IRISH FISHERIES INVESTIGATIONS

SERIES B (Marine)

No. 9 (1973)

AN ROINN TALMHAIOCHTA AGUS IASCAIGH
(Department of Agriculture and Fisheries)

FO-ROINN IASCAIGH (Fisheries Division)

DUBLIN:
PUBLISHED BY THE STATIONERY OFFICE

TO BE PURCHASED FROM THE
GOVERNMENT PUBLICATIONS SALE OFFICE, G.P.O. ARCADE,
DUBLIN.

12½p

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THE DISTRIBUTION AND ABUNDANCE OF ANIMALS AND PLANTS ON THE ROCKY SHORES OF BANTRY BAY

The Distribution and Abundance of Animals and Plants on the Rocky Shores of Bantry Bay

by

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Abstract

A survey of the rocky shores of Bantry Bay is described. This is intended to serve as a means by which future changes may be detected, as well as providing an account of a hitherto undescribed area of the Irish coast. The abundance of littoral animals and plants was assessed at regular vertical intervals on forty transects, and the distribution patterns of these species are described and discussed in relation to two major environmental variables, emersion and exposure to wave action. The method adopted may be suitable as a standard method for surveying rocky shores, and this is discussed in relation to the objectives of the survey.

Introduction

In 1968 Gulf Oil Terminals (Ireland) Ltd. opened a terminal for the transhipment of crude oil on Whiddy Island in Bantry Bay. Here crude oil is pumped ashore from 300,000 ton tankers to await shipment to other European ports in smaller vessels. This development, which may be followed by others, has brought with it some risk that oil pollution may damage the amenities of the area, which include an unspoilt and beautiful coastline and a small but growing fishing industry. This paper describes the initial stages of a biological survey designed to provide the means of detecting any effects that pollution might have on the marine ecology of the bay.

Aims and methods

It is not very likely that oil pollution will cause much biological damage in Bantry Bay; in the first three years of tanker operation only one moderately large spillage and three small ones have occurred. It is therefore important that the results of the survey should be of scientific value whether pollution effects are detected or not, and some of the most direct methods of detecting such effects are not appropriate to these circumstances. For instance, the qualitative determination of species distribution in a fairly uniform habitat can be very effective along a pollution gradient (Moore, 1971), but it may be difficult to find much of biological significance in the results in the absence of pollution. Hence the initial stage of the present investigation has been the making

Irish Fish. Invest. Ser. B, No. 9 (1973).

of a survey of the distribution and abundance of the fauna and flora of rocky shores in the bay, using the transect method developed by Moyse and Nelson-Smith (1963) from the abundance scales devised by Crisp and Southward (1958).

This method was used by Nelson-Smith (1967a) in his survey of the Welsh oil port of Milford Haven, and his belief that it would prove suitable for detecting changes appeared to be justified by the results of a second survey made some eight years later by Crapp (1971). Because this method was adopted for the Bantry Bay survey it has been possible to use the results for three purposes: as the basis of the general description of the area which is given in this paper; as a baseline for monitoring changes; and to define a descriptive framework which is the basis of more detailed population studies which are being carried out at present.

Forty sites were selected in and around Bantry Bay, and on each a transect was made from MLWS (mean low water of spring tides) to the top of the supralittoral zone. Levelling was carried out with the crosstaff instrument devised by Dr. A. Nelson-Smith, in which a spirit level is mounted on a vertical leg and surmounted by an angled mirror. So long as the horizontal distances are fairly short a line of stations can be established at regular vertical intervals by sighting along the horizontal spirit level. Moyse and Nelson-Smith (1963) found that a vertical interval of about one tenth of the spring tide range was most useful in the Dale area of Pembrokeshire, and this principle was extended by Crapp (1970) in adapting the instrument to the metric system. In any area the mean range of spring tides in metres is determined, and the vertical leg is set to a length one tenth of this; thus in Bantry Bay an interval of .3 metres was used on a spring tide range of 2.9 metres. Heights are described relative to chart datum, but as this is at present an arbitary level which is subject to revision the base level of each transect was taken to be MLWS, which is a constant level on the shore and accessible during a reasonable number of tides. Therefore the lowest station of each transect was located .4 metres above chart datum, and in the field this was determined by reference to the predicted height of low water given in the tide tables (Admiralty Hydrographic Department, 1970). The real height of low water may differ from the predicted height because of the effects of wind and atmospheric pressure changes, and this source of error was minimised as far as possible by avoiding extreme weather conditions. Levels were also checked on subsequent visits to the sites.

A list of more than sixty common littoral species was made, and at each station of each transect the abundance of these animals and plants was assessed in terms of the abundance scales devised by Crisp and Southward (1958) and expanded by Ballantine (1961a), Moyse and Nelson-Smith (1963) and Crapp (1970). These scales are given in full below, as details of the most recent additions, the extremely abundant (Ex) and superabundant (S) categories first suggested by Dr. J. R. Lewis, have not been published previously. The older categories are abundant (A), common (C), frequent (F), occasional (O) and rare (R).

1. Lichens and "Lithothamnia".

Ex More than 80% cover
S 50-80% cover
A 20-50% cover
C 1-20% cover
F Large scattered patches
O Widely scattered patches, all small
R Only one or two patches

2. Algae.

Ex More than 90% cover
S 60-90% cover
A 30-60% cover
C 5-30% cover
F Less than 5% cover, zone still apparent
O Scattered plants, zone indistinct
R Only one or two plants

3. Barnacles (except *B. perforatus*), *Littorina neritoides*, and *L. saxatilis neglecta*.

Ex More than 5 per sq. centimetre
S 3-5 per sq. cm.
A 1-3 per sq. cm.
C 10-100 per sq. decimetre
F 1-10 per sq. decimetre, never more than 10 cm. apart
O 1-100 per sq. metre, few within 10 cm. of each other.
R Less than 1 per sq. m.

4. *Balanus perforatus*

Ex More than 3 per sq. cm.
S 1-3 per sq. cm.
A 10-100 per sq. decimetre
C 1-10 per sq. decimetre
F 10-100 per sq. metre
O 1-10 per sq. metre
R Less than 1 per sq. metre

5. Limpets and periwinkles (except *L. neritoides* and *L.s.neglecta*).

Ex More than 200 per sq. metre
S 100-200 per sq. m.
A 50-100 per sq. m.
C 10-50 per sq. m.
F 1-10 per sq. m.
O 1-10 per sq. decametre
R Less than 1 per sq. decametre

6. Topshells, dogwhelks, anemones, and sea urchins.

Ex More than 100 per sq. metre
S 50-100 per sq. m.
A 10-50 per sq. m.
C 1-10 per sq. m., locally sometimes more
F Less than 1 per sq. m., locally sometimes more
O Always less than 1 per sq. m.
R Less than 1 per sq. decametre

7. Mussels.

Ex More than 80% cover
S 50-80% cover
A 20-50% cover
C Large patches, but less than 20% cover
F Many scattered individuals and small patches
O Scattered individuals, no patches
R Less than 1 per sq. metre

8. *Pomatoceros triqueter*

A More than 50 tubes per sq. decimetre
C 1-50 tubes per sq. decimetre
F 10-100 tubes per sq. metre
O 1-10 tubes per sq. m.
R Less than 1 tube per sq. metre

9. *Spirorbis* spp.

A 5 or more per sq. centimetre; on 50% of suitable surfaces
C 5 or more per sq. cm.; on 5-50% of suitable surfaces
F 1-5 per sq. cm.; or on 1-5% of suitable surfaces
O Less than 1 per sq. cm.
R Less than 1 per sq. m.

Most of these categories were originally intended for an assessment over the whole shore, and in this list several have been modified to make them more appropriate to transect work. Ideally abundance values were assessed over a transect width of about ten metres, but on some sites a narrower strip had to be used. The inhabitants of rock pools, gullies, the undersides of stones and the landward faces of boulders and ridges were recorded merely as "present". A scale drawing of the shore in profile was also made.

Results

The results from forty transects must be arranged in some way, and in the case of rocky shores the degree of exposure to wave action will generally be the most suitable criterion for doing this. Sometimes another environmental gradient must also be considered; for example, Nelson-Smith (1967a) ranked his results in order of penetration into the estuarine conditions of Milford Haven. This factor does not apply in the case of the present survey, for although several small rivers enter Bantry Bay at various points no transects were located close to these. Objective physical measurements of exposure are very difficult to make, and therefore the biological exposure scale of Ballantine (1961a) has been used to set the shores into the order given in Table 1.

The eight categories of exposure are artificial creations, for each shore lies at a point on a theoretically continuous transition from extremely exposed to extremely sheltered conditions. However, biological exposure scales have many theoretical and practical flaws, which have been discussed by Ballantine (1961a) and Lewis (1964), not least of which is the fact that they are not very accurate. Partly this is because other factors besides exposure determine the distribution of species; for instance, conditions on steep and gentle slopes are very

Table 1. List of transect sites, with dates of surveys and Ballantine exposure grades.

