off Kogel Bay were swept eastwards into Kogel Bay ; and cards dropped to the south of Kogel Bay, about a mile offshore, and others off Pringle Bay nearby, were swept southwards. If False Bay were a saucer of tea and we blew across it from the south then the surface of the tea would show a similar current pattern to that suggested by the drift cards, ie, two complementary gyrals. (In summer the surface waters drift into a cul-de-sac and in winter they drift out of it so the resultant current systems are not necessarily reversed patterns). Another card dropped off Kogel Bay actually moved southwards and rounded Cape Hangklip proving that, although most surface water off Cape Hangklip moves north-west, some inshore water there flows south-east, out of False Bay. There does not seem to be a similar surface outflow on the western side of False Bay because cards released between Cape Hangklip and Danger Point (see Fig. I) were stranded at Cape Point. The outflow at Cape Hangklip is probably small and it is

possible/...

possible that the surface inflow into the bay causes piling at the head which, in turn, would force water to move outwards beneath the surface. In this way surface currents could influence bottom fauna quite considerably but the possibility remains speculative.

Marchand (1932) has noted that in winter and early spring the Benguela current dominates the hydrology of False Bay while in summer this is done by the Agulhas current. He showed that the change-over is sharp and coincident with the onset of the summertime "south-easterly" winds.

Some interesting hydrological data (Table II) were collected on our behalf by the officers of the "Africana II" early in September 1953. At this date surface salinities were almost identical to those given by Marchand for September, 1930, when the Benguela current dominated False Bay. At the time of the collection of the data of Table II weather conditions were late-wintery, with north-westerly winds and occasional showers of rain and when the salinity and weather are considered together there is a strong suggestion that Table II represents late winter conditions. It is therefore possible to compare late winter conditions with those of early summer for Marchand's section, mentioned above, was made in early summer. In either season temperature and salinity figures decrease with increasing depth. The temperature gradient is rather low in winter but well marked in summer, which is not surprising ; whereas the salinity gradient is high in winter and negligible in summer. In general, winter temperatures and salinities are lower than in summer which is presumably a result of the influences of the Benguela and Agulhas currents.

Station	Depth (metres)	Temp. °C	Salinity‰.	Sigma-t at water temp.	Inorg. Phosphate, mgm. atom per m³.
A.	0	14·28	35·16	26·26	0·34
34°13·5'S 18°31·9'E	10	·22	·16	·28	·50
9·9·53	20	·16	·16	·29	·58
1455-1511 hrs.	30	13·93	·10	·30	·67
B.	0	14·28	35·16	26·26	0·41
34°12·4'S 18°43·5'E	10	·11	·10	·26	·52
10·9·53	20	·11	·10	·26	·55
0904-0930 hrs.	30	13·61	·07	·34	·60
	40	·31	·05	·38	1·60
C.	0	14·28	35·16	26·26	0·61
34°23·5'S 18°40·9'E	10	·26	·14	·26	·74
10·9·53	20	·12	·12	·27	·75
1250-1338 hrs.	30	13·76	·08	·32	·76
	40	·17	·07	·43	1·30
	50	12·80	·05	·48	1·61
	60	11·90	·00	·63	-
	80	·10	34·92	·71	-
D.	0	14·79	35·21	26·20	0·47
34°21·5'S 18°33·3'E	10	·50	·18	·24	·47
11·9·53	20	·37	·17	·26	·48
1117-1155 hrs.	30	·21	·16	·28	·56
	40	13·63	·12	·37	1·00
	50	·31	·10	·43	1·20
	60	12·96	·08	·48	-

Table II. Hydrological data in False Bay under Late Winter Conditions.

Inorganic Phosphate analysis by the molybdate method results being corrected for salinity. Phosphate and sigma-t values are not discussed in the text but are included for completeness. (Unpublished data: by permission of the Director of Fisheries).

Methods/...

Methods.

Although this paper deals with dredging in False Bay some diving observations are relevant and they usefully augment the dredging results. Diving was done with self-contained breathing apparatus to a maximum depth of 26 m.; the methods were described in Part II. The diving observations given here are entirely new except for one or two which are briefly mentioned for their comparative value. At each dredging station positions were obtained by compass bearings and depths by sounding line. For later dredgings this was done both at the start and the finish if the haul were a long one. Hauls were usually of ten to fifteen minutes duration but a few were longer and many were shorter, notably those where rocks were present. Dredging was done from hired motor fishing boats of 20 - 30 ft. length, without special fittings, and consequently the greatest workable depth was about 36 m.. The shallowest limit was about 8 m. because of rocks, swell and surf. The deeper parts of False Bay were sampled on our behalf by R.S. "Africana II", and her personnel. Nowhere in the bay is more than 7 miles from a station and the whole depth range has been covered although by no means exhaustively. All early dredgings were done with the same , rather small dredge but later a larger one was designed for soft bottoms. The early dredge was particularly suitable for rocky bottoms and will be referred to as the "rock dredge", and the latter as the "sand dredge". Other gear was tried but fell by the wayside.

Rock Dredge. Of standard type, about 20 x 8 inches and rather bowed-out at the mouth. Two semicircular iron pieces projecting forwards from either side of the mouth provided a non-snagging front and to each was attached a

four-foot/...

four-foot chain bridle. The bag was of strong netting, 1/4 inch bar. Usually this dredge was used with a leader of 6 fathoms of chain and a swivel so as to provide weight and to counteract the elasticity and spin of the rope warp. The length of the warp was roughly three times the depth.

Sand Dredge. A box-frame about 40 x 9 inches at the mouth and 8 inches fore to aft was constructed of welded flat iron. To one of the long front sections was welded a down-turned lip of heavy steel plate. A four-chain bridle was used, the upper chains being about 4 ft long and the lower about 5 feet which allowed the dredge to sink from the boat with the cutting lip on the underside. The lower chains were attached at the lower front corners of the sides, a position 3 or 4 inches aft of the cutting lip and about an inch higher so that the dredge tended to bite well. An important point in the rigging was that the upper chains were fed through the mouth and shackled to the sides about 4 inches aft of the mouth. A series of holes on either side allowed fore and aft adjustment of the shackles, lengthening or shortening the upper chains. The principle of this rigging was that the lower chains ensured deep cutting whilst the upper chains prevented the mouth from falling forwards. This balance was achieved by underwater observation of the dredge in action and later adjustment of the relative lengths of the upper and lower chains by alteration of the points of their attachment. Adjustment was not very critical but underwater observation was vital for success. Excellent results were finally obtained, the dredge progressing with the mouth inclined forwards at an angle of about 45° and the dredge digging some 2 inches into hard-packed sand and shelly sand. The greater the weight of the dredge the deeper it would dig. The bag was of strong 1/4 inch bar netting and a trap-flap was inserted in the mouth to prevent

the/...

the contents spilling out. As a further precaution the bag was stayed to four legs attached to the dredge frame but these made for awkward handling and probably did not assist greatly. As with the rock dredge a six-fathom chain leader and swivel was used and a rope warp approximately three times the depth.

Dredges of R.S."Africana II". In the stations made by this ship, most of which were deeper than 40 m., ~~their~~ normal ship's equipment was used. The dredges were simple rectangular, frames of about 36 x 9 inches stoutly constructed of flat iron and fitted with four bridles of steel wire each about 3 ft. long and attached in front to a wire warp by shackle and swivel. The normal bag was of about 1½ inch bar trawl netting but for our purposes this was half-lined with either 1/4 inch bar netting or with hessian. The hessian bag obviously choked easily so that its contents were not sifted by the water, and this was often useful in obtaining substratum samples and small fauna.

Bottom Samplers. Two types of cone samplers for soft bottoms were tried but were only occasionally successful. Most bottoms were of hard-packed sand or shelly-sand and difficult to penetrate with a small instrument. More important, much of the sample was usually washed away during recovery and in a swell sampling was found to be futile. However under calm conditions a sample of white sand was successfully raised from 31 m. . Some apparantly good samples of the bottom were retained in our hessian linings to the dredges of the R.S."Africana II". Finally, samples that were indisputably unmodified subsequent to collection were taken by diving and scraping the substratum into a 2 lb. preserve jar which was then sealed with a screw lid. Probably

this/...

this method penetrated the bottom deeper than the cone sampler but no deeper than the dredge.

The substratum samples were analysed for particle size and for organic matter according to the recommendations given in the first paper of this thesis. To check that the cone samplers were obtaining true samples one bottom at 26 m. depth was sampled both by the cones and by diving. Analysis shows no significant difference.

The nature of the bottom was inferred by the traditional method of feeling the warp during towing and from the contents of the dredge. It is not easy to say how many stations were sampled because in some cases the dredge came fast almost immediately and had to be recovered yet its sparse catch was catalogued. In other cases several hauls in one area were combined because of proximity and similar biota. Details of the geographical stations which are considered in this paper are given in the Appendices. Where the sampling of the station was very inadequate (and where miscellaneous records have been used) the convention has been adopted of regarding these as "quarter-stations" : in the Appendices the "quarter-stations" are listed in brackets. Assuming that four quarter-stations are equivalent to one station, then some 72 dredging stations have been made in False Bay, 9 being on rock only, 20 on mixed rock and soft bottoms, and 43 on soft bottoms only. If the diving is included there are I6 rocky stations and 49 on soft bottoms.

Substrata/...

Substrata.

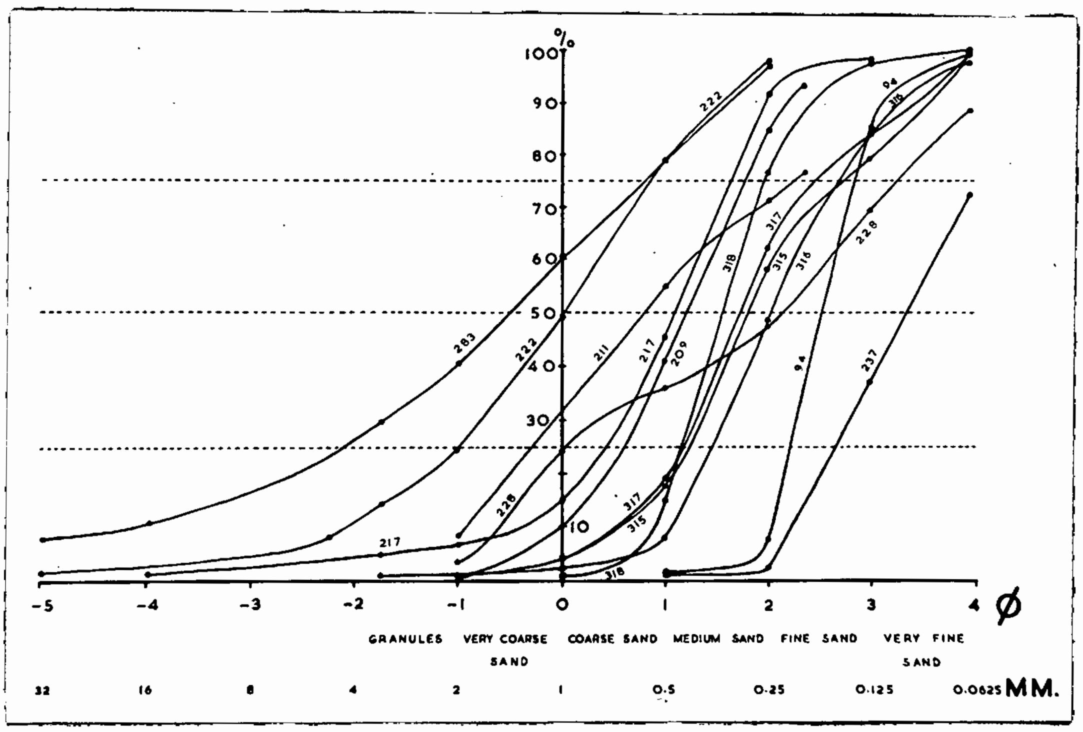
Some information on the substrata of the sea bed off False Bay may be gleaned from British Admiralty charts 636 and 2095. Rock apparently becomes less common with increasing depth but is recorded as deep as 340 m. . Sands and shell go down further, to 900 m. . Mud ranges from 56 m. to 2300 m. and there is a record of *Globigerina* ooze at 3470 m. . This is much as might be expected and so far as the shelf is concerned rocks, sand and mud show no simple vertical zonation.

The chart gives more details of the bottom within False Bay and our dredgings add to our knowledge of it. In general the bed is of shelly sand of various sorts with frequent rocky outcrops ; near the mouth there are muddy bottoms. Most of the rock is hard, either Table Mountain Sandstone or Pre-Cape Granite, but there are limestone reefs in the northern shallows : eg. off Strandfontein.

Although there were few successful samples of soft substrata it is probable that most types were taken. There were eleven samples (positions shown in Fig. 2) and their analyses are summarised in Fig. 3 and Table III. No substratum was silty enough for it to be necessary to carry-out analysis for particles of sub-sieve size.

The median diameters of the samples range over five grades, from Very Coarse Sand to Very Fine Sand but most are Medium or Fine Sands. These agree reasonably well with the field descriptions. There is no correlation between depth of bottom and the median diameter of the

sample/...



<u>Figure 3.</u> <u>Cumulative curves by weight of different substrata related to the Phi scale.</u>

Grade designations and the equivalent diameters are according to the Wentworth scale.

Samples 315 and 317 were taken by different methods from the same substratum.

Station	Sampling method	Depth (metres)	Field Note	Median diameter (microns)	Wentworth designation of particles of median diameter.	Phi Quartile deviation (= half quartile spread).	Phi Quartile skewness	Grades in which organic carbon, W.& B. value, exceeds 0.4%	Available organic carbon, W. & B. value	Available organic matter.
94	Cones	2-3	Clean, hard sand with ripple marks.	175	Fine sand.	0.6/ 2	0.0	Silt	0.004%	0.010%
283	Diving	14	Coarse shelly sand.	1400	Very coarse sand.	2.9/ 2	-0.1	None	0.000%	0.000%
318	Cones	17	Clean, white sand.	340	Medium sand	0.9/ 2	0.0	*	*	*
217	Dredge	18	Shelly sand	470	Medium sand	1.2/ 2	0.0	None	0.000%	0.000%
211	Dredge	22	Shelly sand	580	Coarse sand	2.4/ 2	0.2	*	*	*
315	Diving	26	Khaki sand	290	Medium sand	1.6/ 2	0.2	*	*	*
317	Cones	26	Khaki sand	300	Medium sand	1.4/ 2	0.1	*	*	*
209	Dredge	30	Shelly sand	440	Medium sand	1.6/ 2	0.0	*	*	*
316	Cones	31	Khaki sand	240	Fine sand	1.2/ 2	0.0	*	*	*
222	Dredge	40	Coarse sand and fine shell	960	Coarse sand	1.8/ 2	-0.2	Very fine sand; also silt.	0.031%	0.074%
228	Dredge	64	Coarse, khaki sand.	235	Fine sand	3.2/ 2	-0.5	Silt.	0.144%	0.346%
237	Dredge	78	Green mud	100	Very fine sand.	1.3/ 2	0.0	All grades	3.20%	7.73%

Table III. Characteristics of Some Substrata of False Bay.

Stations 315 and 317 were made at the same spot as a test of the sampling methods.

* Indicates that no organic analysis was made and that the available organic matter was assumed to be negligible.

sample and this is not surprising in view of the comparatively small depth range and the probable differences in current velocity across the bay. Fig. 3 quickly shows how the median half of any sample is spread amongst the grades. The number of grades which comprise the median half may be called the "quartile spread", which is double the Phi quartile deviation. The substratum deposited by the most efficient sorting agencies is that of Stn. 94 with a quartile spread of 0·6 ; actually one sieve contained 78% of the sample as may be seen from Fig. 3. As with the median diameters the quartile spread shows no correlation to depth.

Although the median gives an average particle size and the Phi quartile deviation tells whether the sample consists of few or many grades a further, simple measure can be valuable. This is the Phi quartile skewness which shows whether the larger or the smaller particles predominate in a naturally badly sorted substratum. Positive values indicate a predominance of particles larger than the median size and vice versa. Only one of the curves in Fig. 3 is markedly skewed between the quartiles. This substratum, that of Stn. 228, shows a peculiar mixture of grades ; no Granules, plenty of Very Coarse Sand, fair amounts of Coarse and Medium Sands, plenty of Fine and Very Fine Sands and a fair amount of Silt. The Phi quartile deviation shows this substratum to be the worst sorted but there is no obvious explanation for the odd distribution of particle sizes. Skewness could indicate that part of the sample had been lost during collection but it is very difficult to believe that the greatest loss would occur in the middle of the size range.

So far only the median half of each sample has been considered, chiefly because of the likelihood of poor sampling efficiency at either end of the size range. However the extremes of the curves are interesting. It is noticeable that where largish particles, say greater than 1 mm., are present in fair quantity then very small particles are usually absent and vice versa.

The coarser particles, the Granules and Very Coarse Sands, were nearly all composed of mollusc or barnacle shell and stones were rare. The finer grades were usually a mixture of shell and quartz particles with spicules, broken Echinoderm spines, Foraminifera etc. . Two stations are outstanding in that broken shell was entirely lacking, one (Stn. 94) consisting almost exclusively of quartz particles and the other (Stn. 237) almost exclusively of faecal pellets.

A detailed analysis of the constituents of the substratum was made by H.M.S."Challenger" which sampled "Simon's Bay" between their stations 140 and 141. No exact position is given but since the depth is noted as 20 faths. the sampling must have been outside ~~the modern~~ Simon's Bay proper. The following interesting notes are derived from the report of Murray and Renard (1891) :---

Sample : Shelly quartz sand, yellow-green when wet, greenish coloured when dry. Residue after elimination of calcium carbonate, green.

22% was Calcium carbonate:-

10% were Foraminifera (Miliolidae, Textularidae, Lagenidae, Globigerina, Rotalidae, Nummulinidae).

12% were Other Organisms. (Serpula, Gastropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa).

78% was Residue:-

70% Minerals of m.di.((? mean diameter))-- 2 mm.

Rounded/...

Rounded; quartz, felspar, augite, glauconite, mica, magnetite, hornblende.

7% Fine Washings (Amorphous matter, flocculent organic matter and minute fragments of minerals).

1% Sponge spicules.

Additional Observations. Many of the organisms ((presumably dead ones)) are macroscopic. Quartz is the principal mineral, many of the grains of which are milky and rounded, some of the largest having a diameter of 1 cm., . There is also present a quantity of amorphous flocculent clayey and organic matter, which gives a light green tinge to the deposit.

The "Challenger" sample is probably what has been described here as "Khaki sand" and the nearest sample taken by us was Stn. 316, also "khaki sand". There is excellent correspondence in the constitution of the substratum of Stn. 316 and that of the "Challenger" and one startling discrepancy in particle size since the latter gives the average diameter apparently as 2 mm. whereas the median diameter at Stn. 316 was 0•24 mm. and no particle exceeded 1 mm.. It happens that neither the "Challenger" analysis, nor that of Stn. 316, is typical of the other stations sampled by us because, usually, shelly particles far outweigh the mineral particles. Again, neither contains the most characteristic component of the sands of False Bay, namely the abundance of broken barnacle shell (Balanus) which usually is more voluminous than all other carbonaceous matter. // Most grades of six of the samples were analysed for organic carbon (non-carbonate) and the other substrata were considered to possess negligible quantities. Calculations were made to assess the percentage of organic carbon available for food and to convert this into terms of available organic matter in the substratum. Results are

given/...

given in Table III : fuller results, with discussion of the conversion factors, are given in the first paper of this thesis. Two of the substrata were found to be free of available organic carbon, a third had negligible quantities and in two others the organic carbon was only important in the silt grades. But in Stn. 237 every grade was rich and this was because each consisted of faecal pellets. It cannot be said how much of the organic carbon in this form is actually available as a foodstuff, probably very little, and so the derived figures for "available" carbon and organic matter are likely to be far too high. There seems to be a correlation between available organic matter and depth because stations shallower than 35 m. have negligible organic matter while deeper stations have appreciable quantities which increase with depth.

The only generalisation that can be drawn from these few analyses of substrata is that organic content increases with depth. The distribution of large and small particles across the bay must depend upon water currents but speculation is unwise until more facts are known. The texture analyses do not suggest that water tubulence automatically decreases as depth increases but they do suggest that there are no really strong bottom currents for no coarse gravels were found and no areas of rock laid bare by scouring.

But if generalisations are scanty the particular analyses are very valuable. Most of the bay is covered by shelly sands and the analyses showed that in them the shell was more abundant than mineral particles, and that barnacle shell was at least as common as mollusc. They found the "khaki" quality of the "khaki sands" to be due chiefly to khaki coloured silt although the shell, too, was frequently stained that colour. And they revealed the "green mud" to be composed of faecal pellets which were larger than silt

particles/...

particles (which usually dominate a mud). In addition the analyses suggest the types of bottom of the faunistic grounds to be described below and, for one very characteristic bottom-dwelling species, they give a particularly detailed idea of the bottom texture necessary for its establishment (see p.45 seq.)

The Biology of Rocky Bottoms.

Rock was met with chiefly north of a line from Simon's Bay to Gordon's Bay; also down the eastern side of False Bay. It was uncommon deeper than 40 m. but was once struck at 73 m.. The dredge often filled to overflowing with animals and to find sixty species in one haul was common: about two hundred species were taken from one station.

Although catches differed widely it is possible to sketch a typical bag. Usually the bulk consisted of chunky sponges, broken polyzoa (eg. several species of Cellepora, Chapperia, Retepora and Stomatopora), gelatinous colonial ascidians and bright sea fans (usually scarlet Lophogorgia and orange ? Gorgonia). Starfishes such as the big Marthasterias and smaller Henricia and Patiria were common enough, and the "cock robin" holothurian (Cucumaria insolens) and crinoids. The debris always included a profusion of small life, especially crustaceans such as Porcellana and Dehaanius and innumerable amphipods and isopods which had survived passage through the water within the protection of the larger species mentioned and hidden amongst epizootic hydroids and barnacles. Polychaetes were common in the debris, too. The large whelk, Argobuccinum, was often enough taken to be included with a typical bag.

Large algae were seldom present, and then only in shallow stations. Detached algae were at first suspected to be flotsam and were discarded but this is considered to have been a mistake in the light of diving experience for flotsam algae were rare and, when seen, they were unmistakably battered. It is most unfortunate that so few sponges and polyzoa/...

polyzoa can be identified because they are so very frequent on rocks. This gap in our knowledge must be borne in mind during the following pages.

There were very few stations where rocks alone had been dredged; usually soft substratum were sampled as well. It is possible to augment information on rocky bottoms by including seven stations made by diving with an aqualung. In addition there were five stations on mixed bottoms where it was felt that very much more rock was sampled than sand. A selective inclusion of data from these stations can be made by only considering species already recorded from purely rocky bottoms. The rocky stations that are considered in this section are listed in Appendix I.

In order to test the presence of vertical distribution gradients the stations have been combined into depth-range groups. Grouping was partly natural, some depths being more frequently sampled than others but other range limits were arbitrary. The resultant grouping happened to match very well with the grouping of soft-bottomed stations (discussed later) and for simplicity the figures have been rounded off to give one grouping system for the stations of rocky and soft bottoms. Reference to Appendix I will show the precise depths of rocky stations if desired. The groups adopted are : 0-5 m., 5-15 m., 15-25 m., 25-35 m., 35-50 m., 50-80 m., and >80 m..

It is not suggested that this grouping actually represents the vertical zonation of the species of the bottom. But some sort of vertical subdivision was necessary in order to see if there were vertical changes in the biota. The grouping was a matter of convenience, influenced by field experience and it does not seem to be entirely artificial for the range limits correspond strikingly to the critical and uncritical levels later calculated for the vertical distribution of 827 species of False Bay on the basis of their known, extreme ranges.

~~of each.~~ To give some idea of rocky biota and their vertical distribution the most frequent species of certain depth ranges are listed in Table IV.. No rocky stations fall into the first or last depth groups of the system explained above and for lack of ~~the~~ data two of the deep station groups are combined. Table IV. also shows the number of stations in each depth group. As explained earlier (see "Methods") very badly sampled stations are rated as "quarter-stations". In assessing the frequency with which species are found three categories are recognised, namely "Ubiquitous", "Very Common" and "Common", corresponding roughly to presence in >90%, 75-60%, and 50-40% of the dredging stations of the depth group being considered. Some species were very abundant in a few dredgings yet did not occur in enough dredgings to merit one of the frequency categories. These species are included in Table IV as "Locally very common".

Table IV lists eighty-three species, most of which are frequent in less than 25 m. depth. At deeper levels information is scanty for there were few dredgings on rock and these were not very productive, either because of a sparse fauna, or because the dredging technique was poor. The analysis of frequent species must not be taken too far on the data available and it may be noted that a typical dredge haul would look very different to what might be expected from an inspection of Table IV. It must be remembered that only those species which have been identified have been included in Table IV and that no distinction is made between large and tiny species ; the only criterian has been frequency of occurrence. On the other hand it is reasonable to assume that unidentified species would show similar distributional trends to those listed.

Depth range in metres	5-15	15-25	25-35	35-80
Number of stations	8	7¾	3¼	2
Number of frequent species found	35	60	11	13
Algae				
Sargassum heterophyllum	X	•	•	•
Brachiopoda				
Kraussina crassicostata	•	•	XX	•
Polyzoa				
Menipea crispa	•	X	X	•
Hydrozoa				
Aglaophenia pluma v. parvula	L	•	•	•
Antenella africana	L	X	•	•
Campanularia n.sp. (FB.119 L)	•	•	•	L
Clytia gracilis	•	X	•	•
Dictyocladium coactum	•	X	•	•
Eudendrium n.sp. (FAL.52 V)	•	X	•	•
Halecium beanii	•	X	•	•
- parvulum	•	X	•	•
- - n.var.(FAL.274 R)	•	X	-	XX
Hebella scandens	•	X	X	XX
Kirchenpaueria pinnata	•	X	•	•
Lytocarpus filamentosus	•	XX	•	•
Plumularia pulchella	•	X	•	•
- setacea	L	XX	•	•
Salacia articulata	•	•	X	•
Sertularella arbuscula	X	XX	XX	L
- polyzonias	•	•	X	•
Other Coelenterates				
Corynactis annulata	X	XX	•	•
Anthothoe stimpsoni	X	XX	•	•
Pseudactinia flagellifera	X	•	•	•
? Gorgonia albicans	•	XX	•	•
Lophogorgia flammea	XX	XX	•	•
Polychaeta				
Autolytus tuberculatus	X	•	•	•
Dasychone nigromaculata	•	X	•	•
- violacea	•	XX	•	•
Hydroides dipoma	•	X	•	•
Laeonereis sp. (FB.302 J)	•	XX	•	•
Lepidonotus clava v. semitecta	XXX	XXX	•	•
Lumbrinereis cavifrons	X	X	•	•
- coccinea	•	X	•	•
Nainereis laevigata	•	X	•	•
Nereis willeyi	X	•	•	•
Nicolea macrobranchia	•	X	•	•
- venustula	X	•	•	•
Paleonotus chrysolepis	•	X	•	•
Pionosyllis sp. (FAL.269 Q)	•	X	•	•
Platynereis dumerilii	X	•	•	•
Polydora hoplura	•	•	•	L
Potamilla reniformis	X	-	-	L
- torelli	•	X	•	•
Stylarioides n.sp. (FB.315 A)	•	•	•	XX
Syllis armillaris	X	XX	•	•
- prolifera v. zonata	X	X	•	•
- variegata	•	•	X	•
Terebella schmardaei	X	X	•	•

Gastropoda/...

	5-15	15-25	25-35	35-80
Gastropoda				
Argobuccinum argus	XX	XX	•	•
Burnupena puncturata	•	X	•	•
Crepidula hepatica	L	•	•	•
Pelecypoda				
Anomia ephippium	•	X	•	•
Lima rotundata	•	X	•	•
Musculus cuneatus	•	L	•	•
Mytilus crenatus	XX	XX	•	•
Saxicava ? arctica	X	•	•	•
Cirripedia				
Balanus algicola	•	L	•	•
- maxillaris	•	L	•	•
- trigonus	XXX	XX	XX	•
Amphipoda				
Amaryllis macrophthalma	•	X	•	•
Ampelisca spinimanus	•	•	•	XX
Paramoera capensis	X	•	•	•
Isopoda				
Arcturella lineata	X	•	•	•
Cirolana sulcata	•	X	•	•
- venusticauda	•	X	•	•
Lanocira capensis	•	•	•	XX
Anomura				
Eupagurus ? deprofundis	•	X	•	•
Paguristes gamianus	•	X	•	•
Porcellana streptocheles	•	XXX	X	•
Brachyura				
Dehaanius dentatus	•	XX	•	•
Ophiuroidea				
Dictenophiura anoidea	•	•	•	XX
Ophiactis carnea	XX	XX	X	XX
Ophiothrix triglochis	X	XX	XXX	XX
Asteroidea				
Henricia ornata	X	X	•	•
Marthasterias glacialis	XX	X	•	•
Patiria bellula	•	X	•	•
Echinoidea				
Parechinus angulosus (juveniles)	XXX	XX	•	•
Crinoidea				
Comanthus wahlbergi	•	X	•	•
Holothuroidea				
Cucumaria insolens	XX	XX	•	•
Pentacta doliolum	•	X	•	•
Tunicata				
Didemnum stilense	L	X	-	XX
Pyrua stolonifera	L	•	•	•
Styela costata	X	X	•	•

Table IV. The most frequently found species of rocky bottoms. Definitions of "stations" and of "frequent species" are given in the text. Symbols: XXX Ubiquitous XX Very Common X Common L Locally very common.

It will be seen that only three species in Table IV are noted as frequent over a discontinuous depth range viz. <u>Halecium parvulum n. var.</u>, <u>Potamilla reniformis</u> and <u>Didemnum stilense</u>. Probably the discontinuity is an artefact and this has been presumed in the derived Fig. 4 which shows only the depth ranges in which the species are particularly common and not their extreme ranges as is more usual with such diagrams. Fig. 4 shows that there is a distinct though small group of species that is frequent at any depth viz. <u>Sertularella arbuscula</u>, <u>Ophiactis carnea</u>, <u>Ophiothrix triglochis</u> and probably <u>Potamilla reniformis</u> and <u>Didemnum stilense</u>. Other species are seldom frequent over great ranges and the only large overlap of species occurs between 5 and 25 m.. It might seem unjustifiable to divide this range but for the remarkable number of species that are frequent only in its upper, or in its lower half, a feature that is not readily accountable . A fairly distinct group of species characterises the range 35-80 m. (and possibly deeper).

Fig. 4 shows that as depth increases different species become frequent ; in other words a vertical distribution pattern clearly exists so far as the frequent species are concerned. In the final discussion to this paper it will be shown that a similar pattern also exists when the extreme ranges of these species are considered as distinct from their optimal ranges.