No.	Name of Site	Date	Exposure Grade
1.1	Mizen Head	17. 8.71	1. Extremely exposed
2.1	Collack	18. 8.71	2. Very exposed
2.2	Mehal Head	30.12.70	
2.3	Shot Head	31.12.70	
3.1	Lion Point	21. 8.71	3. Exposed
3.2	Reen Point	19. 8.71	
3.3	Whiddy Point West	6. 8.71	
3.4	Reennagough Point	11. 7.71	
3.5	Dereenacarrin	11. 8.71	
3.6	Ardaturrish Point	10. 7.71	
4.1	Yellow Rock Bay	22. 8.71	4. Semi-exposed
4.2	Harris Cove	12. 8.71	
4.3	Gerahies	5. 9.71	
4.4	Carrigacloash	20. 8.71	
4.5	Gun Point	28. 2.71	
4.6	Muccurragh Point	26. 2.71	
4.7	Iskanafeelna Point	24. 8.71	
4.8	Eagle Point	4. 9.71	
4.9	Ardnagashel West	23. 8.71	
4.10	Reenavanny	9. 7.71	
5.1	Cooskeen Cove no. 1	29. 1.71	5. Fairly sheltered
5.2	Crowdy Point	13.11.70	
5.3	Reenydonagan Point	13. 8.71	
5.4	Ardaturrish Bay	21. 8.71	
5.5	Bocarnagh Bay	12. 8.71	
5.6	Illauncreeveen Bay	24. 8.71	
6.1	Ardnagashel East	6. 9.71	6. Sheltered
6.2	Gurteenroe Point	1. 2.71	
6.3	Furkeal	12. 7.71	
6.4	Coomageragh	30. 1.71	
6.5	Derrycreigh	10. 8.71	
6.6	Glengarriff Castle	21. 7.71	
6.7	Cooskeen Cove no. 2	24. 2.71	
7.1	Black Rock	7. 9.71	7. Very sheltered
7.2	Roches Point	25. 2.71	
7.3	Snave Bay	9. 9.71	
7.4	Dunnamark Point	7. 9.71	
8.1	Corriveillaun	3. 9.71	8. Extremely sheltered
8.2	Fir Lands	8. 9.71	
8.3	Inchintaggart	11. 8.71	

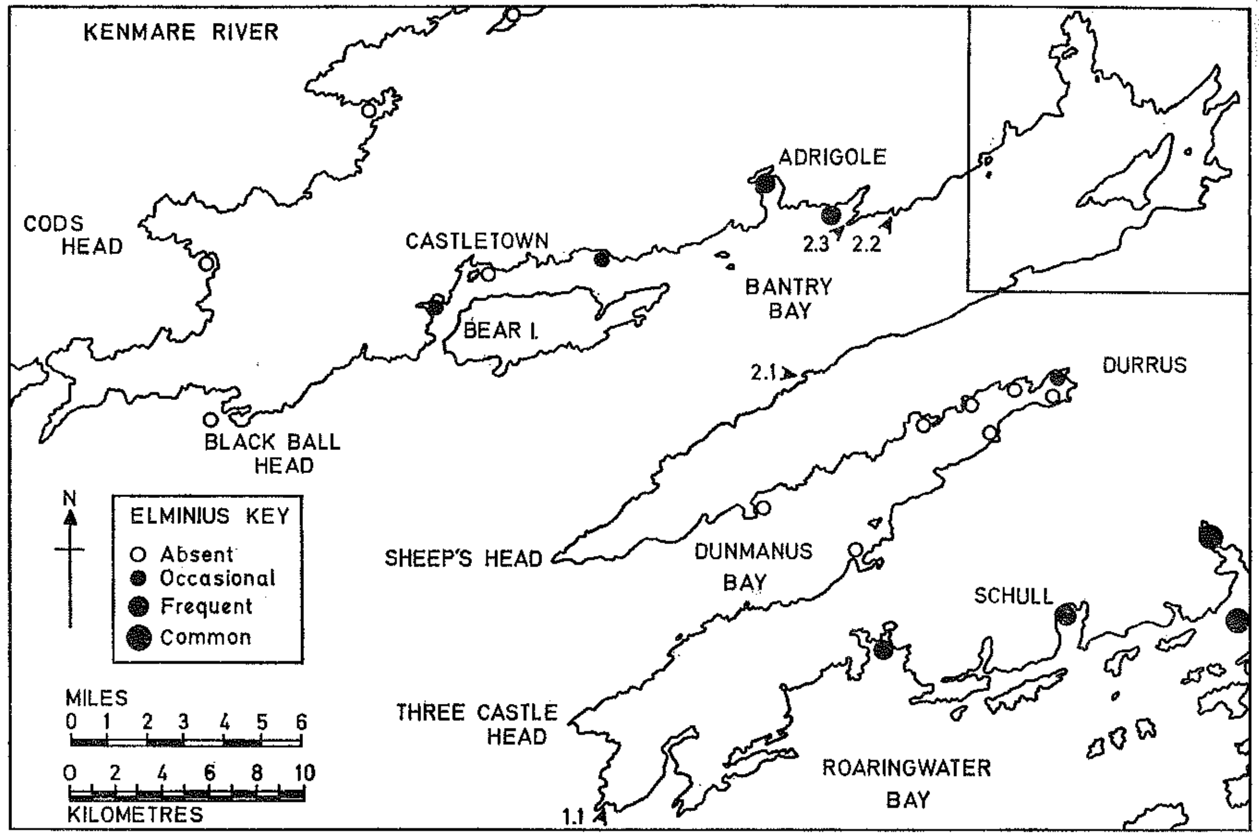


Fig. 1. Map of part of south west Ireland, showing the location of the four most exposed transects, and the distribution of *Elminius modestus* in February, 1972. The enclosed area at the top right hand corner is shown on a larger scale in Fig. 2.

different. Very steep and almost flat shores, as well as those with marked changes in slope at different levels, were avoided in the survey, but nevertheless it was inevitable that very varied topographies would be encountered. It is also difficult to decide how many species may be used as indicators of exposure, and to define the relative importance of each one. Therefore it was possible to assign each shore to one of the eight categories with reasonable confidence, but although the order given within each category appears to be reasonable, there is little real significance in it.

Another biological exposure scale, with five categories, was devised by Lewis (1964). Lewis' unit 1 ("very exposed") is equivalent to Ballantine's units 1 and 2 in the Bantry area, and his units 2 ("exposed") and 3 ("semi-exposed") are equivalent to Ballantine's units 3 and 4 respectively. Lewis' unit 4 ("sheltered") includes Ballantine's units 5 and 6, whilst unit 5 ("very sheltered") is equivalent to units 7 and 8 on the Ballantine scale. Lewis' scale is a general one that covers the whole of the British Isles, but he points out that it is possible to specify more detailed stages in the exposure transition in a more local area, as Ballantine did in the Dale area of South Wales. In a small area it is better to use the more detailed scale, but any biological exposure scale becomes progressively less accurate with increasing distance from the area for which it was devised, and the more detailed the scale, the smaller the area over which it applies. In several respects it has proved difficult to apply Ballantine's scale in the Bantry area, and this will be discussed later.

The locations of the transects are shown in Figs. 1 and 2, and the results are presented in diagrammatic form in Figs. 3-10. In each diagram the horizontal axis represents the exposure transition from site no 1.1 to no. 8.3, except where only one site in each category is represented. The vertical axis represents height in metres above chart datum, and the width of the "kite-shaped" histograms for each species at each site is proportional to the abundance recorded at each station, as illustrated in the scales given in Figs. 3, 7, and 10.