Table IV gives some impression of the commonest biota of the deeper infratidal rocks and Fig. 4 shows their vertical distribution. The vertical distribution pattern is on a vastly larger scale to that of the intertidal region and shows considerable blurring so that there is no stratification of zones dominated by different animals.

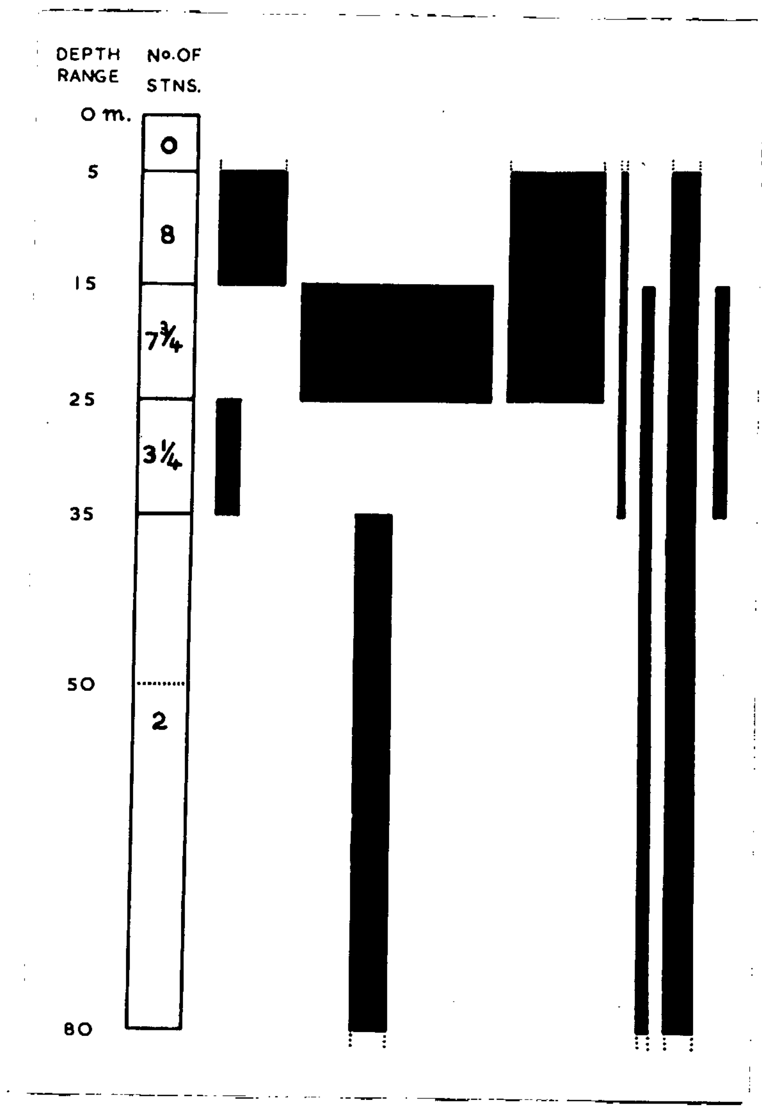


Figure 4. Vertical distribution groups of the most frequently found species of rocky bottoms and the number of stations made in each depth range.

Based on Table IV.

The breadth of each block is proportional to the number of species represented.

Blocks are extended with dots above 5 m. and below 80 m. because no dredgings were made shallower or deeper.

The depth ranges 35-50 m., and 50-80 m. are amalgamated because of scarcity of stations.

Remembering that only the optimal depth ranges have been considered and that the paucity of stations exaggerates the discontinuity of the biotas of adjacent depth groups then the changes in biota with increasing depth must be very gradual. Even so Fig. 4 suggests that there are particularly critical depths at about 15 m., 25 m. and possibly 35 m. . A lot more could be said here on the distribution of rocky species but it is more profitable to make the comments in conjunction with soft bottomed species and this is done at considerable length in the final discussion of this paper.

There are two chief drawbacks to the rocky work namely the difficulty of finding deep rocky stations and the poor sampling efficiency of dredging. Aqualung diving is the best method for sampling shallow rocks but diving alone is dangerous deeper than 25 m. and even with a team it is unwise to dive deeper than 40 m. without elaborate preparation(Rebikoff 1955). Beyond these limits dredging must suffice for the average biologist. Yet we may interpret the deepest dredgings in terms of experience in shallower diving. Part II has shown that diving in False Bay to 17 m. reveals a bewildering mosaic of communities each often of small area but repeated elsewhere. It is clear than some of these communities are regulated by such environmental features as illumination or sedimentation and it has been remarked that different aspects of rocks often show different and characteristic biotas eg. under overhangs, in crevices, in caves. In considering the dredging results one can reasonably assume two things ; first that the dredge only samples the tops of reefs and so avoids overhangs and crevices with their specialised faunas : and second that the mosaics will be sampled at random, the dredge gathering a jumble of components depending on which way it bounced and unlikely to be qualitatively or quantitatively representative of the biota. A long dredging on rock might be representative

but/...

but lengthy ones are rare. On the other hand the suggestion has been made in Part II that patchiness in the biota might tend to disappear with increasing depth and if this were true then the deeper samples , poor though they are, would represent the fauna of the crevices there as well as of the open faces whilst the shallower samples would be from open faces only. This can only be proved by deep diving.

The Biology of Soft Bottoms.

This section deals with purely soft bottoms and stations of mixed rock and soft substratum are ignored.

Soft bottoms quite obviously cover most of the bay but on the northern and eastern sides there are so many rocky outcrops that it is unusual to sample soft substratum only. On the other hand most of Simon's Bay is free from rocks and purely soft bottoms were often sampled ~~both in this locality~~ there and outwards towards the deepest parts of False Bay. The types of soft substratum have been differently and sometimes ambiguously described by different field-collectors. More recently samples have been kept and their analyses are given above and cover most of the suspected textures. Very coarse, gravelly substratum ~~which~~ was suspected a few times but no sample of it was obtained and the suspicion of its presence might have been wrong. Data of the stations considered are given in Appendix II.

Diving Observations.

Direct underwater observation is so unequivocal that the brief notes made on soft bottoms are given to assist

interpretation/...

interpretation of dredging results.

(1) Gordon's Bay. Depth 1½ - 3 m.

This station is well sheltered from the swell in almost any weather. Clean, hard-packed, brown sand with ripple-marks. Surface sample by cone sampler, Stn. 94 : Median diameter 175 microns (grade "Fine Sand"); excellently sorted ; particles almost all mineral, shell almost entirely absent ; available organic matter 0·01%.

No surface fauna was visible but there were quite a lot of holes (ca. one per sq. m.), probably those of bivalves. The bottom was not sampled by hand but dredging trials observed by diving were conducted here and the experimental dredge was seen to dig 2 to 4 inches. Thus, for fairly large species, the bottom was better sampled than by hand. The catch included 12 different species, none of which was common. There were two small soles(*Trulla capensis*), two gastropods(*Bullia annulata*) and two bivalves(*Tivela compressa*), but other species were singly represented ie. *Bullia digitalis*, *Philine*, *Tellina madagascariensis* and *T. triangularis* (the only records of these two bivalves in False Bay), the polychaetes *Audouinia tentaculata* and *Nepthys capensis*, and the hermit crabs *Diogenes costatus* and *D. brevirostris*.

(11) Simon's Bay (northern end). Depth 3 - 5 m..

This station receives only slight protection from swell. In appearance it was similar to much of the shallow sandy infratidal of the western shore of False Bay. Hard-packed, whitish, coarse shelly sand with ripple marks. Clean (ie. no silt). (No sample).

The bottom appeared to have no surface fauna. The bottom was not sampled by hand but an experimental dredge was observed by diving. The dredge penetrated 4 to 6 inches and caught eight species chief of which were a dozen *Philine* and three crabs (*Ovalipes punctatus*) both species clearly from the top inch of sand.

Probably/...

Probably the same can be said of Bullia laevissima (5), B. annulata (3) and a fragment of Nephthys sp. but one Mactra glabrata was caught and this may be representative of a deeper layer. The hydroid, Leuckartiara octona, was epizootic on B. annulata.

(111) Oatland Point : The Channel. Depth 4 - $5\frac{1}{2}$ m..

Coarse, shelly sand. (No sample).

The only organism evident was the green alga Caulerpa filiformis which grew in small but luxuriant beds genuinely anchored in the sand and not attached to rocks beneath, although stones and rocks were nearby. Amongst it Cucumaria insolens was common. Flitting over the sand were many elusive, brown-mottled Gobies. There were no conspicuous holes in the sand.

(1V) Oatland Point : 80 m. east of Big Rock. Depth 10 - 11 m..

Clean, very coarse, shelly sand swept into ripples of approximately 0·6 m. wavelength and 0·15 m. amplitude, running roughly S.W. to N.E., ie. normal to the usual south-easterly swell. (No sample).

No nearby reefs, rocks or stones. Bottom imperceptibly sloping.

An interesting area about 30 X 30 m. was leisurely examined. Patches of Caulerpa filiformis were conspicuous. The distribution suggested that in spite of the negligible slope, this was the lower limit of this alga. The plants were healthy but not luxuriant (November). The hydroid Campanularia integra were abundant on Caulerpa but otherwise the visible animals seemed evenly distributed and independent of the presence or absence of the alga. Numbers of Philine aperta were half buried in the sand while the hermit, Paguristes gamianus and tubes of Diopatra neapolitana were common. A notable find at this depth was one Astropecten irregularis which is most uncommon above 15 m. . The species mentioned are typical of sandy bottoms, though not

necessarily/...

encrustations were common on old shells. Other species represented many groups : scraps of algae (eg. Plocamium ? membranaceum) sea-pens of the Virgularia type; Nemertines (Cerebratulus, Zygonemertes); many polychaetes, amphipods and isopods; several small cumaceans, gastropods, pelecypods, and brittle-stars etc.. Gibbula rosea and Marginella zonata were characteristic little species, the latter not recorded elsewhere in False Bay. Indeed this station provided several notable additions to our collections particularly the polychaetes Dorvillea egena and Kefersteinia cirrata (the latter a new South African record), the asteroid Patiria formosa and several new species of Amphipods and Isopods. It is felt that these comparatively rich results in an unpromising looking place are due to collection by diving as distinct from dredging for most of the species would have been washed out of the dredge bag.

(V1) About 40 m. north of Noah's Ark (Simon's Bay)

Depth 14 m..

Shelly sand mixed with white mud. Old Mytilus valves and clumps of large, empty barnacle shells (B. maxillaris). No ripple- marks. This type of substratum was not seen elsewhere. A possible explanation of the "white mud" is that it is due to guano on Noah's Ark. (No sample).

The most striking feature was the number and variety of asteroids and, to a lesser degree, of ophiuroids. Large Marthasterias were abundant; Astropecten and Patiria bellula were common. The commonest brittle-star was Amphiura incana but Ophionereis and Ophiothrix were scarcely less so. Argobuccinum argus was another common large animal. There were also sea-pens (? Actinoptilum, and ? Virgularia), elusive cerianthid anemones and many muddy

tubes/...

tubes of Sabella pavonina. Seven other polychaetes were found, one of which, Lumbrinereis cavifrons, inhabited a sandy pocket in the folds of a cerianthid tube. The only record of the large gastropod, Clavus taxus, is from this station. All told there were some thirty species, but not one amphipod or isopod which is rather surprising.

(V11) Fish Hoek Bay. Depth 17 m.

Clean, white sand sculptured into hummocks and ridges about 0·15 m. high and not arranged in regular order but seemingly dependent upon the biota. There were no stones or rocks. Sampled by cone-sampler, Stn. 318: med. diam. 340 microns ("Medium Sand"); excellently sorted; mostly quartz sand, very little broken shell; organic matter apparently negligible.

This bottom supported a surprising abundance of visible species, more than any other soft bottom examined by diving. Scattered pods of the giant colonial tunicate Pyura were most conspicuous, a rough estimate would be one pod per 16 sq.m.. Most pods were a little smaller than a football and comprised a dozen or more individuals each much smaller than those of rock-attached colonies. The pods examined were not anchored in the sand by a stolon as occurs in the quiet waters of Langebaan Lagoon but were free to roll with the current. The pods weigh little underwater and the fact that their individuals were arranged radially suggests that rolling is frequent. Many animals and some plants were anchored in the sand. Red crinoids (Annametra) were very common and in a few places there were dense populations covering several square metres. These patches were often partially buried in sandy hummocks but it is uncertain whether the hummocks were due to accumulation

of/...

of sand amongst the crinoids or whether these animals occupied hillocks by preference and then dug themselves in. Next in abundance were the muddy tubes of Sabella pavonina, projecting six to eight inches above the sand, and also many tubes of Diopatra neapolitana although these were patchily distributed. A brown alga (?Dictyota) was fairly common but the other small species were in very small numbers or epiphytic. The tectibranch Philine which is so frequently found on sandy bottoms appeared to be absent and its place was taken by another, a sloppy, rather translucent species of similar size (possibly Aglaija sp.): this was fairly common. There were quite a number of bluish, usually speckled anemones "rooted" in the sand and not attached to subsurface stones. These were at first taken to be cerianthids but tubes were absent and they appear to be Anthostella or Bunodosoma. The only other surface species were many small Diogenes costatus and a few big Marthasterias.

Small epibiota were common on Pyura and projecting Sabellid tubes. On the tunicate were small, Terebellid polychaetes, (Nicolea macrobranchia and Lanice wollebacki), Balanus trigonus and motile species such as Porcellana, various isopods (particularly Synidotea hirtipes) and a new tanaid (Apseudes n. sp. FAL. 320 G). The Sabellid tubes supported small red and green algae.

Altogether forty-one species were found. Apart from those mentioned there were small numbers of soft-bottomed species such as the crabs Hymenosoma and Philyra, the brittle-star Amphiura incana, and a gastropod, probably Solariella dilecta.

(V111) Approx. 34°09·6'S/18°27·4'E Depth 26 m.

Khaki sand, level, no ripple-marks. Sampled by hand and also by cone-sampler for comparison of methods, samples designated Stns. 315 and 317 respectively : med. diam. 290-300 microns ("Medium Sand") ; well sorted ;

markedly/...

markedly more mineral than calcareous matter (the latter mostly shell but including twiggy, ? Lithothamnion, polyzoa, Foraminifera and ostracods); if fragments of worm tubes are disregarded then the available organic matter was negligible. At first sight the sandy bottom appeared bare apart from small tufts of algae, probably Ulva and Aodes. However numerous large Philine , a few crinoids (Annametra) and an occasional Astropecten were found half-buried in the sand. The numerous polychaete tubes lying on the surface proved to be empty but sieving showed that many small species such as Lumbrinereis albidentata , Heterocirrus capensis and Amphicteis gunneri were burrowing in the substratum. In all twenty-five species were taken, mostly small polychaetes as mentioned and amphipods of which the commonest were Ampelisca spinimanus and Tryphosa normalis. Soft-bottom molluscs were represented by a juvenile Marginella and a pink Tellina ? tulipa.

Dredging Results.

Dredge catches on soft-bottoms were never as rich as hauls over rock. Appendix II shows that thirty species is about the average catch per station although some bottoms appeared to be almost barren and others comparatively rich. Some idea of the appearance of dredge catches from different substrata may be gained from notes on the different grounds described later.

(1) The General Distribution of the Commonest Species.

A very fair impression can be given of the most commonly found species of the bay by an analysis similar to that already given for rocks and presented in Table IV and Fig. 4. All soft-bottom stations have been considered as full ones and it has not been necessary to augment the data by selective inclusion of records from mixed hard and soft bottoms. Species of great local abundance have not been included because this aspect of distribution will be dealt with later. The depth ranges adopted were discussed in connection with Table IV.

Before considering the analysis it must be mentioned that it over-stresses the importance of depth. The conditions that determine the distribution of species are, in general, correlated with depth but depth alone has little or no significance. This brief analysis is included for comparison with the similar treatment of rocky species but the comparison is made in the final discussion to this paper and not in this section. The apparent over-emphasis on depth is counteracted in the following section.

The most frequently found species of soft bottoms number sixty-seven as listed in Table V but certainly a dozen of these are more typical of hard substrata than of soft, eg. Balanus trigonus and Anomia ephippium which occur on empty shells. Such species are bracketted in Table V because they are not typical of soft bottoms although frequently present. A different group of species is equally typical of hard and of soft bottoms as can be seen from comparison with Table IV and the diving notes. These species are marked with asterisks in Table V. Although they are so common on rocks it would be an error to omit them from a discussion on soft substrata. The vertical distribution of the species in Table V is summarised in Figure 5 save only that the non-typical, bracketted species are omitted. Fortunately sponges and polyzoa are unimportant on these soft bottoms and so their omission does not affect the general picture.

Depth range in metres	0-5	5-15	15-25	25-35	35-50	50-80	>80
Number of stations	3	9	14	8	6	5	2
Number of frequent species found	3	13	20	6	25	21	11
Polyzoa							
(Menipea crispa)	•	•	•	•	X	•	•
(- triseriata)	•	•	•	•	XX	•	•
Hydrozoa							
Aglaophenia pluma (3 var. but chiefly dichotoma)	•	•	X	•	•	•	•
(Antennopsis scotiae)	•	•	•	•	X	•	•
(Campanularia integra)	•	X	•	•	•	•	•
Other Coelenterates							
Epizoanthus similis	•	•	•	•	•	XXX	•
Pennatulid (FAL.237 C)	•	•	•	•	•	•	XX
Nemertea							
Cerebratulus sp. (FAL.51 V)	•	•	•	•	X	XX	X
Polychaeta							
Diopatra neapolitana	•	XX	X	•	•	•	•
Drilonereis n.sp.(FAL.237 D)	•	•	•	•	•	•	XX
Glycera convoluta	•	•	•	•	X	X	•
Goniada sp. (FAL.240 K)	•	•	•	•	•	•	XX
(Lepidonotus clava v. semitecta)	•	XX	•	•	•	•	•
Lumbrinereis albidentata	•	•	•	•	•	XX	XXX
Nephthys capensis	X	•	•	•	•	•	•
(Nereis operta)	•	X	•	•	•	•	•
Onuphis emerita	•	•	•	•	•	X	•
Onuphid (FAL.237 H)	•	•	•	•	•	•	XX
Orbinia angrapequensis	•	•	•	•	•	•	XX
Phyllochaetopterus socialis	•	•	•	X	X	•	•
(Platynereis dumerilii)	•	•	X	•	•	•	•
Prionospio pinnata	•	•	•	•	•	•	XXX
Sabella pavonina	•	•	•	•	•	XXX	•
Sthenelais limicola	•	•	•	•	•	XX	•
Travisia forbesii	•	•	•	•	•	X	•
Gastropoda							
Ancilla cf. errorum	•	•	•	•	X	XX	•
- fasciata	•	•	•	•	•	XX	•
Bullia annulata	X	—	X	•	•	•	•
- laevissima	•	•	X	•	•	•	•
Hinia speciosa	•	•	XX	—	X	•	•
Philine aperta	X	X	XXX	XX	•	•	•
Solariella cogener	•	•	•	•	•	X	•
Turritella sanguinea	•	•	•	•	XX	•	•
Pelecypoda							
(Anomia ephippium)	•	•	•	•	XXX	•	•
Dosinia pubescens	•	•	•	•	•	•	XXX
Tellina ? tulipa	•	•	•	•	•	•	XX
Cirripedia							
(Balanus trigonus)	•	•	XX	•	•	•	•
Amphipoda							
Ampelisca brevicornis	•	•	•	•	•	X	•
(Paramoera capensis)	•	•	X	•	•	•	•
Photis uncinata	•	•	•	•	X	XX	•
Tryphosa n.sp. (FAL.185 D)	•	•	•	•	•	XX	•

Isopoda/...

(ctd.)	0-5	5-15	15-25	25-35	35-50	50-80	>80
Isopoda							
Synidotea hirtipes	•	•	XX	•	•	•	•
Anomura							
Anapagurus hendersoni	•	•	X	-	X	XX	•
Diogenes costatus	•	•	•	•	X	X	•
- extricatus	•	X	X	•	•	•	•
Eupagurus placens	•	•	•	•	X	X	•
Galathea intermedia	•	•	•	•	X	•	•
*Porcellana streptocheles	•	XX	XX	-	X	•	•
Brachyura							
*Dehaanius dentatus	•	XX	-	X	•	•	•
Goneplax angulata	•	•	•	•	•	•	XX
Hymenosoma orbiculare	•	•	XXX	XX	X	•	•
(Macropodia rostrata)	•	X	•	•	•	•	•
Mursia cristimanus	•	•	•	•	XX	•	•
Philyra punctata	•	•	XX	•	•	•	•
Ophiuroidea							
Amphiura incana	•	X	XX	•	•	•	•
- simonsi	•	•	•	•	X	•	•
*Dictenophiura anoidea	•	•	•	•	X	•	•
Ophiocten amitinum	•	•	•	•	X	XX	•
*Ophiothrix triglochis	•	•	•	•	X	•	•
Asteroidea							
Astropecten irregularis v. pontoporaeus	•	XX	X	XXX	XXX	XXX	•
Luidia africana	•	•	•	•	•	XX	•
*Marthasterias glacialis forma rarispina	•	XX	XX	XX	XX	•	•
Echinoidea							
Spatangus capensis	•	•	•	•	•	XXX	•
Crinoidea							
*Annametra occidentalis	•	X	•	-	•	•	•
Cephalochorda							
Branchiostoma capense	•	•	•	•	XX	•	•
Pisces							
(Chorisochismus dentex)	•	•	X	•	•	•	•
Heteromycteris capensis	•	•	XX	•	•	•	•

Table V. The most frequently found species of soft bottoms.

Species marked with an asterisk are typical of soft bottoms but are also common on rocks. Species in brackets are more typical of rocks than of purely soft bottoms. (Conventions as in Table IV).

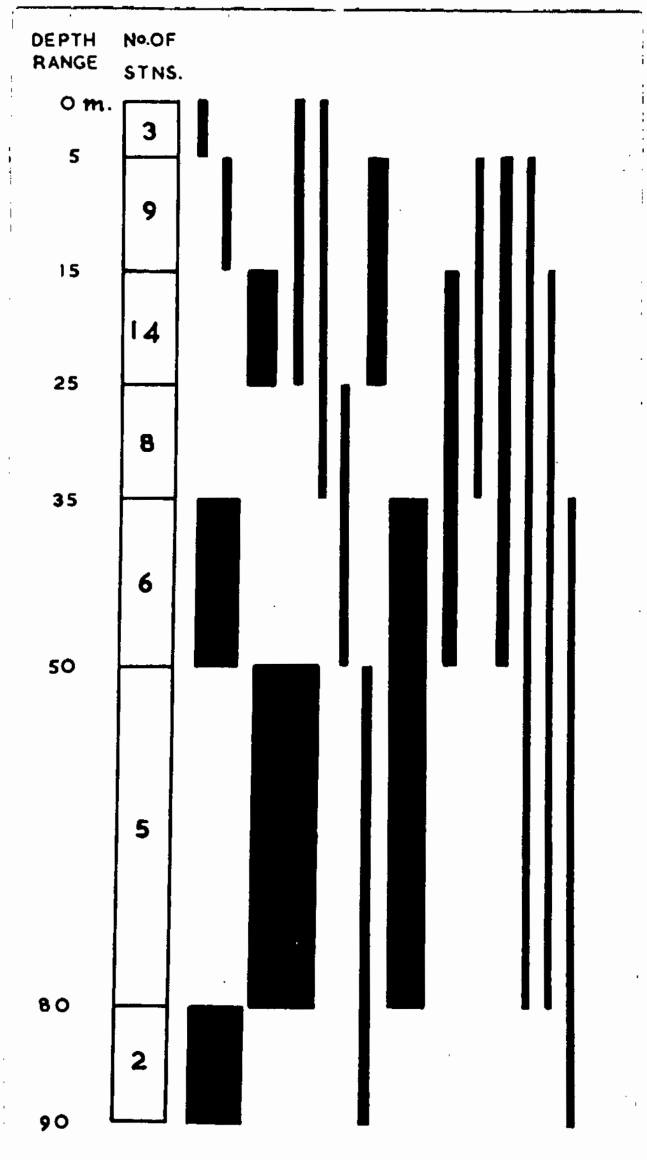


Figure 5. Vertical distribution groups of the most frequently found, typical species of soft bottoms and the number of stations made in each depth range.

Based on Table V.

The breadth of each block is proportional to the number of species represented.

[illegible]

The most distinctive groups of species lie between 50 and 80 m., and below 80 m. Overlap is negligible between the two groups. The next section shows these groups to correspond to different grounds with characteristically different substrata. There is a marked group of species from 35 to 80 m. but at shallower depths grouping becomes indistinct. No species remains frequent throughout the depth of False Bay and only a few are frequent over great ranges. The most notable of these are the starfishes Astropecten (5 to 80 m.) and Marthasterias (5 to 50 m.), the anomurans Porcellana (5 to 50 m.) and Anapagurus (15 to 80 m.) and the nemertine Cerebratulus (35 to at least 90 m.).

Fig. 5 suggests that the shallowest range, (0 to 5 m.), has few frequent species. In actual fact the range is particularly barren of life as revealed by the diving notes and so the absence from Fig. 5 of a distinctive group of species in that range is significant. Below this shallowest range there are more species and Fig. 5 shows that the biota of the depth ranges becomes increasingly well characterised as depth increases. ~~The lack of distinctive groups of species in the shallower ranges m ay be due to depth being less important than other factors such as turbulence and bottom texture which are likely to vary considerably from place to place.~~

(11) The Recognition of Grounds.

The concept of grounds is well established and there is strong evidence that they are present in False Bay. Different dredge hauls from similar depths and in the same general locality sometimes produced strikingly different catches. For example three stations at 24 to 29 m., north of Roman Rock, were not more than 1 1/4 miles apart yet each was characterised by an organism in large numbers which was virtually absent from the others. Moreover the number of species shared by any two stations was very small (see Table VI).

	34°10'S /18°27¾'E	34°10¼'S /18°27¾'E	34°09½'S /18°28¼'E
	24 m.	26 - 29 m.	26 - 27 m.
Number of Spp.	28	19	17
No. of Spp. shared	(------- 3 ------)		(----- 5 -------)
	(--------------- I --------------)		
	(I--->		<----I)
Characteristic Sp.	Twiggy Lithothamnion	Chaetopterus varieopedatus	Ampelisca spinimanus
Common Sp.	Hymenosoma orbiculare	Balanus trigonus	Amphiura incana.

Table VI. Distribution of species between three nearby Stations.

In reviewing the possibility of grounds the author is handicapped by insufficient stations and the lack of opportunity for sampling with recent gear areas worked by others in the early days. There seems good evidence for seven grounds. Hydrological data are derived from Table I and from Marchand (1932). Reference should be made to the map, Fig. 2.

(a) The Fish Hoek / Glencairn Ground.

Many stations from Fish Hoek Bay to south of Glencairn; an inshore strip some 2½ miles long. Possibly extending further northwards to Muizenberg (see ~~Notes~~ below).

Depth : 7 - 23 m.

Hydrology : probably 13 - 18°C and 35·03 - 35·56‰ .

Substratum : clean, white sand, irregularly hummocked and ridged.

Sample/...

Sample, Stn.318: med. diam. 340 microns ("Medium Sand") ; excellently sorted; mostly quartz sand, very little broken shell; organic matter seemingly negligible.

Characterised by : a rich biota including many algae and loose "footballs" of the giant tinucate, *Pyura stolonifera*.

Associated Spp.: the starfish *Marthasterias* was widespread in small numbers. Almost as frequent were : *Diopatra neapolitana;* the tectibranch *Philine*; the gastropods *Hinia speciosa* and *Bullia laevissima*; the large isopod *Synidotea hirtipes*; the small crabs *Dehaanius*, *Hymenosoma*, *Macropodia rostrata* and *Philyra*; the anomuran *Porcellana*, the crinoid *Annametra* and the starfish *Astropecten*.

Total Spp.: at least 170.

Notes : the diving observations for Fish Hoek Bay (pp.31-32) are entirely relevant and should be referred to. Because early dredgings yielded quantities of algae(eg. *Ulva*) and loose *Pyura* this area was called the "flotsam" ground. On the other hand diving (April 1955) showed no flotsam to be present except for *Pyura* : possibly the presence of algae is seasonal. Otherwise dredging and diving results tally well and the existence of this ground is well established. *Pyura* was absent from one station and seemed to be less common off Glencairn than in Fish Hoek Bay. The multitude of species is largely due to epibiosis upon such attractive supports as *Pyura* and algae, the epibionts in turn sheltering small worms and crustacea. Common epizoonts were the hydroids *Campanularia integra* and *Antennularia cymodocea* and several small polyzoa and polychaeta. Small, crevice-loving species were chiefly isopods (eg. *Leptanthura laevigata*, *Cirolana sulcata*, and *Arcturella corniger*) and amphipods (eg. *Amaryllis macrophthalma*, *Aora typica*, *Ampithoe ramondi*, *Lysianassa variegata*, *Microlysias xenokeras*, and *Paramoera capensis*) but juvenile

Parechinus/...

Parechinus and the bright, little holothurians Cucumaria insolens were often found.

It is known that fishermen used to drag grapnels for Pyura ("Redbait") not only in Fish Hoek Bay but in the Muizenberg corner and so this ground probably extends northwards to Muizenberg. Much less Pyura has been obtained recently, presumably due to intensive collecting.

(b) Twiggy "Lithothamnion" Ground.

Two stations between 34°09½'-10'S and 18°27'-27¾'E. Also found at 34°11'S 18°27¼'E.

The first two stations about 1 mile apart and the last (less distinctive) over a mile to the south.

Depth: 15 - 26 m..

Hydrology: probably 13-18°C and 35·03-35‰

Substratum: no samples were taken with the dredgings and the notes say merely "sand and twiggy Lithothamnion fragments". Recently attempts were made to sample the substratum but exploration with a tallowed sounding lead revealed only traces of the " twiggy Lithothamnion". Samples were taken by diving and by cones midway between the two northern stations. Samples, Stns. 315 and 317: med. diam. 290-300 microns ("Medium Sand") ; well sorted; markedly more mineral matter than calcareous; negligible available organic matter. Of course, if the coralline had been abundant it would have markedly affected the mechanical analysis.

Characterised by: abundance of a twiggy, Lithothamnion-type, unjointed coralline. It could not be said whether this was living or dead.

Associated Spp.: the commonest were Philine and to a lesser degree, the starfishes Astropecten and Marthasterias.

Also/...

Also frequent were the polychaete Nicolea macrobranchia, Hymenosoma, Amphiura incana and crinoids (Annametra and Comanthus wahlbergi).

Total Spp. : at least 90.