An autecological, or species by species, approach has been adopted in describing the results, because this is the simplest way of treating results obtained by the method used. This tends to emphasise the influence of

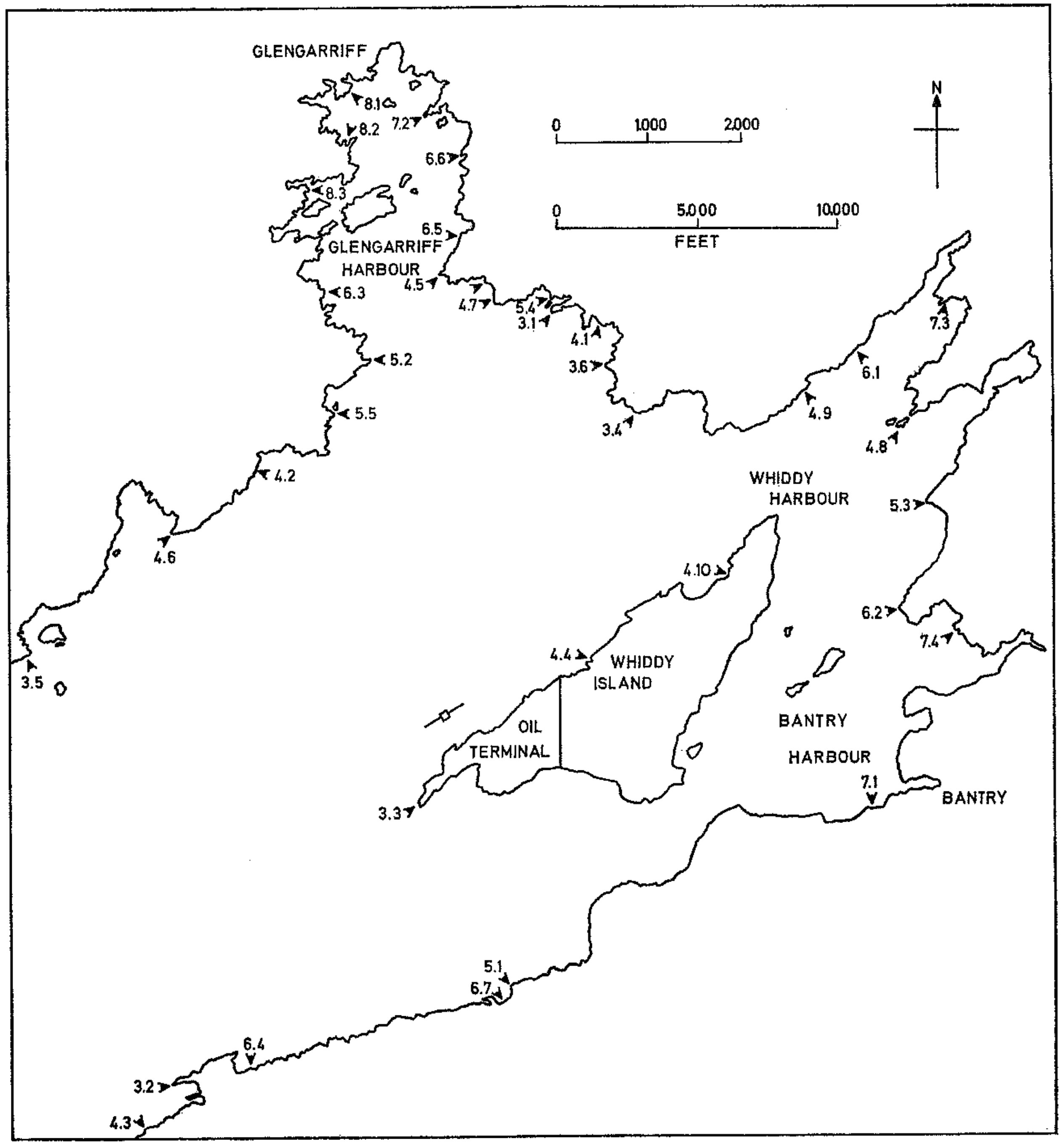


Fig. 2. Map of inner Bantry Bay showing the locations of all but the most exposed transect sites.

the main physical gradients, emersion and exposure to wave action, at the expense of descriptions of community structures in different habitats. It is difficult to avoid this without describing everything twice, but some references to the principal community patterns observed will be made in the text. Notes on the results are given below, starting with a brief description of the geology of the area, and passing via the lichens and the brown, green and red algae to the animals. Nomenclature of species is based upon Ferry and Sheard (1969) for the lichens, Parke and Dixon (1968) for the algae, and the Plymouth Marine Fauna (Marine Biological Association, 1957), except where otherwise stated. The nomenclature of Lewis (1964) is followed in referring to the vertical zones of the shore. This account of the results is intended as a general description of

the area, not as a basis for making comparisons with any surveys made in the future. This should be done with the aid of detailed records which have been deposited with the Fisheries Division in Dublin and in the Department of Zoology in University College, Cork.

The geological background.

The stratigraphy of the area has recently been described by Coe and Selwood (1968). Bantry Bay lies in a syncline, the hinge zone of which runs through Eagle Point and Whiddy Island (Fig. 2). The youngest rocks are the Carboniferous Slates, which form most of the shores of the bay, but the underlying rocks of the Upper Old Red Sandstone are exposed in some places, particularly in and around Glengarriff Harbour. Between Coomageragh and Cooskeen Cove (Fig. 2) the shore is mostly smooth, vertical, and inaccessible, whilst boulder and pebble beaches are found between Cooskeen Cove and Dunnamark Point and along the southern and eastern shores of Whiddy Island. There are a few rocky outcrops on these beaches, and the Black Rock transect is sited on one of these. Around the rest of the bay shores of bedrock predominate, and areas of sand or mud are scarce.

Flowering plants (Fig. 3) were not considered as individual species, but are of significance mainly because the lowest level at which they were abundant was taken as the upper limit of each transect. This level rose from below MHWS on extremely sheltered shores to 20 metres or more above MHWS in extreme exposure.

Anaptychia fusca (Fig. 3). The supralittoral zone at Dale in Pembrokeshire was divided into four zones by Ferry and Sheard (1969). In the present survey only the distribution of the most obvious supralittoral lichens was recorded, but these same zones could be recognised. These are not shown completely in Fig. 3 because the vertical axis has been restricted to save space. The entire supralittoral zone lies above the area covered by the diagrams for the extremely exposed site, whilst on the very exposed shores only the lowest part of zone 1 is included.

The uppermost zone, zone 4, merges with the non-maritime vegetation above the transects, and the highest species recorded was *Anaptychia fusca* in zone 3.

Grey lichens (Fig. 3) were considered as a group, and extend throughout the supralittoral zone. *Lecanora atra*, assigned to group 3 by Ferry and Sheard, was found at the upper levels of most transects, but other species, principally of *Lecanora* and *Lecania*, extended down through zones 2 and 1.

Ramalina siliquosa and *Xanthoria parietina* (Fig. 3) were the dominant species of zone 2.

Caloplaca spp. (Fig. 3) were the dominant lichens of the lowest zone, zone 1, and were absent from extremely sheltered shores.

Lichina confinis (Fig. 3) was mainly found in the upper part of the littoral fringe, but often extended above this into the lower part of the supralittoral. The species was found on all the sites, and was not absent from the most sheltered ones, which contradicts Ferry and Sheard's (1969) statement on its distribution but agrees with the observations of Lewis (1964).

Lichina pygmaea (Fig. 3) was found principally on the more exposed shores, but was recorded from dry and sunlit rocks on fairly sheltered and sheltered shores. This species scarcely ever extended below MHWN.

"Verrucaria maura" (Fig. 3). This term was used to refer to *V. maura* itself, and also to the other species of *Verrucaria* which share its thin, dull, black form and littoral fringe habitat. These species extended almost down to MHWN on many shores, and were also found in zones 1-3 of the supralittoral zone, especially in damp areas. In the littoral fringe they were abundant or superabundant, not surprisingly in view of the fact that the dominance of *Verrucaria* is one of the most important criteria used to define the extent of this zone.

"Verrucaria mucosa" (Fig. 3). This term was used to refer to *V. mucosa* itself, and also to the other species of *Verrucaria* which share its thick, shiny, greenish form and eulittoral habitat. These were not very prominent on the shores studied, and this may reflect the fact that shores with loose boulders and pebbles were avoided, for these species seem to be most successful on shores where there is a certain amount of scouring and abrasion.