Notes : the stations were dredged in April 1947 and February 1953. Certainly the two early dredgings were very characteristic yet when the bottom was observed by diving in April 1955 (see diving observations at "Approx. 34°09·6'S / 18°27·4'E", p.32) Lithothamnion was scarcely present. It seems that the coralline had disintergrated, been covered by sand, or been swept elsewhere. In fact, this"ground" was valid in 1947 but no longer is so. The two early northern stations were strikingly similar quite apart from the coralline found at both. The biota of the southern station did not correspond so well and possibly the coralline found there had been transferred from the northern stations in the intervening six years.

In general the species found were those of sandy bottoms in this region excepting the species typifying the different grounds. For example Pyura was absent and Ampelisca spinimanus and Diopatra neapolitana were scarcely present. On the other hand the southern station had abundant Chaetopterus and is regarded as marginal with the Chaetopterus ground.

(c) Chaetopterus Ground.

One Stn. at 34°10¼'S /18°27¾'E. Also found 1 mile to S.W. at 34°11'S /18°27½'E.

Depth: 23 - 29 m.

Hydrology: probably 13-18°C and 35·03-35·30‰.

Substratum: of first stn. "sand"; of second "coarse sand (? muddy) and twiggy ? Lithothamnion". No sample.

Characterised by : abundance of the tubicolous polychaete, Chaetopterus varieopedatus.

Associated/...

Associated Spp.: ? Spiochaetopterus, Philine, Hymenosoma. Amphiura incana.

Total Spp. : 21 in the first station (see "Notes" below).

Notes : the second station is regarded as marginal with the Twiggy "Lithothamnion" Ground and has been mentioned under that head. Regarding the first station too little is known for many notes but Astropecten was common there and not surprisingly, the little barnacle, Balanus trigonus. A few crabs (Pseudodromia latens) were found at both stations and the only other records of this in False Bay are from nearby. Chaetopterus is by no means exclusively a species of soft bottoms; there are more records of it from rock in False Bay than from soft bottoms but it may be too deeply buried in the latter for the dredges to reach.

(d) Ampelisca spinimanus Ground.

Three Stns. between 34°09' - 10'S / 18°27·9' - 29·5'E, an oblong area about 2 miles long.

Depth: 22 - 31 m.

Hydrology: probably 13-18°C and 35·03-35·30‰.

Substratum: fine sand, clean and white at the shallowest station, khaki in the sample taken from 31 m. recently. Sample Stn. 316; med. diam. 240 microns ("Fine Sand"); well sorted; mostly quartz, only a little broken shell; available organic matter probably negligible.

Characterised by: abundance of the sandy tubes of the amphipod, Ampelisca spinimanus.

Associated Spp.: Philine, the isopod Leptanthura laevigata, two other amphipods Lysianassa variegata and Tryphosa onconotus, Hymenosoma, Astropecten and the small holothurian Taeniogyrus dayi.

Total Spp.: 67.

Notes :/...

Notes: the stations were made in January 1947 and April 1948. The substratum sample was obtained in April 1955, when a few amphipods were extracted including six Ampelisca spinimanus, but the only tubes present were not the sandy tubes of Ampelisca but the muddy tubes of a polychaete (? Fabricia capensis) which were numerous. Had the ground changed over the years ? Re-dredging this area was impossible and so the present status of this ground is uncertain.

At two stations Amphiura incana was plentiful and, to a lesser extent, Marthasterias, small cephalopods (?Sepiola, FB.1004) and the scaleworm, Lepidonotus clava v. semitecta. Diopatra was only common at the shallowest station. The substratum sample contained one specimen of Philine and twelve species of tiny polychaetes of which juvenile Lumbrinereis albindentata were the commonest apart from ? Fabricia.

(e) Diopatra neapolitana Ground.

Most of the north-western and northern parts of False Bay, an area of some 120 sq. miles (see Fig. 2)

Depth: 10 - 40 m.

Hydrology: probably 13-18°C and 35·03-35·55‰ .

Substratum: usually coarse sands containing much broken shell. Samples Stns. 209, 217, 222, 283; med. diam. vary variable, 1400-440 microns ("Very Coarse" to "Medium Sands"); mostly well sorted(quartile spread of 0·6 to 1·8) and either not skewed or negatively skewed (max. -0·2); at least 75% of each sample consisted of "Medium Sand" or coarser grades; there appears to be negligible fine matter (combined "Very Fine Sand" and "Silt" comprise less than 3%); more than half the particles are shelly (much Balanus shell as well as mollusc). Negligible available organic matter. The substratum is discussed below.

Characterised/...

Characterised by: tubes of the polychaete _Diopatra neapolitana_.

Associated Spp.: these are numerous and are listed in Table VII with indications of their vertical distribution. The largest and most conspicuous are probably _Aglaophenia_, _Philine_, _Astropecten_ and _Marthasterias_.

Total Spp.: around two or three hundred. Precise calculation is not worthwhile until the ground is better defined.

Notes: the tubes in the dredges were truncated and usually empty. Their freshness suggested the presence of living worms. Error is more likely to arise from omitting records of empty tubes than from considering them as indicating living animals. It is not suggested that _D. neapolitana_ densely populates all this area but it is the most characteristic, sessile species. It is particularly abundant between 10 and 20 m. depth although absent from some stations eg. Stn. 211 at 22 m.. _Diopatra_ was uncommon deeper than 40 m. but a few tubes were found around 61 m. and the deepest local record is 86 m.. Distribution must be closely connected with substratum characteristics since they affect larval settlement and tube formation and in fact comparison of distribution with substratum analyses is very suggestive. _Diopatra_ tubes are easily dredged and so their absence from a station is not likely to be due to poor sampling. It is found that of the six coarsest substrata (reading along the medians) represented in Fig. 3 _Diopatra_ is characteristic of all but Stn. 211 where it is absent. It is absent from all the finer substrata. A coarse-textured substratum appears to be necessary for _Diopatra_; the median diameter may apparently range widely provided it is greater than 340 microns. Stn. 211 complies with these

Depth in metres	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40
<u>Hydrozoa</u>						
Aglaophenia pluma v. dichotoma		XX	XX	XX	XX	
<u>Polychaeta</u>						
? Spiochaetopterus typicus	XX	----	----	----	----	XX
Platynereis dumerilii	XX					
<u>Gastropoda</u>						
Bullia annulata		X	X	----	----	X
- laevissima		XX	XX			
Hinia speciosa		X	X			
Philine aperta	XX	XX	XX	----	----	XX
<u>Cirripedia</u>						
Balanus trigonus		X	X			
<u>Amphipoda</u>						
Amaryllis macrophthalma	XX	X				
Aora typica	XX					
Ampelisca spinimanus			X	X	X	X
Caprella equilibra	X	X	X	X	X	
Corophium triaenonyx	XX					
Lysianassa variegata	X	X	X	X	X	X
Microlysias xenokeras	XX	X				
Paramoera capensis	XX	X	X			
<u>Isopoda</u>						
Cirolana sulcata	X	X				
Synidotea hirtipes	XX	XX	X	X	X	X
<u>Anomura</u>						
Anapagurus hendersoni		XX	XX			
Diogenes extricatus		X	X	X		
Porcellana streptocheles		XX	XX			
<u>Brachyura</u>						
Hymenosoma orbiculare		X	X			
Philyra punctata		X	X			
<u>Ophiuroidea</u>						
Amphiura incana		X	X	XX	XX	
Astrocladus euryale				X	X	
Dictenophiura anoidea						XX
Ophionereis dubia	XX					
<u>Asteroidea</u>						
Astropecten irregularis v. pontoporaeus	X	X	X	X	X	XX
Marthasterias glacialis forma rarispina	XX	X	XX	XX	XX	
<u>Cephalochorda</u>						
Branchiostoma capense				XX	XX	
<u>Pisces</u>						
Heteromycteris capensis		XX	XX			

<u>Table VII.</u> <u>The commonest species of the Diopatra neapolitana Ground.</u> (Conventions as in Table IV).

specifications but Diopatra is absent and this may be due to the excessive presence of "Very Fine Sand - plus - Silt" at the expense of "Medium Sand" as shown by the skewness of the curve. This suggestion is rather corroborated when the small-particle end of the scale in Fig. 3 is looked at for it is clear that Diopatra is only found where small particles comprise less than 25%; and none of the five Diopatra stations possesses more than 3% of particles smaller than 125 microns. The inference is that silt and fine sands, or the associated environmental features, are unfavourable to this species. So far as large particles are concerned there is much variation in the substrata supporting Diopatra. The worm uses shell at the top of its tube, pieces at least as big as "Granules", but evidently it can collect sufficient even when very few are available for "Granules" comprise tiny percentages of Stns. 209 and 318. A final deduction can be made from Figure 3 : comparing the curves suggest that "Medium Sand" is chiefly used for tube-building for this is the only grade common at all the Diopatra stations.

Stn. 318 is assigned to the distinctive Fish Hoek / Glencairn Ground which thus appears to be a modified Diopatra neapolitana Ground. But the other grounds described from the north-west of False Bay virtually lack Diopatra. The Twiggy "Lithothamnion" Ground is represented by analyses for Stns. 315 and 317 and the Ampelisca spinimanus Ground by Stn. 316. These analyses suggest that the absence of Diopatra from these grounds is due to excessive small particles (grades finer than "Fine Sand") for there is ample of the seemingly essential "Medium Sand".

Only five species of the thirty-one listed as common associates of this ground are anchored to the substratum. The most conspicuous is the large hydroid Aglaophenia which

is/...

is a feature of the bottom off Kalk Bay and Muizenberg, and also at Stn. 209. The tubicolous amphipod Ampelisca spinimanus is common at a station about 2½ miles east of the A. spinimanus Ground as shown in Fig. 2 which suggests that the station is marginal between the two grounds and that there is no sharp boundary. A. spinimanus occurs elsewhere in the D. neapolitana ground in insignificant quantity.

Many of the motile species are frequently found over this depth range on soft bottoms as can be seen by comparing Table VII with Table V; eg. the gastropods Bullia, Hinia and Philine ; the hermits Anapagurus and Diogenes extricatus; Porcellana; the crabs Hymenosoma and Philyra; the brittle-stars Amphiura incana and Dictenophiura ; the starfishes Astropecten and Marthasterias; the lancelet Branchiostoma and the sole Heteromycteris. This is not surprising since the D. neapolitana Ground comprises so great a proportion of the soft bottoms. The lancelet is probably commoner than our records suggest for it quickly gets through the dredge-net. Its distribution is interesting in view of the importance of "Amphioxus Shell-Gravel" elsewhere in the world. Its depth range here is 9 to 73 m. which is almost identical to that of D. neapolitana. Not only does it seem to exist throughout the D. neapolitana Ground, and in at least part of the Fish Hoek/Glencairn Ground, but it is apparently found wherever there is coarse sand. It is common at Stn. 211, where Diopatra was not recorded, and at several stations outside the D. neapolitana Ground from Gordons Bay to Cape Point (in the ground described next). Clearly Branchiostoma tolerates a wider variation in substratum texture than D. neapolitana.

A new species of Diopatra is the dominant organism of green, sandy mud at around 120 m. for possibly hundreds of miles along the west coast of southern Africa. This species has not been identified with certainty from False Bay.

(f) Spatangus / Epizoanthus Ground

5 Stns. east of Cape Point and north of Rocky Bank. Another, Stn. 238, at 34°20·6'S/18°39·4'E, probably marginal between this ground and the next one. An area about 8 miles in diameter.

Depth: 62 - 82 m.

Hydrology: probably 11-13°C and 34·92 - 35·27‰ .

Substratum: khaki, shelly sand containing quite a lot of silt. Sample Stn. 228; med. diam. 235 microns ("Fine Sand"); badly sorted, there being a relative lack of "Coarse" and "Medium Sands" ; plentiful broken shell in the coarser grades gives the appearance of a coarse sand; 0·346% available organic matter, almost entirely in the "Silt".

Characterised by: many large, purple Spatangus capensis; and little, sandy, colonial anemones Epizoanthus similis commensal on shells occupied by Anapurgus hendersoni.

Associated Spp. Anapurgus was only recorded from four stations because the shells supporting the commensal Epizoanthus were sometimes empty, but their appearance suggested recent evacuation by the hermit which was usually abundant. In addition to the ubiquitous starfish Astropecten, which was common here, the fan-worm Sabella pavonina was found at all stations albeit in small numbers. Other common species were the nemertine Cerebratulus, the polychaetes Lumbrinereis albidentata and Sthenelais limicola , the little handmaiden shells Ancilla cf. errorum and A. fasciata, the amphipods Photis uncinata and Tryphosa normalis, and the little ophiuroid Ophiocten amitinum. The big starfish Luidia africana was less common.

Total Spp.: at least 110.

Notes:/...

Notes: the stations had strikingly similar faunas. A fair number of species are to be found in the *Spatangus/ Epizoanthus* Ground that are definitely absent from the shallows. For example the following have not been recorded shallower than 40 m. (the lower limit of the *D. neapolitana* Ground): *Epizoanthus*, *Sthenelais limicola*, *Travisia forbesii*, *Ancilla cf. errorum*, *Clavus tumida*, *Natica forata*, *N. saldontiana*, *Solariella cogener*, *Nuculana belcheri*, *Ampelisca brevicornis*, *Ophiocten amitinum*, *Luidia* and *Spatangus*; to mention only the most important. Yet this ground, although very distinctive, definitely has alliances with the shallower stations north of it eg. *Spatangus* is recorded in small numbers at Stn. 222 and *Epizoanthus* is common at a station 5 miles west of Stn. 222. But the two nearest stations north of this ground, despite a number of species in common with it, do not resemble it closely enough for inclusion. It is interesting to note the presence of very small numbers of *Diopatra neapolitana* at the two northern-most stations of the *Spatangus/Epizoanthus* Ground, and of *Branchiostoma* at the two stations nearest Cape Point. This ground will be compared with the adjoining Green Pellet Mud Ground, described below, under the heading of the latter.

(g) Green Pellet Mud Ground.

2 Stns. $2\frac{1}{2}$ miles apart in the mouth of False Bay between Rocky Bank and Cape Hangklip. Stn. 238, at 34°20·6'S /18°39·4'E, is probably marginal between this ground and the preceding ground. Information in British Admiralty chart 636 suggests the ground to comprise a circular area about 6 miles diameter as shown in Fig. 2.

Depth: 78 - 88 m.. ..

Hydrology: probably 10·5°C-11·5°C and 34·90-35·10‰ .

Substratum: green "mud" composed of faecal pellets.

Sample/...

Sample Stn. 237; med. diam. 100 microns ("Very Fine Sand"!); well sorted; virtually free of shell and sand grains, all grades composed of similar oblong faecal pellets without sculpturing, the silt apparently of broken pellets; "available" organic apparently very high, 7·73%, and distributed through all grades (see "Notes" below).

Characterised by: the nature of the substratum and the presence of the bivalve, Dosinia pubescens, in fairly large numbers.

Associated Spp.: *Small Pennatulids (FAL. 237 C), the polychaetes *Drilonereis n. sp. (FAL. 237 D), *Goniada sp. (FAL. 240 K), Lumbrinereis albidentata, *Onuphid (FAL. 237 H), Orbinia angrapequensis, *Prionospio pinnata, the small bivalve Tellina ? tulipa (FB. 914), and the crab Goneplax angulata. Those marked with an asterisk have not been found shallower.

Total Spp.: at least 44.