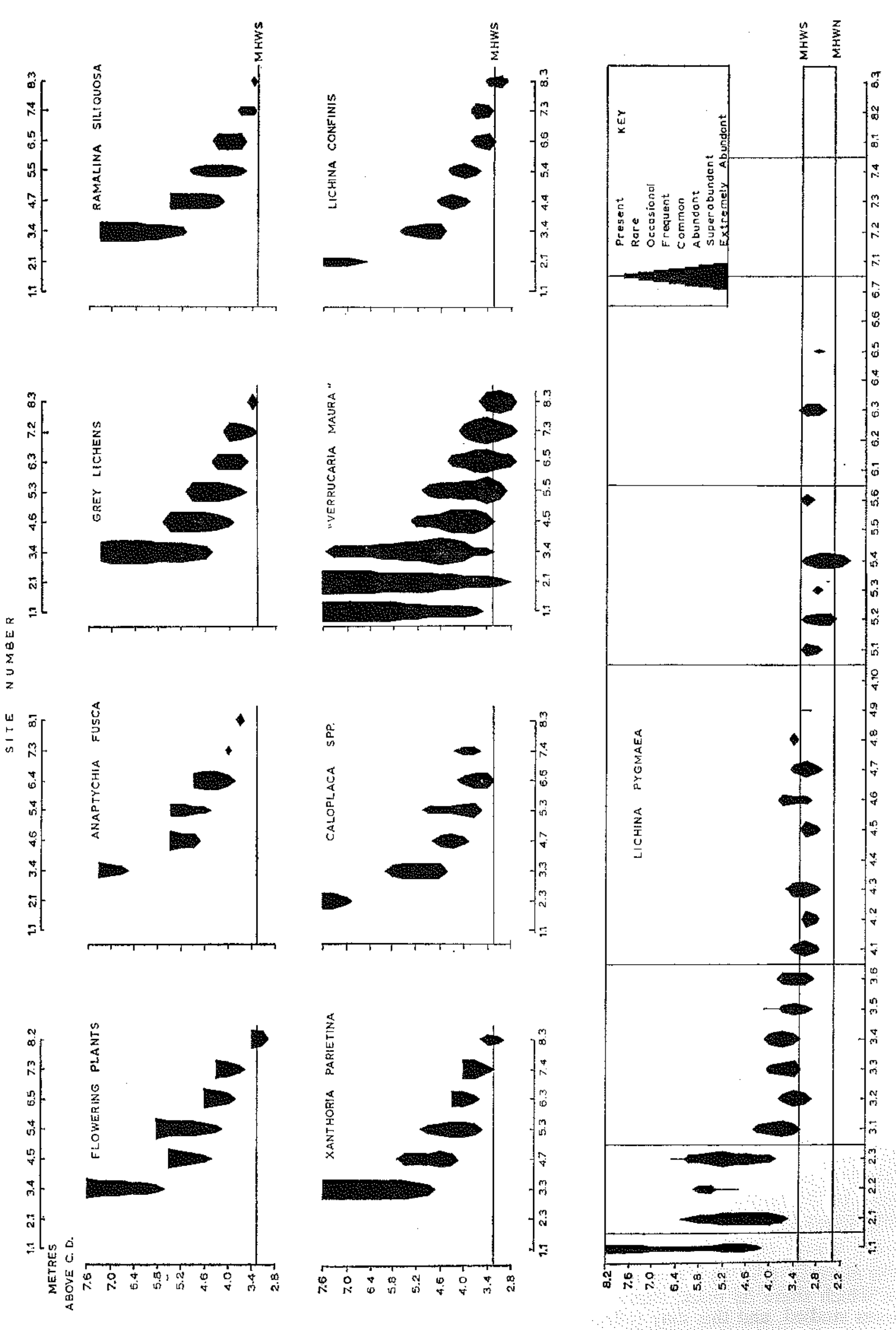


Fig. 3. Distribution of various species of lichens in Bantry Bay.

Pelvetia canaliculata (Fig. 4) formed the highest belt of fucoid algae on all shores except those of grades 1 and 2. On exposed shores the species was present as scattered plants which were found almost entirely above MHWS. With increasing shelter the *Pelvetia* belt was more luxuriant and at a lower level, and scarcely any plants were found above MHWS on extremely sheltered shores.

Fucus spiralis (Fig. 4) was found on very exposed shores as the small form *nanus*, and a complete range of plants linked this with the larger form *spiralis* on the more sheltered sites. Under these conditions, similar to those referred to by Lewis (1964), it was very difficult to determine the boundary between the two forms. Form *spiralis* certainly extended onto semi-exposed sites, and very luxuriant growths were found on the flatter surfaces at Carrigacloash, Ardnagashel West, and Reenavanny.

Fucus distichus subsp. *anceps* was not found during the survey; the Bantry area is some way to the south of the presumed limits of its range (Powell, 1957b).

Fucus vesiculosus (Fig. 4) is a very successful species in Bantry Bay, and was found on all shores except the extremely exposed Mizen Head. On very exposed and exposed shores form *linearis* Huds. (=form *evesiculosus* auctt., Powell, 1957a) was found alone, generally forming luxuriant growths on the exposed shores. On semi-exposed shores form *linearis* was mixed with form *vesiculosus*, and great variations in total cover were found between one site and another. The species was least successful on the steepest shores (Harris Cove and Iskanafeelna Point), where it was represented solely by form *linearis*. On the flattest shore (Carrigacloash) *F. vesiculosus* covered almost the whole of the eulittoral zone, and the two forms were mixed together in hopeless confusion; not only did they grow side by side, but many plants appeared to have characters of both forms. The remaining sites appeared to lie between these two extremes, with the species absent from the steepest slopes but forming dense growths on the flatter areas.

A similar variation in total cover was found on the fairly sheltered shores, but form *linearis* was usually absent from these. The plants were notably patchy in distribution, and often appeared to form clumps of one age group. Knight and Parke (1950) found that *Fucus vesiculosus* was a fast growing and short lived species, and plants more than two years old formed a very small proportion of the population. This is probably true in Bantry Bay, where the age of a plant could be roughly deduced from its appearance, and unless a very high percentage cover was recorded it was usually possible to distinguish between small areas dominated either by sporelings, one year old plants, or plants aged two or more years.

On more sheltered shores *F. vesiculosus* was sometimes found in luxuriant patches, but it was increasingly replaced by *Ascophyllum nodosum* as exposure decreased. On very sheltered shores the species formed a thin and irregular border around the *Ascophyllum* dominated areas, and on extremely sheltered shores it was generally confined to the lower part of the shore below the *Ascophyllum* belt.

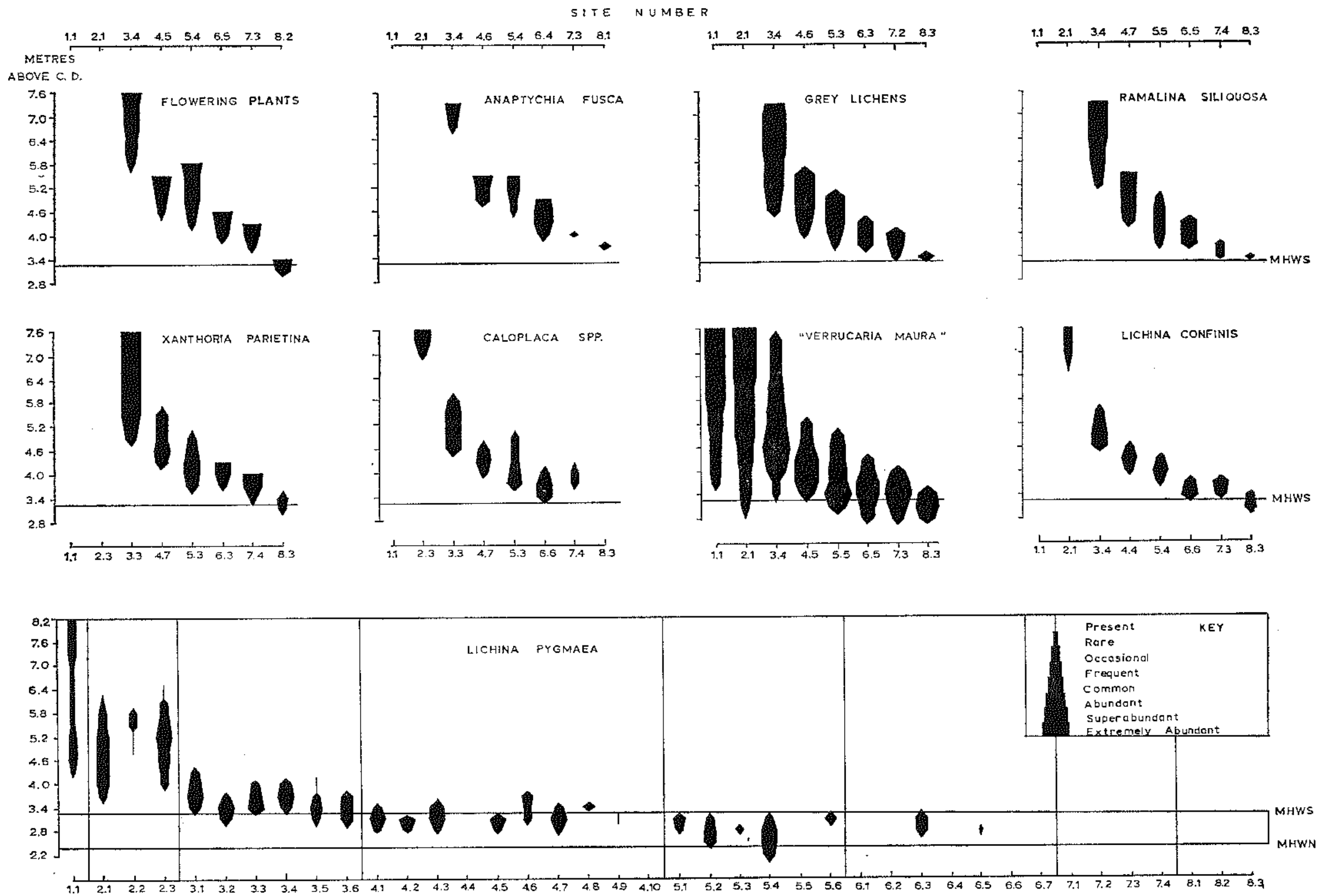
Fucus ceranoides was very common where rivers and streams entered the bay, but was not recorded from any of the transects.

Fucus serratus (Fig. 4) was scarcely to be found on exposed shores, but was increasingly successful in greater shelter, reaching a maximum on the very sheltered shores. On extremely sheltered shores *F. serratus* was less abundant, but extended down well below MLWS.

Ascophyllum nodosum (Fig. 4) usually covered the entire rock surface between MLWN and MHWN on extremely sheltered and very sheltered shores, except on the steep and shaded Black Rock transect. On sheltered shores *Ascophyllum* was most successful on gentle slopes and broken surfaces, as at Glengarriff Castle and Gurteenroe Point, but very few plants were found on steep and smooth shores such as Furkeal. Large patches of *Ascophyllum* were found on the fairly sheltered shores at Ardaturrish Bay and Illauncreeveen Bay, but under more exposed conditions little more than scattered stumps of the plants were found.

Alaria esculenta (Fig. 4) rose almost to MTL on the most exposed shores, although most of the plants were found below MLWN. On exposed shores its distribution was more irregular, and the species was confined to deep and shaded pools on the semi-exposed shores at Harris Cove and Gerahies.

Laminaria digitata (Fig. 4) was the dominant sublittoral kelp recorded in this survey. On the extremely exposed and very exposed shores it was replaced by *Alaria*, except at Shot Head. On the exposed shores *L. digitata* was found up to MLWN, except at Lion Point, where only a few plants remained of a population that had been



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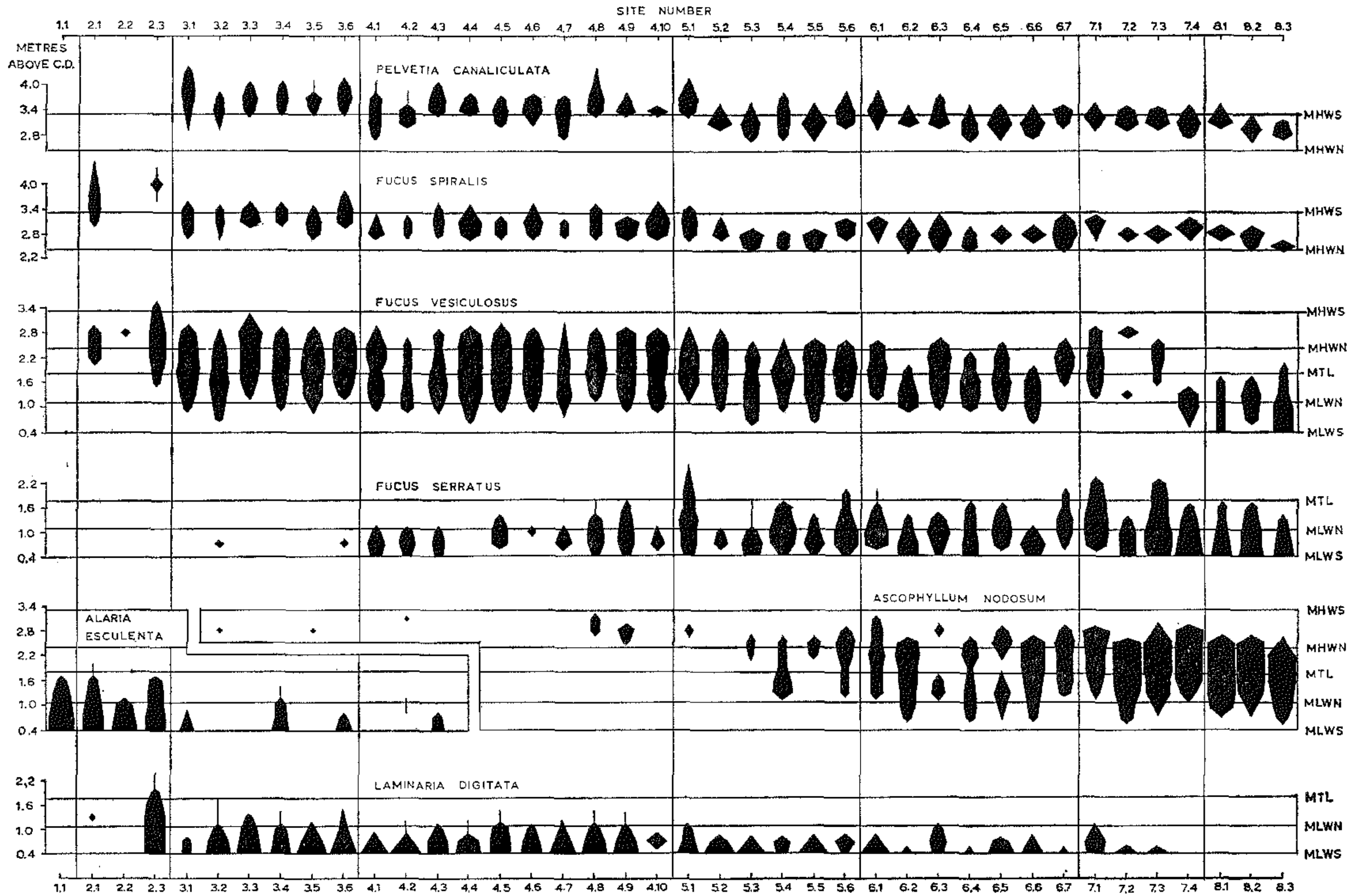

Fig. 4. Distribution of some brown algae in Bantry Bay.

superabundant in December 1970 (eight months previous). At this time the kelp had borne very large numbers of the small limpet *Patina pellucida*, and it seems likely that these animals had grazed down the *L. digitata*. By August most of the *Patina* had either died or moved away, although the few remaining kelps (*L. digitata*, *Sacchoriza polyschides*, and *Alaria*) were very heavily infested.

Laminaria digitata dominated the upper part of the sublittoral zone on semi-exposed and fairly sheltered shores, except at Reenavanny, Ardaturrish Bay and Illauncreeveen Bay, where the sea urchin *Paracentrotus lividus* was the dominant species. Grazing by these animals had presumably eliminated kelps, but a ragged fringe of plants was found immediately above the upper limit of the urchins, probably indicating that *L. digitata* has a slightly greater tolerance of emersion than *Paracentrotus*. On some sheltered and very sheltered shores *L. digitata* barely extended above MLWS, but the main zone was always present below this, except at Dunnamark Point, where there was a sandy bottom below this level. The species was not found on the three extremely sheltered shores.

Laminaria saccharina was found on only eight transects, being recorded at MLWS at Black Rock (superabundant), Gun Point (common), Furkeal (frequent), and Iskanafeelna Point, Illauncreeveen Bay, Coomageragh and Cooskeen Cove no. 2 (occasional). At Roches Point it was abundant below MLWS. This distribution pattern is not easy to explain, and although most of the occurrences are on more sheltered shores the species does not appear to penetrate into greater shelter than *L. digitata*. It is possible that where *L. saccharina* does appear to replace *L. digitata* in shelter (Ballantine 1961a, Lewis, 1964, Moyse and Nelson-Smith 1963) this is a result of its greater tolerance of silt (Jones and Williams, 1966).

Laminaria hyperborea was essentially sublittoral and characteristic of the more exposed sites. It was frequent or occasional at MLWS at Lion Point, Reen Point, Ardaturrish Point, Gerahies, Carrigacloash, Gun Point and Mucurragh Point, and could be seen below this level on most other exposed sites.

Sacchoriza polyschides could be seen in the sublittoral zone on many shores, but only rose as high as MLWS at Collack, Lion Point, and Gerahies.

Himanthalia elongata (Fig. 5) was usually absent on extremely exposed and very exposed shores, but with increasing shelter often formed a distinct belt until replaced by *Fucus serratus* on fairly sheltered shores.

Enteromorpha spp (Fig. 5) were found on almost every transect, but were generally no more than frequent or occasional on the open rock. The habitats in which these algae are most successful, in the vicinity of fresh water or seasonally on pebble beaches, were not found on any of the transects, and although high level rock pools were often filled with *Enteromorpha* these occurrences were only noted as "present".

Ulva lactuca (Fig. 5) had the same sort of ubiquitous distribution as *Enteromorpha*, but was confined to the lower levels of the shore except in exposure. In some places fairly thick beds of *Ulva* were found below MLWN or observed in the sublittoral zone.

Cladophora spp. (Fig. 5) (probably *C. rupestris*) were found on most shores except on the extremely exposed and very exposed sites, and were most successful on the very sheltered and extremely sheltered sites, where they were sometimes abundant under dense *Ascophyllum*.

Codium spp. (Fig. 5) were found in the lower part of the eulittoral zone on all the exposed, semi-exposed and fairly sheltered shores. The plants were widely scattered on the surface (usually occasional), and in the highest or most exposed places were confined to pools or crevices. These algae were not always found on the more sheltered shores, and were increasingly confined to the lowest levels.

Gigartina stellata (Fig. 5) extended through much of the eulittoral zone on very exposed and extremely exposed shores, but did not form distinct zones. In greater shelter the species was confined to the lower part of the shore, and was found in more luxuriant stands. On sheltered shores a thick belt of red algae was often found between MLWS and MLWN, and *Gigartina* formed a large proportion of this at Ardnagashel East and Furkeal. The species was found on only two of the very sheltered shores, and was absent from extreme shelter.