Notes: the pellety nature of the mud can be seen by the naked eye but is not conspicuous. The origin of these pellets is uncertain both as to species and to locality; they are very light and possibly were formed elsewhere and transported by currents. It is problematical how nutritive this substratum is to other species and the figure calculated for "available" organic matter may be misleading.

The biota of this ground is very characteristic and markedly different to the adjacent Spatangus / Epizoanthus Ground. Only Lumbrinereis albidentata is common in both but some of the commonest species of each may be found in small numbers in the adjacent ground. Marked exceptions to this are the characteristic species of each ground ie. Dosinia, Spatangus and Epizoanthus.

More than half the species of this ground are polychaetes, mostly represented by single specimens.

Muddy/...

Muddy cocoons of Diopatra sp. are common at one station and these may well belong to the new species so characteristic of green sandy mud of deeper water along the west coast. Also of common occurence at only one station are the anemone ? Edwardsia capensis, the little gastropod Nassarius circumtextus and the amphipod Hippomedon longimanus, none of which has been found shallower. Widespread species of False Bay represented on this ground are the nemertine Cerebratulus, the polychaetes Glycera convoluta and Orbinia angrapequensis and the ubiquitous Astropecten.

Notes on Intertidal Beaches.

The ecology of the beaches of False Bay is scarcely known. There are twenty identifications from the lower half of the intertidal zone, all from the western beaches of False Bay, chiefly from Simon's Bay. These species are listed in Table VIII, in addition to which there are unidentified nemertines and mysids. It is difficult to assess the intertidal abundance of these but certainly the "white mussel", Donax serra, used to be very common but has ~~since~~ been depleted by bait gatherers; and the plough shell, Bullia digitalis, is common on wet sand. Other species of Bullia occur at the edge of the waves but do not seem to be truly intertidal and this applies to the hermit Diogenes extricatus and the portunid crab Ovalipes. The lugworm Arenicola, is common in a few southern beaches and the polychaetes Nephthys capensis, Audouinia tentaculata, Notomastus fauvelii and Spio n. sp. are quite common in Simon's Bay. Nemertines are common on most beaches. The lack of amphipods is felt to be due to insufficient field collections (talitrids are common in beach rubbish). There is no deep benthic record of the isopod Eurydice longicornis which was found intertidally in Simon's Bay and over 25 m. of water near Seal Island

in/...

	Greatest Depth (m.)
Nemertea	
Lineus ruber	42
Polychaeta	
Arenicola assimilis v. affinis	0
Audouinia tentaculata	3
Lumbrinereis sp.	?
Nainereis laevigata	36
Nephthys capensis	3
Notomastus fauvelii	24 (?)
Spio n. sp. (CP.381 J)	0
Gastropoda	
(Bullia annulata)	(62)
- digitalis	25
(- laevissima)	(46)
Conus ? textile (CP. 349 A)	?
Pelecypoda	
Donax serra	0
? Tellina sp. (CP.381 C)	?
Venus verrucosa	0
Isopoda	
Eurydice longicornis	?
Pontogeloides latipes	0
Anomura	
(Diogenes extricatus)	(30)
Paguristes gamianus	27
Brachyura	
(Ovalipes punctatus)	(91)

Table VIII. Species recorded from intertidal beaches of the western shore of False Bay from M. S. L. to E. L. W. S. with their greatest known local depth. Species in brackets are found no higher than E. L. W. S..

in a floating illuminated trap at night.

It is likely that beach faunas are affected by horizontal hydrological differences (discussed in Part II). For instance Arenicola assimilis was only found in the south, at Buffals Bay, and this is a sub-antarctic species, unlikely to extend into the warmer northern parts of False Bay. A fragment of Arenicola from Simon's Bay beach is possibly that of another species.

When the species which are not really intertidal are ignored

sixteen/...

sixteen intertidally recorded species remain in Table V111. There is no information about the deepest limits of four but the others may be put into two groups: One comprises seven species which extend down to datum and as far as 3 m. below it, these being truly intertidal in nature. The other comprises five species which extend much deeper and which are therefore shallow-water species capable of penetrating into the intertidal region.

Notes on the Benthic Fauna outside False Bay.

Records are available of some bottom fauna of the continental shelf collected by fishing trawls of R. S. "Africana II". Only stations between the meridians of Cape Point and Cape Agulhas (see Fig. I) are considered, very briefly, to see whether or not the soft bottoms of False Bay resemble those just outside. The stations have been grouped according to their depth.

(a) 31 - 38 m.. AFR. 842 (35°34·5'S I9°I8'E), 3I m., grey sand:
AFR. 865 (34°35·5'S I9°I8·2'E), 37 m., mainly smooth, few rocks.
AFR. 866 (34°36·8'S I9°I6·4'E), 38 m., mainly smooth.

36 Spp. were identified, of which only one, the polychaete Syllis spongicola, has not been recorded from False Bay. None was found in large numbers but Bullia laevissima and Marthasterias were widespread since they were at all three stations. The following were at two stations; Argobuccinum argus, Hinia speciosa, Turritella sanguinea; Tivela compressa; Balanus maxillaris; Synidotea hirtipes; Pallinopsis intermedia; Astrocladus euryale; and Astropecten. All of these except for the pycnogonid, Pallenopsis, were common in parts of False Bay.

It/...

It may be significant that *Diopatra neapolitana* was not found. This depth range corresponds to the *Diopatra neapolitana* Ground of False Bay but since sampling was by fish trawl and not by dredge it cannot be taken that the omission of *Diopatra* from these stations proves its absence. (Still, the species of *Diopatra* that is so abundant on the west coast is caught there in vast numbers by the trawls). This uncertainty precludes detailed comparison with False Bay but it can be said that these outside stations do not differ markedly from similar depths within the bay in regard to the species present although their relative abundance may differ.

(b) 66 m. AFR. 864 (34°35·4'S I9°I4·7'E), 66 m., rough and smooth in patches.

Only 8 spp. were recorded all of which occur in False Bay. The only one that was common here was *Astrocladus euryale*; but *Turritella sanguinea*, *Goneplax angulata*, *Pagurus arrosor*, *Astropecten* and *Luidia africana* were found in small numbers and all these are common in False Bay at this depth. There is no resemblance to the *Spatangus / Epizoanthus* Ground of False Bay, for *Spatangus* was not found (and it should have been caught by the trawl if present).

(c) I68 m. AFR. 882 (34°39·2'S I8°42·4'E), I68 m., green mud.

It is not known whether or not this mud was composed of faecal pellets.

I7 benthic spp. are recorded and three seemed to be abundant, the hermit *Parapagurus dimorphus*, its commensal *Epizoanthus carcinophilus* and the starfish *Brisasster fragilis*. The fauna was dominated by starfishes of which

there/...

there were no less than seven species but there were few of each apart from Brisasster. (Conspicuous absentees from the list of starfishes were Astropecten, Luidia and Marthasterias). Two species of ophiuroids added to the echinoderms. The anemone Bolocera capensis and the gastropods Argobuccinum murrayi and Volutilithes abyssicola were present, all of which are very characteristic of the trawling grounds northwest of Cape Town.

This station bore no resemblance to any bottom in False Bay and only one species, the crab Goneplax angulata was to be found here and in False Bay.

Discussion on Soft Bottoms.

A tiny, extremely well sheltered beach was found in the southernmost corner of Simon's Bay, next to the naval dockyard, just before the author's departure from South Africa and too late for detailed investigation. A swim with goggles revealed that the bottom at about 2 m. depth consisted of rather silty sand riddled with holes of Upogebia sp. and covered in algae (?Aodes). This bottom was unlike any other seen in False Bay and offered a striking contrast to the bare expanses of sand that stretched for miles around the bay at this depth. Although little is known of the beach faunas and although the shallows have been poorly sampled it is quite clear that both regions are sparsely populated compared to deeper bottoms of False Bay. Obviously the majority of shallow sandy bottoms are barren because of excessive wave action.

Turbulence in the shallows is chiefly caused by wave action but deeper bottoms are probably more influenced by bottom currents than by the swell above. There is an important difference between these types of turbulence: swell and wave action churn the bottom and are likely to

cause/...

cause the finer particles to be removed but water currents are as likely to add particles to a substratum as to remove them, depending upon circumstances. If wave-action were the only factor causing turbulence then bottom textures would be related to depth. But the chart and the substratum analyses show that bottom textures are not related to depth. Obviously the bottom of False Bay is greatly influenced by currents and since some particles are large the currents must be fairly strong. To recapitulate. Bottom textures are not simply related to depth: turbulence in the shallows is chiefly due to wave action but over deeper bottoms it is chiefly due to currents which appear to be quite strong in places. It is deduced that the barrenness of shallow bottoms is due to their instability under the churning action of waves and not intrinsically due to their texture, or due to water velocities over them.

We have considered some aspects of turbulence and bottom texture and should look at the composition of the substratum for a moment. Although the cleanliness of beach sands is largely due to wave action a feature that is no less important in False Bay is the absence of an influx of silt. The absence of muddy rivers not only keeps the beaches clean, ie. free of silt and organic rubbish, but keeps the whole bottom of the bay clean. The substratum analyses showed that they were very poor in organic matter : down to 35 m. there was negligible available organic matter, but it increased gradually at greater depths. If the available organic matter influenced the presence of species very strongly one would expect the fauna to be poor down to 35 m. and then to become progressively richer but Appendix II shows that stations become rich at about IO m.. This suggests that the presence or absence of organic matter is unimportant in

shallow/...

shallow substrata where there is considerable wave action. The fact that stations only become rich deeper than IO m. suggests that wave action only exerts an important restraining influence on the biota down to that depth although, of course, its range of influence does not stop suddenly.

What is known of beach faunas suggests that they have two components, the truly intertidal descending less than 3 m. below datum, a nd the shallow-water component that is equally at home down to about 40 m.. Diving and dredging show other biotic changes to occur across the bed of the bay, the distributional gradients being broadly related to depth but chiefly dependent upon local conditions of which turbulence (churning effect) and substratum texture and composition seem to be the most important.

Outside False Bay the species on the continental shelf down to about 70 m. are the same as those in False Bay but they are apparently not arranged in the same grounds (this may only be because sampling is inadequate). But the biota of the station at I68 m. differs radically from that of shallower stations both on the shelf and in False Bay. Actually this is not a peculiarity due to the mud there because the biota is almost identical to that of mixed rough and soft bottoms trawled between IOO and 550 m. (AFR. stations 808,830,831,833,835). There seems no doubt that the fauna of the deeper part of the shelf bears no resemblance to that shallower than, say, 80 m. and none to that in False Bay.

In fact the broad correlation of biotic change with depth continues from the intertidal region in False Bay, across its bed a nd onto the shelf to well below IOO m. depth.

Conclusions/...

Conclusions on the Benthic Ecology of False Bay.

There are so many differences between soft and rocky bottoms that it is illuminating to compare and contrast them rather than merely to treat each separately, as is more usual. Only matters that are relevant to this work will be raised.

Some sampling differences can be considered first. Rocks rapidly become scarce as depth increases whereas soft bottoms become more widespread. For this reason it is difficult to drop a dredge onto deep rocks. Even when they are found one may suppose that they are not flat (or they would have been covered by sediment) and pinnacles of rock are not easily dredged. Dredges can never sample the over-hangs and clefts that are so much a feature of rocks and which, below the range of diving, are likely to remain unexplored. There are, therefore, several reasons why sampling of rocky biota rapidly becomes difficult as depths increase whereas soft bottoms are amenable to sampling of a uniform efficiency over considerable depth ranges.

Fortunately these sampling differences do not hide the fact that rocks and soft bottoms support very different biotas. Although the fact is well known this work shows it particularly clearly. For instance it is plain if we compare the most frequently found species of rocks and of soft bottoms, as listed in Tables IV and V. Even so there is an appreciable number of species that are frequent on either substratum : they are shown in Table V. Most of these are small epizoonts that are, perhaps, best regarded as rocky species but they contribute to soft bottom ecology and must not be disregarded.

The less common species show the same correlation with substratum but this is not so easy to demonstrate because of fewer records. Yet rocks are the characteristic habitat of sea fans such as *Eunicella*, of gastropods such as *Patella* and *Haliotis*, the crab *Plagusia*, the crawfish *Jasus*, the small asteroid *Asterina* and of most ascidians. Omission of such species from an account of rocky ecology would be quite wrong. Other species are typical of soft bottoms e.g. the sea pens, *Actinoptilum* and *Virgularia*, gastropods such as *Clavatula* and *Clavus*, bivalves such as *Tellina*, *Mactra* and *Tivela*, the anomuran *Galathea* and most species of *Amphiura*. Many more examples may be obtained from the annotated list of species found during the survey (Part I of this series).

We may now turn to the pattern of distribution of species. One phenomenon appears to be true for all species ie. that the depth range over which a species is most abundant bears no constant relationship to its extreme depth range : in other words it is not always at the shallower end, or in the middle, or at the deeper end of the extreme range. This is shown, for example, in the diagrams of the vertical distribution of species on rock faces in Part II of this series : it also emerges as a fact when the ranges of frequent occurrence of the species listed in Tables IV and V are compared to their extreme ranges. (as given in Part I of this series). This comparison makes interesting revelations about the positions of the extreme range limits.

It shows that all but one of the frequent, rocky species will extend to depths shallower than I5 m. and most of them, 92% in fact, to less than 5 m.. With increasing depth more and more of these species die-out and there is no significant appearance of species which are characteristic of deep rock only. The one exception

is/...

is the brittle-star Dictenophiura which ranges from 36 m. to more than 200 m. and which is common on both hard and soft bottoms.

The pattern of distribution of the most frequent species of soft bottoms is quite different. When the extreme ranges of really typical species are considered (those of Table V, excluding bracketted species) the upper and lower limits have an interesting distribution as can be seen from Table IX. More than half extend into water shallower than I5 m. but there is no doubt that significant numbers appear as depth increases. The species have a fair depth range and two-thirds extend deeper than 80 m.. The last statement should be amplified since it was remarked in the previous section that the biota on the deeper half of the continental shelf was very different to that shallower than, say, 80 m.. In point of fact, although 66% extend deeper than 80 m., 53% are not recorded deeper than 90 m. and only I3% extend below that depth. The depth of 80-90 m. appears to be the lower limit of a shallow, shelf fauna.

	Upper Limits, % of all species	Lower Limits, % of all species
Intertidal to 5 m. depth	33%	2%
5 - I5 m.	20	0
I5 - 25 m.	II	0
25 - 35 m.	5	9
35 - 50 m.	I5	7
50 - 80 m.	I6	I6
Deeper than 80 m.	0	66

Table IX. The Distribution of the Extreme Depth Limits of Fifty-five Species Common on Soft Bottoms.

Table/...

Table IX shows that there is clearly a progressive change in fauna with species appearing, flourishing and being replaced by others as depth increases. This is quite contrary to the distribution of rocky species. There is another difference between the patterns of distribution on the different bottoms that is actually masked in Table IX. Although 53% of frequent, soft bottom species can, on occassion, be found shallower than I5 m. it is not very often that they are found so shallow. Table V shows how few are common in the shallows: in addition, it was pointed out in the previous section that soft bottoms down to IO m. depth were very barren. On the other hand rocky species are very abundant in the shallows (see Table IV).