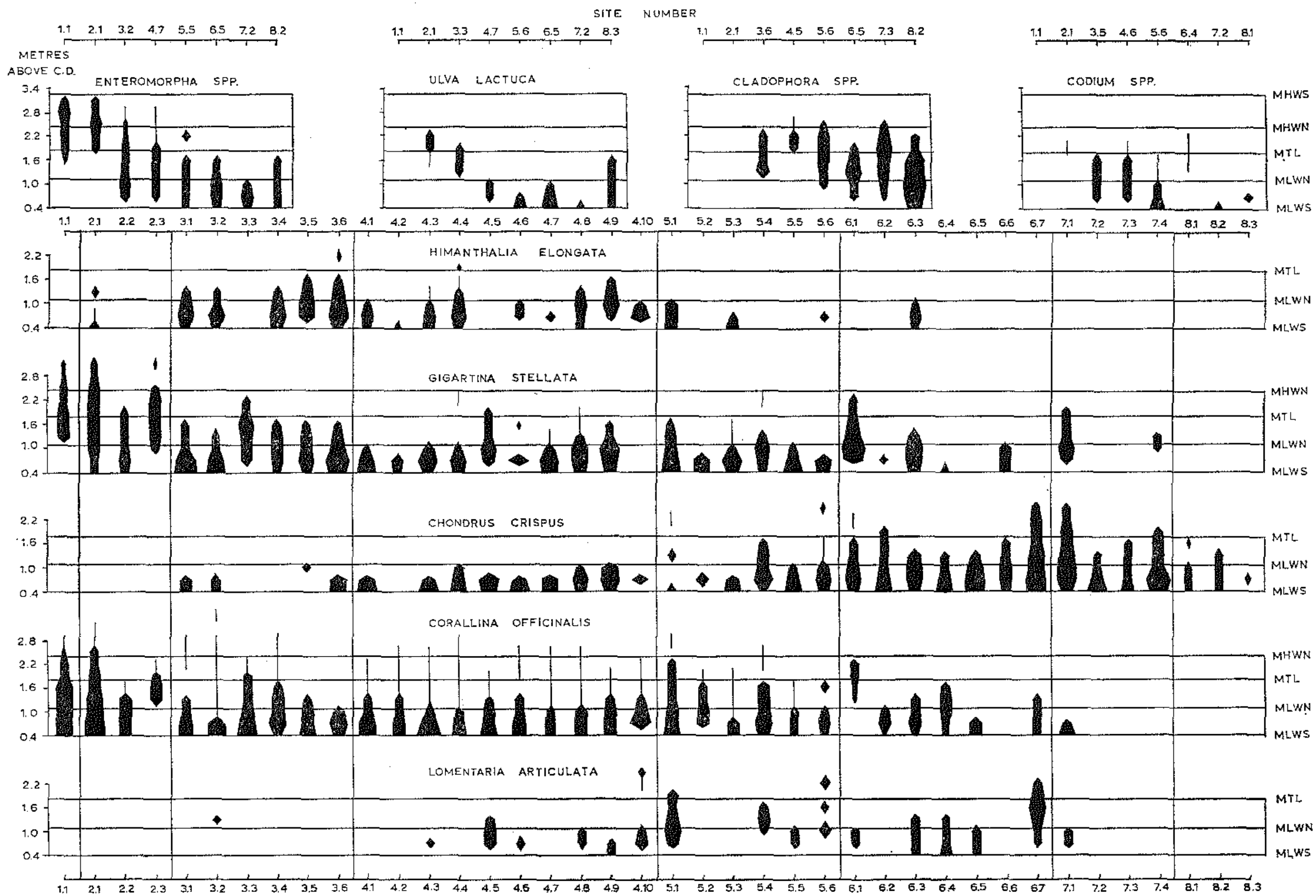

Fig. 5. Distribution of various species of algae in Bantry Bay.

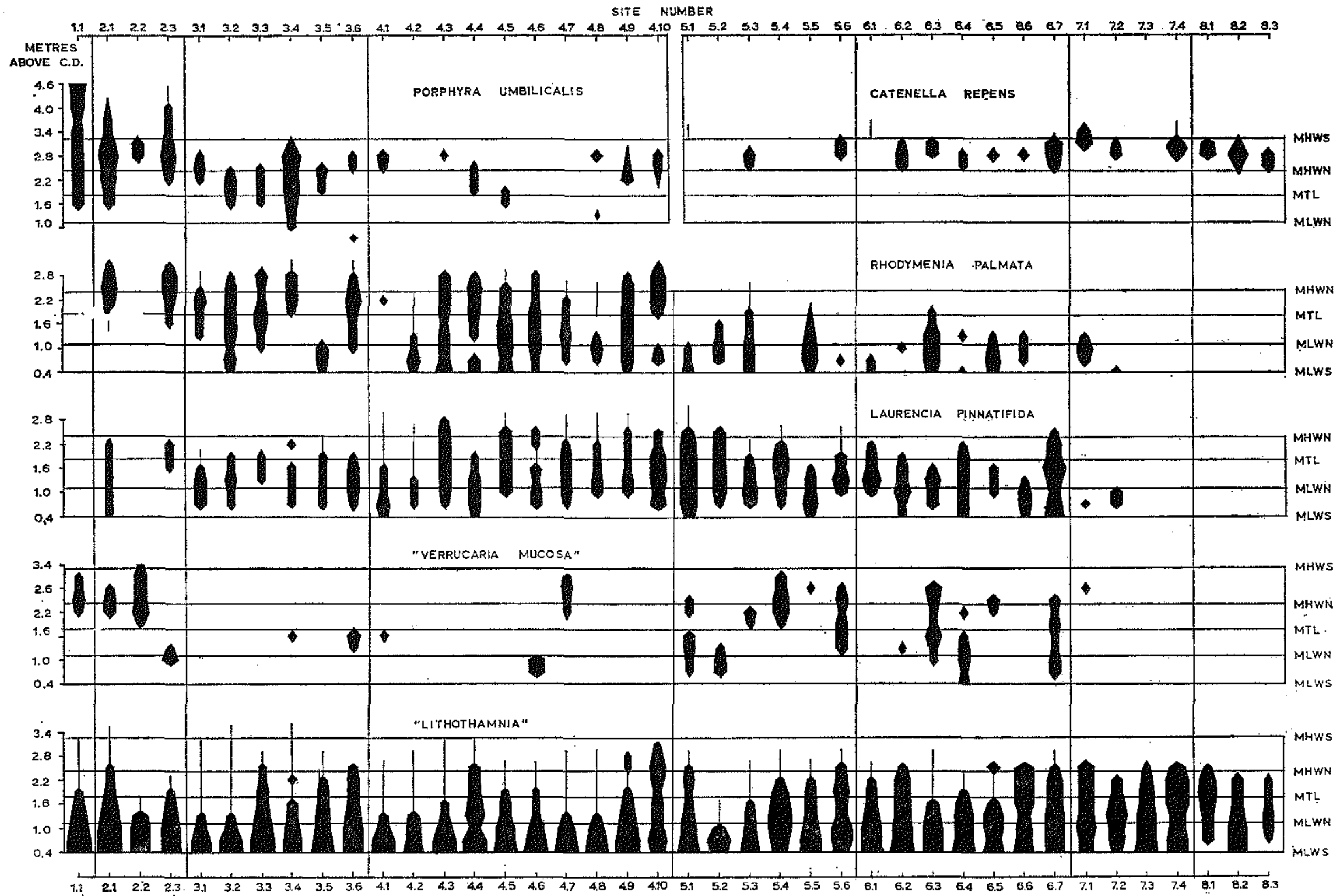

Fig. 6. Distribution of some red algae and a lichen in Bantry Bay.

Chondrus crispus (Fig. 5) formed mixed populations with *Gigartina* on exposed, semi-exposed and fairly sheltered shores, and dominated and replaced *Gigartina* in greater shelter. In extreme shelter it was less successful in the littoral zone, and was never more than occasional.

Furcellaria fastigiata was not included in the list of species studied, and this omission proved to be unfortunate when it was frequently encountered on the lower shore in shelter, most notably at Cooskeen Cove no. 2 and Roches Point.

Corallina officinalis (Fig. 5) was found on the open rock in the lower shore, and in pools at higher levels, on exposed, semi-exposed and fairly sheltered shores. On very exposed and extremely exposed shores it was found on open rock up to MHWN, whilst on sheltered shores only a few plants were found under fucoid algae. *Corallina* was absent from the most sheltered shores.

Lomentaria articulata (Fig. 5) was confined almost wholly to semi-exposed, fairly sheltered and sheltered shores, and on these an irregular distribution pattern was found.

Porphyra umbilicalis (Fig. 6) was present in the eulittoral zone, mainly as scattered plants, on exposed and semi-exposed shores. In greater shelter it was not found, except for rare specimens at Cooskeen Cove no. 2 and Roches Point. High level belts of *Porphyra* were found only on extremely exposed and very exposed shores, where they were continuous with the eulittoral plants. At Mizen Head the species was frequent up to three metres above MHWS in summer, but the high level belts were barely present at Mehal Head and Shot Head even in winter. The thin remnant of the high level belt found on the Collack transect when this was surveyed in August 1971 had developed into a superabundant band in February 1972.

Catenella repens (Fig. 6) was found, rather erratically, under the *Fucus spiralis* and *Pelvetia* belts on the more sheltered shores.

Rhodymenia palmata (Fig. 6) was absent from the most sheltered shores, but was otherwise widely distributed. There was a marked change in its vertical distribution with changes in exposure, as illustrated.

Laurencia pinnatifida (Fig. 6) was widely distributed in the eulittoral zone, although absent from the most sheltered shores and relatively sparse in great exposure.

"*Lithothamnia*" (Fig. 6) was used as a convenient term for the encrusting coralline algae. These were found on every transect, principally at the lowest levels and in pools, but extending up the shore on the open rock in exposure and under the fucoids in shelter.

Patella aspera (Fig. 7) was the dominant limpet of extremely exposed and very exposed shores, on which it was found up to MHWS. On exposed shores it was found up to MHWN and sometimes higher in pools and was co-dominant with *P. vulgata* around MTL; below this *P. aspera* was dominant. *Patella aspera* was generally co-dominant with *P. vulgata* at the lower levels of semi-exposed shores, but above this relatively few *aspera* were found, and the species was confined to pools above MTL. On fairly sheltered shores some *P. aspera* were found at MLWN and below and in pools, but on the open rock it was always subordinate to *P. vulgata*, and it was scarcely found at all in greater shelter.

Patella depressa (for synonymy see Ballantine, 1961b) is believed to be absent from Ireland, and was not found in this survey.

Patella vulgata (Fig. 7) was restricted to the upper levels on extremely exposed and very exposed shores, where it was subordinate to *P. aspera* except around MHWS. With increasing shelter the zone dominated by *P. vulgata* extended further down the shore: as described above, the boundary lay at around MHWN on very exposed shores, at MTL on exposed shores, and around MLWN on semi-exposed shores. On fairly sheltered and sheltered shores *P. vulgata* was abundant (or more) and dominant throughout the eulittoral zone, but became increasingly scarce under the dense *Ascophyllum* cover of very sheltered and extremely sheltered shores.

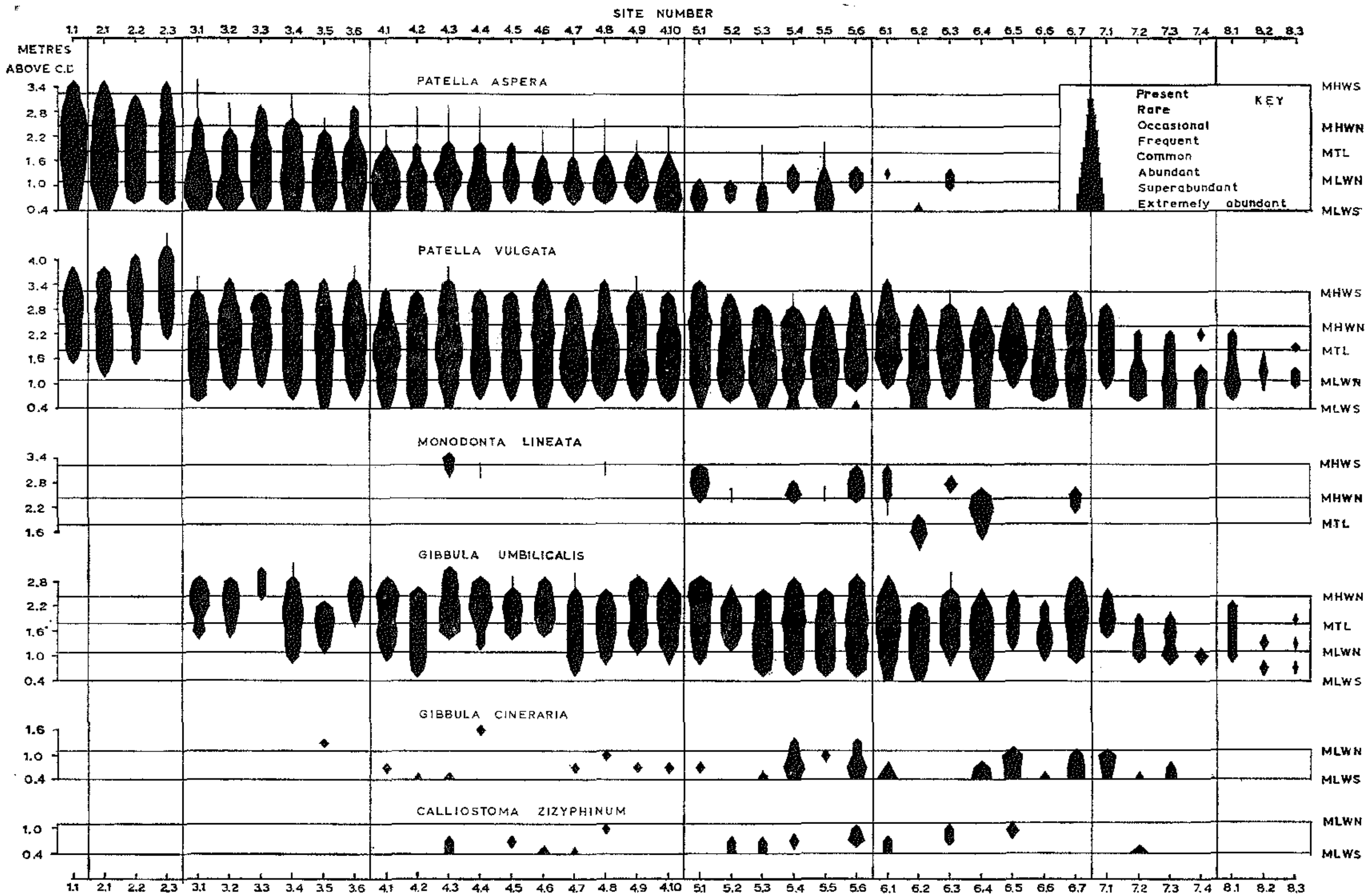

Fig. 7. Distribution of limpets and topshells in Bantry Bay.

Monodonta lineata (Fig. 7) was found mainly on fairly sheltered and sheltered shores, although a few individuals were found in high level pools and hollows on three semi-exposed shores. The distribution of the species was fairly erratic, and its relative scarcity may reflect the fact that all the transects were located on bedrock shores, for *Monodonta* was often observed to be abundant on sheltered pebble beaches.

Gibbula umbilicalis (Fig. 7) was common or abundant on exposed and semi-exposed shores, where it was most numerous around the holdfasts of *Fucus vesiculosus*, possibly finding local shelter here. The species was most successful on fairly sheltered and sheltered shores, but became scarce in greater shelter.

Gibbula cineraria (Fig. 7) was recorded from the lowest stations on many transects, but was commonest on the more sheltered shores, although absent from extreme shelter.

Calliostoma zizyphinum (Fig. 7) was found in the same habitat as *G. cineraria*, but was less common.

Mytilus edulis (Fig. 8). In this survey *Mytilus galloprovincialis* Lamarck was not separated from *M. edulis L.* Tebble (1966) considered that *galloprovincialis* was probably a race or variety of *edulis*, but it may in fact represent a separate species (Lewis and Seed, 1969). However, although mussels of the *galloprovincialis* type frequently appeared to be numerous or predominant, notably on the more exposed shores, they were often difficult to distinguish from *M. edulis* in the field, and lumping the two forms together could be justified for practical reasons if not for taxonomic ones.

Mytilus edulis in the Bantry area was clearly divided into exposed shore and sheltered shore populations. The former reached their maximum development on extremely exposed and very exposed shores, and at Mehal Head and Shot Head the *Mytilus* community dominated the whole of the lower eulittoral zone except on vertical surfaces, where barnacles and limpets were numerous. On exposed shores the mussel patches were less extensive, and were intermingled with fucoid and barnacle dominated areas. On semi-exposed shores the extent of *Mytilus* dominated areas was much more variable, and this may be illustrated with reference to three examples. At Iskanafeelna Point the shore was steep and almost free of fucoids, and mussels were confined to cracks and crevices and were all very small. More mussels were found at Eagle Point, mainly in a high level belt of moderately large animals, whilst at Ardnagashel West mussels of small to medium size were superabundant under the fucoids.

On fairly sheltered and sheltered shores *Mytilus edulis* was only present, if at all, as very small individuals, and the development of sheltered shore populations was restricted to very sheltered and extremely sheltered conditions. Here large clumps of mussels were often found under the *Ascophyllum*, and these animals were large and relatively few in number.