The difference between the abundance of life on shallow rocks and the barren appearances of beaches and shallow, soft bottoms is really striking : it is well worth looking at further. The beaches and shallow sands of False Bay are generally devoid of plants and sparse in animals. It is true that the green alga, Caulerpa filiformis (olim C. ligulata), colonises small patches of sand at 4 - II m. off Oatland Point and to the north; whilst south of Oatland Point there are extensive beds of kelp, Ecklonia maxima, (although these occur suspiciously near rocks and may actually spring from stones in the substratum). But the alga, Gracillaria confervoides, is absent although it is found in Hout Bay on the western side of the Cape Peninsula and in Saldanha Bay. This is presumably because it is exclusively a cold-water species. The sandy shallows of False Bay have nothing to compare to the fields of Cymodocea, Zostera and other angiosperms

that/...

that are so much a feature of sandy bottoms in the warmer waters of the Mediterranean and tropics. Cymodocea is not found nearer than Portuguese East Africa, some 2,000 miles away, where climatic and hydrological factors are very different to False Bay but Zostera capensis is abundant only 30 miles from False Bay in the Klein River Estuary at Hermanus (see Fig. I.) (Scott, Harrison and Macnae 1950). It is also abundant in Langebaan Lagoon, a southerly arm of Saldanha Bay. Its absence from False Bay therefore appears to be because of excessive wave action and lack of silt in the substratum.

When compared to the shallow bottoms of warmer waters the relative barrenness of False Bay is particularly marked, not only for the lack of plant fields but also for the lack of sponges and corals. Of course plants, sponges and corals have a great ecological effect.

In attempting to account for the different species to be found on hard and soft bottoms, and for their different distribution patterns, we must look at the nature of the substratum. So far as rocks are concerned granite and sandstone are hard and do not permit an infauna: they support identical biotas. Occasionally limestone was sampled and the soft rock was riddled with boring species. Unfortunately its epibiota cannot be compared with that of the hard rocks since the limestone reefs were situated rather uniquely and sampling was poor. It is apparent that the nature of a rock chiefly influences its infauna. This difference does not operate for the majority of rocks in False Bay, which are hard. The influence of the texture and nature of soft substrata on their biota has been clearly shown,

particularly/...

Throughout this depth range there were no tendencies to vertical zonation but it is interesting to record that the deepest patches of Pyura community hereabouts were at 12 m.. There was an absence of such typical fringe species as Ecklonia and the gastropods Turbo sarmaticus, Oxystele sinensis and Haliotis midae. The rarity of algae should be emphasised for only one small, red species, Plocamium ? membranaceum (FAL.268 A), was found and it was very sparse.

c) 75 m. SE of Lighthouse.

A rock face fell vertically from about 8 m. to 15 m. depth at which it rested on a sloping rock that disappeared beneath shelly-sand at 17 m.

At 14 to 15 m. the chief coloniser was Balanus trigonus, with Corynactis almost as common. Other important features were big, beige, encrusting sponges (FAL.274 X), a purple Chapperia-type polyzoon, and great bunches of hydroids, principally Sertularella arbuscula and Nemertesia cymodocea with epizootic species. Gorgonians and alcyonaceans were present, but not in large numbers; Pseudactinia was common and vermilion Balanophyllia-type corals fairly common. There were a few crinoids, all of which seemed to be orange Comanthus wahlbergi, and three species of starfish, viz. Marthasterias, Henricia and Patiria. There were no holothurians and no mat of Mytilus crenatus ~~and~~ although occasional, small specimens were present. Argobuccinum was common. In regard to algae, there were only sparse Plocamium ? membranaceum and sparse Dicurella ? flabellata (FAL.274 B).

It was interesting to find Pyura in community form at the

top/...

top of the rock face, i.e. at about 8 m., below which occasional, scattered *Pyura* extended as deep as 14 m..

(iv) The Quay, Gordon's Bay Harbour.

The vertical face of the quay consisted of rough-faced stone blocks with deep, narrow crevices between them. The face was examined from 0 to 3 m. depth.

The quay, in conjunction with the rest of the upper end of this little harbour, was very sheltered and all the biota, rocks and harbour fittings were coated in fine silt for tidal currents here were very gentle. In March 1953, the most conspicuous feature was a growth of fine, fluffy, reddish and greenish algae (FAL.137 T,U) which covered almost everything, including living sea fans. It has not been possible to check this face at another season to determine whether these algae were seasonal such as the fluffy *Falkenbergia* that was abundant outside Lagoon Rock, at Oatland Point, during the same month.

The biota looked very drab because of the fluff and the silt. Even the scarlet *Lophogorgia flammea*, which was common though small, did little to brighten-up the masonry. Fanworms such as *Sabellastarte longa* and the polychaete *Audouinia australis* found homes between the blocks and their protruding tentacles looked less dusty than anything else. The only other sessile species were the tunicates *Styela costata* and a *Pyura* - type species (FAL.137 N); the former often supported little barnacles, *Balanus trigonus*, and the hydroid *Plumularia setacea*. On the other hand, quite a few mobile species were seen, from the largish crab *Plagusia chabrus* to small polychaetes and amphipods. *Parechinus* was rather common, and the big starfish *Marthasterias*, and there were a few gastropods such as *Melatoma*

sinuata,/...

range that were made but this is, emphatically, untrue. Nearly all extensions were made according to literature records referring to False Bay. A mere handful of the 850 - odd species listed have had extensions made from the greater area outside False Bay itself which has been considered as "the False Bay region" and there are good reasons for this. Firstly, False Bay is better known than the larger region; secondly, False Bay species do not extend particularly higher (eg. into the intertidal) nor deeper in the larger region defined. The intention of such depth extensions was to utilise every scrap of information available but actually very little resulted apart from the very useful and fairly plentiful information from False Bay itself. There is no doubt at all that the data are suitable for analysis of the critical levels of False Bay.

In several respects the data are not all that could be desired. Principally, it is unfeasable to separate the species of rocks and of soft bottoms for separate analysis because so many dredgings were on mixed bottoms. Although a cautious attempt has been made in the annotated list to sort-out what types of substratum each species favours it would still be difficult to segregate purely rocky and purely soft bottom species into useful separate lists. The lists would be short and would tend to exclude the species which have been most often found. One could forsake fact for the tempting embrace of "intuition" to decide arbitrarily that species belong to either group, or to both; but that is better left until intuition can be guided by a lot more facts. Other criticisms are, briefly, uneven sampling (see Table I), lack of identification of some groups and confusion whether species

actually/...

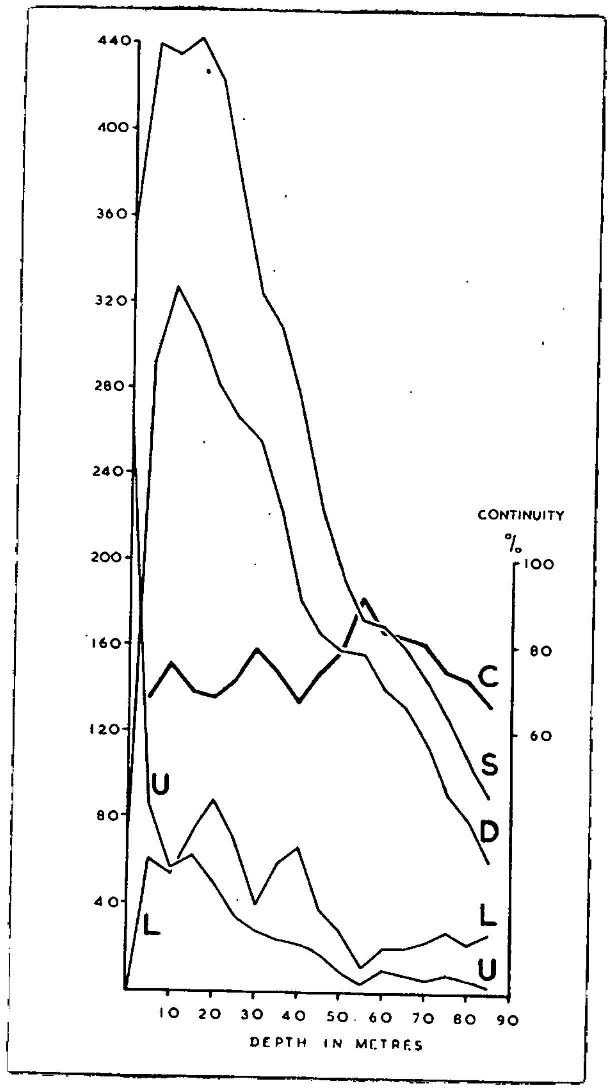


Figure 6. For different depths are shown the number of species found (curve S), the number of upper (U) and lower (L) limits of distribution and the difference (D) between the number of species and of total limits. The heavy curve (C) represents tendency to continuity of distribution (D expressed as a percentage of S).

Based on Table X.

The vertical scale on the left applies to all curves except C, for which the scale is given on the right.

actually extend into the intertidal region proper or only as high as datum, i.e. into the infratidal fringe.

The ostracoda, porifera and madreporaria have been omitted from consideration because of fragmentary records. Eg. no ostracod has been identified from this work but the annotated list includes a useful list of thirteen found by the "Challenger" in False Bay: the reference to their distribution is, for all, merely "15 - 20 fath." which, if included in the analysis for critical levels, would produce a bias towards these levels. The results of analysis of the vertical distribution of 827 species are given in Table X and the derived curves in Fig. 6; these curves have been smoothed by plotting the average values of adjacent depth groups.

A striking feature of Table X is that 322 species out of 827 have their upper limits above datum. Even if a few of them are erroneously attributed to such high levels the proportion is high. Some light is shed on just how intertidal or not these species are by the work on intertidal transects; Fig. 7 in Part II includes such species (there designated "infratidal species") and shows that they never rise above M.L.W.N. level. They are by no means intertidal in nature but can withstand occasional emersion. 14% of all species have their upper limits from datum to 5 m. depth which suggests that many infratidal species cannot tolerate intertidal conditions under any circumstances.

The curves in Fig. 6 do not cross datum because of the process of smoothing. The small peak at 15 m. in the curve for upper limits ("U") may be an artefact and, if it is ignored, the curve drops rapidly and gives no further

suggestion/...

1 Depth Range (metres)	2 No.of Lower Limits	3 No.of Upper Limits	4 Total No.of Limits	5 Total No.of Species	6 Diff:between Total No. of Species and Total No. of Limits	7 Difference as % of Total No. of Species
Int.	--	322	322	322	0	0
0- 5	64	121	185	444	259	58
5-10	56	52	108	432	324	75
10-15	52	59	111	436	325	75
15-20	93	66	159	448	289	64
20-25	80	33	113	389	276	71
25-30	57	36	93	344	251	73
30-35	21	21	42	306	264	86
35-40	96	27	123	310	187	60
40-45	37	19	56	233	177	76
45-50	41	17	58	214	156	73
50-55	14	3	17	176	159	90
55-60	8	7	15	168	153	91
60-65	32	14	46	175	129	74
65-70	7	4	11	144	133	92
70-75	43	8	51	146	95	65
75-80	13	9	22	113	91	80
80-85	32	4	36	104	68	65
85-90	22	3	25	76	51	67
>90	58	3	61	55	--	--

Table X. The Distribution of Species and of their Upper and Lower Limits Relative to Depth.

suggestion of particularly critical levels, in particular, no level that suggests the upper limit of a well defined, deep-water fauna.

The curve of lower limits ("L") has a minor peak at 5 m., two well-marked peaks at 20 m. and 40 m. and a plateau deeper than 70 m.. Naturally most of the species with lower limits at ~~0.5~~ 0 – 5 m. also occur above datum but they only comprise 12½% of the 322 species that cross datum. Many algae belong to this small group of very limited distribution on either side of datum and the phrase "fringe species" would aptly describe the group except that such dominant fringe species as Ecklonia and Pyura extend deeper, to 10 and 17 m. respectively. (The reader is reminded that the affinities of the species of

the infratidal/...

the infratidal fringe are discussed in detail in Part II). Nearly half of the species that only reach down to 20 m., or so, rise above datum; more than a third of those stopping around 40 m., and more than a quarter of those stopping around 70-80 m., rise above datum. This merely shows that although 39% of all the infratidal species have a sharp upper limit just above datum, presumably determined by the factor of emergence, their lower limits are spread over a considerable range and are probably not all determined by one, predominant environmental factor. It is not reasonable to lump together all species that rise above datum as a natural, distributional group. On the other hand, it is clear that, as depths increase, a smaller proportion of the species there penetrate to the intertidal region.

When the number of species at any level is considered it must be remembered that the intertidal zone actually contains many more than is apparent from the table because only infratidal species are under review. 444 species are listed at 0 - 5 m. depth and 73% of these rise above datum which is rather surprising even although we know that they only rise for half a metre, or less, above it. The vast peak of curve "S" shows that well over 400 species can be found at any depth to 20 m. but numbers drop rapidly at greater depth. The decrease in number of species must certainly reflect the decrease in rocks. Again, this curve is particularly affected by intensity of field work but although there were relatively few deep stations they seemed to sample soft bottoms rather adequately (see notes under "Spatangus / Epizoanthus Ground" and "Green Pellet Mud Ground").

Colman/....

Colman calculates measures from which a graph is derived (his Fig. 15), the peaks of which indicate the levels where most species are "happiest". Such measures are calculated here (Table X, column 6) and the resultant curve included in Fig. 6 (curve "D"). This suggests that more infratidal species flourish between 5 and 15 m. than at any other level. A more useful curve to express continuity of distribution, or the absence of tendency to change, can be derived by expressing curve "D" as a percentage of curve "S". The result is included in Fig. 6 as curve "C" (and the calculations in Table X, column 7). This curve is less likely to be affected by differences in sampling efficiency. It shows peaks centred on 10, 30 and 55 - 60 m., which presumably are levels around which continuity is good; in other words these are un-critical levels. In addition, the continuity curve "C", modifies interpretation of the total species curve, "S". A valley shows that continuity is low from 0 - 5 m. and so the large number of species present is chiefly due to overlapping of the lower ends of distribution of some and the upper ends of distribution of others. Similarly at 20 m.. And the long drop in number of species with increasing depth does not reflect progressive cessation of one large group of species (such as rocky species as a whole) because of the "valley" in continuity at 40 m. which suggests another region of over-lapping distribution end-points. Lastly, the continuity curve is low enough at 80 m. to suggest a region of change there-abouts.

It would not be worthwhile to extract more information from the analysis on the data available. The points that

have been/....

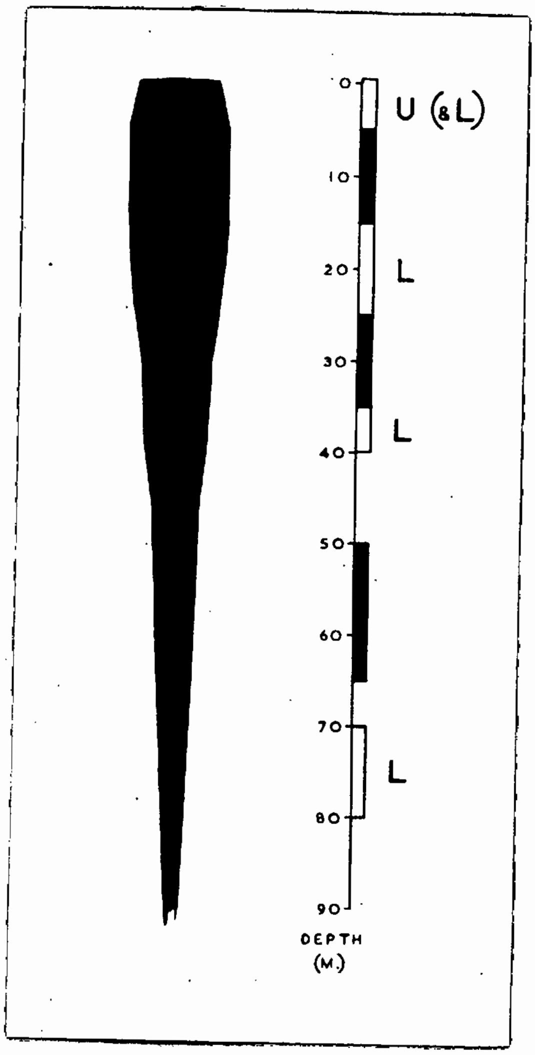


Figure 7. On the left, a distribution diagram representing the number of infratidal species found at any depth. On the right, critical levels (open boxes) and non-critical levels (black boxes) are shown.

U Upper limits of distribution.

L Lower " " "

have been made are very plainly indicated by the figures and should be reliable. The chief ones have been put together to construct Fig. 7.

The left half of Figure 7 shows strikingly how many species of the infratidal extend as high as datum and their abrupt cessation just above it. From half a metre above datum to five metres below it is extremely critical for in this range 54% of the infratidal species have their upper limits. In Part II (Fig. 7) it is concluded that from 0.2 m. above datum to 0.1 m. below is critical while from 0.3 m. to 0.7 m. below datum, and possibly deeper, is definitely uncritical. This analysis finds the whole region down to 5 m. critical, 5 m. ranges being the minimal considered. The two conclusions are not contradictory for they were made in different contexts and the matter of scale must be taken into account. Sufficient changes may occur within an uncritical zone of the intertidal to be very critical if they occurred infratidally where vertical changes are gradual. The "uncritical" zone at 0.3 - 0.7 m. below datum (as noted in Part II) may actually be critical when regarded on the scale of infratidal changes. Then, again, it may still be uncritical and have a critical zone below it but shallower than 5 m.; this is actually suggested by the information in Figs. 9 and 11 of Part II (showing the vertical distribution of species on rocks). This is rather splitting hairs and only further detailed work can decide at what level infratidal species die out between datum and 5 m. depth. The important points are that so many do die out thereabouts, and that caution is necessary in comparing analyses of critical levels of the intertidal and infratidal regions.

On the/....

On the right of Fig. 7 an attempt is made to show critical and uncritical levels relative to the depth range of False Bay. They are based on curves "L", "U" and "C" of Fig. 6. The fact that many intertidal species have their lower limits just below datum is indicated in the diagram by an "L" in brackets opposite the first depth range group, 0 - 5 m.. Fig. 7 suggests a shallow water biota that dies out in steps as depth increases: there are no signs of a marked, deep water biota replacing it.

Fig. 7 cannot be presented without some comment on how much it shows the influence of different substrata. Are the critical levels of species of hard and of soft ~~identical~~ bottoms identical? It seems extremely unlikely in view of the discussion above on their different patterns of distribution. Several other points spring to mind. Rocky species are usually much more varied than those of soft bottoms and so the critical levels of the latter might have been swamped in the analysis. This is particularly likely in the shallows where rocks are so densely populated and sands are so barren and, moreover, so poorly sampled. As a result of previous discussion, it appears that two depths are important to soft substrata: about 10 m., above which sands are pretty barren; and about 80 m., below which the shallow faunas undoubtedly give way to a deeper, shelf fauna. There are no particularly important levels in between, when the whole bay is considered, because of the overlap of the depth ranges of the different grounds. I consider that the right half of Fig. 7 applies almost exclusively to rocky species. It is true that from about datum to 5 m. depth is critical for the upper limits of both rocky and soft bottom species; but a wider range, say 0 - 10 m., probably is truer for soft bottom species. The most critical level for lower limits of soft bottom species is more likely to be just below 80 m. than just above it.

If the critical levels in Fig. 7 apply to rocky species, as seems possible, the difficulty is to account for them. The shallowest is obviously due to emergence, turbulence, competition etc., but what determines those around 20, 40 and 75 m.? They cannot be explained now and so future work must test their existence (which is very strongly shown in Fig. 6) and correlate with environmental factors.

One set of data cannot give a true impression of the changes that are found across the sea bed. An attempt has been made to achieve this objective by diving descriptions of particular places, by consideration of the commonest species, by identification of common areas or grounds and by analysis of the distribution of all identified species.

SUMMARY.

1. False Bay is a purely marine bay over 400 square miles in area and with a maximum depth of 90 m. It lies at the boundary of cold and warm water currents to the east of the Agulhas Bank where there are fishing grounds. This first report describes the general nature of the environment and its biota but further work is necessary for a complete analysis of so large and complex an area.

2. Dredgings/...

2. Dredgings on hard and soft bottoms, supplemented by diving observations, are used for a preliminary description of the bottom.
3. Vertical gradients are found in the distribution of all species but the patterns of distribution are different on hard and soft bottoms. Tentative explanations are advanced.
4. Several faunistic grounds are described and an attempt has been made to correlate faunistic changes with changes in the environment.
5. Results are reviewed together with observations on the ecology of intertidal and shallow rocks and with what is known of local beaches and of the shelf fauna off False Bay. An analysis of critical levels is made.
6. A dredge is described that, by special rigging, will dig some two inches into hard-packed, shelly sand without the need for great weight.
7. Underwater observation of dredging gear in action has proved almost indispensable.

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Appendix I. List of Stations made on Rock with Five Stations from Mixed Bottoms that are predominantly Rocky.

Stations made by diving are noted, the others are by dredging. Where the station number is bracketted the record is a miscellaneous one or a poor sampling; no proper station was made and the record is regarded as a "quarter-station" for some purposes of calculation in the text. "F.B." Stations were those made prior to the beginning of 1952 after which stations were given "FAL." serial numbers.

Depth	Station Code Numbers		Position
4-5½	FAL. 256	x	Oatland Point: "Outside" of Lagoon Rock (Diving).
4-6½	FAL.169-175	x	Oatland Point: Big Rock (Diving).
7	FAL.121-123		Glencairn (Diving).
8	FAL.56-57		Gordon's Bay.
7-11	FAL.108-110		Gordon's Bay.
8-11	FB.140,143,214,332,425,573, 578,579,663,790,795,923,977, 982,1081,1086,1115,1118, 1174,1178,1206.	@	Glencairn.
11-14	FAL.262	x	Noah's Ark (Diving).
12-14	FAL.278-282	x	W.N.W. of Roman Rock (Diving).
14-17	FAL.268-272	x	E.S.E. of Roman Rock (Diving).
14-17	FAL.274-277, 307	x	S.E. of Roman Rock (Diving).
14-17	FAL.78-88		Kogel Bay, South.
15-18	(FAL.301)		Off Zwartklip.
16-19	FAL.66-70		Rooi Els.
17	FB.56,136,281,327,421,572, 622,789,976,1008,1080, 1114,1173,1204	@	Glencairn.
18	FAL.48-55	@	Off Gordon's Bay.
18	(FAL.288,304)		Off Gordon's Bay.
15-25	(FAL.265)		Between Seal Is. & Strandfontein.
24	FAL.6-8,13,103		E. of Seal Is.
27½	FB.54,119,202,405,451,651, 752,904,1057,1102,1202		½ mile E. of Seal Is.
27-28	FB.51,114,201,307,401,407, 414,605,653,757,905,955, 1001,1053,1103,1164	@	Off Strandfontein.
33	(FAL.297,302)		Rocky Bank.
36	FAL.207-208	@	Off Steenbras R. mouth.
42	(FAL.296)		Rockland P. N.W.1/4N., 2½ miles.

cont'd....

Depth	Station Code Numbers	Position
42	FAL.213-216	Kogel Bay, North.
55	(FAL.235)	Off Rooi Els.
64	(FAL.236)	Off Pringle Bay.
73	(FAL.298,303)	Cape Pt. Light N. x W.½W., 8 miles.

x Observations of these stations are given in a previous paper (Part II of this series).

@ Sand also sampled.

Appendix II. List of Stations made on Soft Bottoms.

Conventions as explained in Appendix I

Depth (metres)	Station Code Numbers.	Position	Bottom	No. of species
1½ - 3	FAL.94, 107	Approx. 34°09.4'S/18°51.7'E.	Clean hard sand with ripple marks.	12
3 - 5	FAL.115	Approx. 34°11'S/18°25.6E.	Hard, coarse shelly sand.	8
4 - 5½	FAL.146	Oatland Point (Diving)	Coarse, shelly sand.	2
7 - 9	FB.53, 204, 251, 302, 503, 552, 602, 753, 802, 909, 952, 961, 1058, 1061, 1152	Approx: 200 yds off Fish Hoek.	Sand, loose <u>Pyura</u> & Algae.	57
7 - 11	FAL.60	Approx: 34°17.8'S/18°49.3'E.	White sand.	5
9 - 10	FB.138, 139, 216, 217, 282, 328, 330, 331, 508, 574, 576, 577, 623, 625, 626, 791, 793, 794, 922, 924, 978, 980, 981, 1082, 1084, 1085, 1116, 1117, 1176, 1177	Approx: 34°10'S/18°26.1'E.	Sand.	46
9 - 18	FB.132, 134, 210, 211, 325, 326, 403, 420, 471, 568, 570, 618, 620, 666, 668, 784, 786, 787, 908, 920, 921, 930, 959, 972-975, 1006, 1076, 1078, 1123, 1172	Approx: 34°08.6'S/18°27'E.	Sand, loose <u>Pyura</u> & Algae.	67
10 - 11	FAL.258-259	Off Oatland Point (Diving)	Coarse, shelly sand.	34
11 - 15	FB.102, 103, 105-112, 301, 306, 314, 408, 504, 553, 603, 754, 803, 1154, 1060, 1170	Off Fish Hoek.	Shelly sand.	51
12 - 14	FAL.283-287	Roman Rock (Diving)	Coarse, shelly sand with scattered surface shells & pebbles.	55
14	FAL.260-261	Noah's Ark (Diving)	Shelly sand mixed with white mud.	30
14	FB.137, 215, 329, 575, 624, 792, 923, 979, 1083, 1175, 1205	34°10.2'S/18°26.2'E.	Shelly sand.	27
15 - 19	FB.123, 312, 410, 506, 558, 609, 658, 762, 911, 963, 1065, 1203	34°09.5'S/18°27'E.	Sand & twiggy ? <u>Lithothamnion</u> fragments.	32
16 - 18	FB.127, 142, 320, 333, 580, 583, 584, 589, 614, 662, 664, 779, 780, 797, 807, 927, 929, 971, 984, 1011, 1089, 1121, 1182, 1184	34°08'S/18°29.5'E.	Sand, broken shell & shingle.	42
17	FAL.(318), 319-320	Fish Hoek Bay. (Diving)	Clean, white sand.	41

Depth (metres)	Station Code Numbers	Position	Bottom	No. of species
19 - 20	FB. 52,117,203,309,556,607,656,760,907, 958,1055,1166	34°07.5'S/18°29.3'E.	Shingle with hydroid overgrowth.	35
20 - 23	FB.145,207,319,413,507,563,564,567,612, 617,767,771-775,806,914-916,969, 1010,1069,1109,1162	34°09.2'S/18°26.8'E.	Sand, shell & crinoids.	65
22	FB.101,104,113,402,551,601,751,801,901, 902,951,953,1059,1151,1201	Approx:1 mile off Fish Hoek.	Sand & loose <u>Pyura.</u>	43
22	FAL.61-63	Approx:34°17.5'S/18°49.2'E.	Sand.	24
22-24	FB.128,146,321,334,418,501,590,782,800, 810,918,972,1012,1074,1111,1122, 1185,1186	Approx:34°07.7'S/18°30.7'E.	Shelly sand.	34
22 -24	FB.125,206,316,562,610,765,768,912,913, 966,1004,1066,1107,1183	34°09'S/18°27.9'E.	Clean, white sand.	36+
23	FAL. 116-117	Approx:34°10.9'S/18°27'E.	Coarse sand (? muddy) & twiggy ? <u>Lithothamnion.</u>	37+
23 - 24	FB.116,308,404,555,606,655,759,804,957, 1054,1120,1159	34°07.8'S/18°31.5'E.	Shingle with thick hydroid overgrowth.	25
23 - 27	FB.120,121,313,559,560,659,660,763,764, 805,964,965,1062,1063,1155,1156	34°08'S/18°29'E.	Sand & <u>Diopatra</u>.	31
24	FB.122,205,252,311,409,505,557,608,657, 761,910,962,1003,1064,1105,1157	34°10'S/18°27.5'E.	Sand & twiggy ? <u>Lithothamnion</u> fragments.	43
25	FB.133,569,619,667,785,809,1007, 1171	34°11'S/18°27.3'E.	Sand.	16
26	FAL. 314-315	Approx:34°09.6'S/18°27.4'E... ...(Diving).	Khaki sand.	25
26 - 27	FB.317,412,588,611,616,799,928,967, 1009,1067	34°09.5'S/18°28.3'E.	Fine sand & <u>Ampelisca.</u>	24
26 - 29	FB.144,318,665,766,769,770,968,1005, 1068,1108,1161	34°10.3'S/18°27.8'E.	Sand & <u>Chaetopterus.</u>	21
27 - 28	FB.115,654,758,906,956,1002,1056,1104, 1165	34°08'S/18°31.5'E.	Fine shingle	21
27 - 30	FB.323,502,554,604,756,903,954,1051, 1167	34°10'S/18°29.5'E.	Fine sand & <u>Ampelisca.</u>	28

Depth (metres)	Station Code Numbers.	Position	Bottom	No. of species
28	FAL. 28-29	Approx. 34°13'S/18°29'E.	Discoloured large shells; ? sand also.	27
30	FAL. 209-210	34°06.8'S/18°40.3'E.	Shelly sand.	33
31	FAL. 316	Approx: 34°09.6'S/18°29.3'E. (bottom sampler only)	Khaki sand.	24
33 - 36	FAL. 30-31	Approx: 34°12'S/18°29'E. & northwards.	Broken shell; ? sand too.	41
35	FAL. 3,5	34°09.5'S/18°35.8'E. to 34°08.7'S/18°34.8'E.	Probably shelly sand.	18
36	FAL. 226-227	34°10.5'S/18°32.4'E.	Probably shelly sand.	26
37 - 38	FAL. 64-65	Approx: 34°17.3'S/18°48.7'E.	Shells; probably sand too.	25+
40	FAL. 222-225,293	34°13.9'S/18°31.6'E.	Coarse sand & fine shell.	91+
46	FAL. 186-188	34°12.8'S/18°36.5'E.	Much shell; ? sand too.	64+
48	FAL. 233-234	34°15.3'S/18°44.8'E.	Coarse khaki sand with shells, pebbles and stones.	25+
50	FAL. 230-232	34°17.4'S/18°31.4'E.	Probably coarse sand & shell.	37+
62	FAL. 205-206	34°17.6'S/18°39.2'E.	Broken shell; ? sand too.	39
64	FAL. 228-229,267	34°20.3'S/18°31.8'E.	Coarse khaki sand.	47
64	FAL. 241-242	34°18.5'S/18°34.2'E.	Khaki sand, grit and shell.	29
73	FAL. 183-185,306	34°22.1'S/18°35.2'E.	Khaki, shelly grit and gravel.	65+
77 - 82	FAL. 243-244	34°22.5'S/18°37.3'E.	Sand, grit and shell.	32
78	FAL. 237,250	34°22.7'S/18°43.1'E.	Green, pellet mud.	27
82	FAL. 238-239	34°20.6'S/18°39.4'E.	Probably mixed, green, pellet mud & sand.	39
88	FAL. 240,251	34°23.7'S/18°40.9'E.	Green, pellet mud.	27