There was considerable variation in the size of the mussels on different shores, presumably reflecting differences in growth and mortality rates similar to those described by Seed (1969). It looked as if growth was probably slowest under the driest and the most exposed conditions, whilst large animals were removed from the lower shore by very heavy predation, such as that investigated by Kitching *et al.* (1959).

Nucella lapillus (Fig. 8) (=*Thais lapillus*, for synonymy see Rehder, 1962) was absent from the extremely exposed Mizen Head, but large numbers of small animals were found, mainly in pools and crevices, on the very exposed shores. *Nucella* was very numerous on exposed, semi-exposed and fairly sheltered shores, but was less abundant on sheltered sites. This decrease in numbers became very marked on very sheltered and extremely sheltered shores, where the few animals found were usually exceptionally large. *Nucella* was not recorded from the Black Rock transect, but this was probably a very local occurrence, as a few animals had been found there on an earlier visit.

Actinia equina (Fig. 8) was widely distributed in the bay, although absent from the extremes of shelter and exposure.

Anemonia sulcata appeared to be most important as a sublittoral species, but a few animals were found at or above MLWS at Gun Point, Iskanafeelna Point, Reenavanny, Crowdy Point, Furkeal, Coomageragh and Cooskeen Cove no. 2.

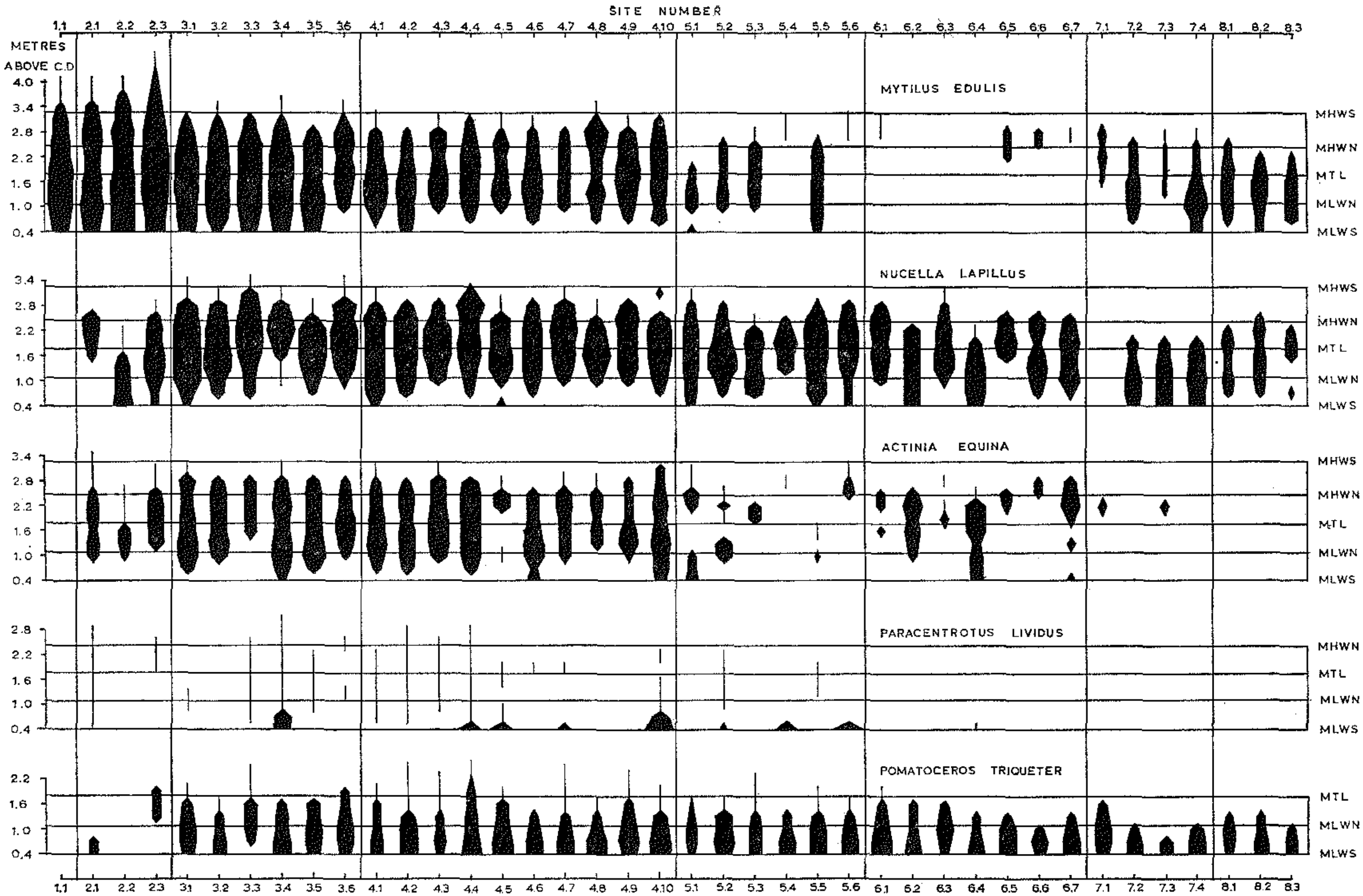

Fig. 8. Distribution of various species of animals in Bantry Bay.

Sagartia elegans was not included in the survey, but was very abundant (as var. *venusta*) in rock pools on the very exposed shores.

Paracentrotus lividus (Fig. 8) was essentially a sublittoral species, but was one of the most obvious inhabitants of rock pools on many shores, ranging from very exposed to fairly sheltered conditions. On three shores this sea urchin dominated the visible part of the sublittoral zone, and this phenomenon, associated mainly with semi-exposed and fairly sheltered conditions, appeared to be changeable over a period of time. At Reenavanny and Ardaturrish Bay the urchins were living on rock that was densely encrusted with the tubes of *Pomatoceros triqueter*, but at the latter site the urchins were much less numerous than they had been in 1969, and many young *Laminaria* plants, together with some patches of *Ulva lactuca*, were observed. At Illauncreeveen Bay the urchins appeared between January and August 1971, replacing a dense kelp bed, and there were relatively few *Pomatoceros* tubes on the rock.

It seems likely that there is an interrelationship between urchins, kelp, and *Pomatoceros* in the sublittoral zone which is similar to that known to exist between limpets, fucoids, and barnacles in the littoral zone (Southward, 1964). Thus it is possible that urchins, by grazing down the sporelings and possibly the adults of the kelp species, create conditions in which large numbers of the suspension feeding *Pomatoceros* can thrive, in the same way that limpets, by grazing down fucoid sporelings, create suitable conditions for dense populations of barnacles. This sort of interrelationship is probably a very important biological factor in the sublittoral ecology of Bantry Bay, but obviously it does not fully explain the distribution of *Paracentrotus*, any more than interactions with fucoids and barnacles account wholly for the distribution of limpets. Thus in some places *Paracentrotus* was observed living amongst *Anemonia sulcata* in the sublittoral zone, whilst in others it was seen amongst stones and gravel. On some shores groups of *Paracentrotus* were observed as high as MLWS, living in clearings amongst the kelp and other algae (at Reenagough Point, Carrigacloash, Gun Point, Iskanafeelna Point and Crowdy Point).

Asterias rubens was unfortunately not included in the list of species surveyed, but young starfish were observed at the lowest stations on many transects.

Pomatoceros triqueter (Fig. 8). The serpulid tubeworms were identified with the aid of Nelson-Smith (1967b). *P. triqueter* was common or abundant at the lower stations of most transects, except at the extremes of shelter and exposure, and was most numerous in association with *Paracentrotus* as described above.

Spirorbis borealis (Fig. 9) was found on the lower shore on sites of the four most sheltered grades, with the exception of a few animals found just above MLWS at Mucurragh Point.

Spirorbis rupestris (Fig. 9) was found at higher levels than *S. borealis*, but was similarly confined to the more sheltered shores, except for a few animals at Gerahies.

Spirorbis pagenstecheri was found mainly on the extremely sheltered shores, on which it was frequent or occasional from MLWS almost to MHWN. It was also recorded from the lowest stations at Reenydonagan Point, Illauncreeveen Bay, Derrycreigh, Glengarriff Castle, Black Rock, and Dunnamark Point.

Spirorbis tridentatus was not found at all.

Chthamalus stellatus (Fig. 9) was most successful at or above MHWS in exposure, and on extremely exposed, very exposed and exposed shores was extremely abundant at this level. This distinct belt of *Chthamalus* was less marked on semi-exposed shores, and was lost on fairly sheltered ones, where the species scarcely extended above the *Pelvetia* band. In the lower part of the eulittoral zone the distribution of *Chthamalus* appeared to be influenced mainly by the abundance of mussel and fucoid communities, and the species was therefore most successful on those semi-exposed and fairly sheltered shores where barnacles and limpets were the dominant species. Here *Chthamalus* was often surprisingly successful in competition with *Balanus balanoides* at the lower stations, and this was probably a consequence of heavy predation by *Nucella lapillus;* Connell (1961) found

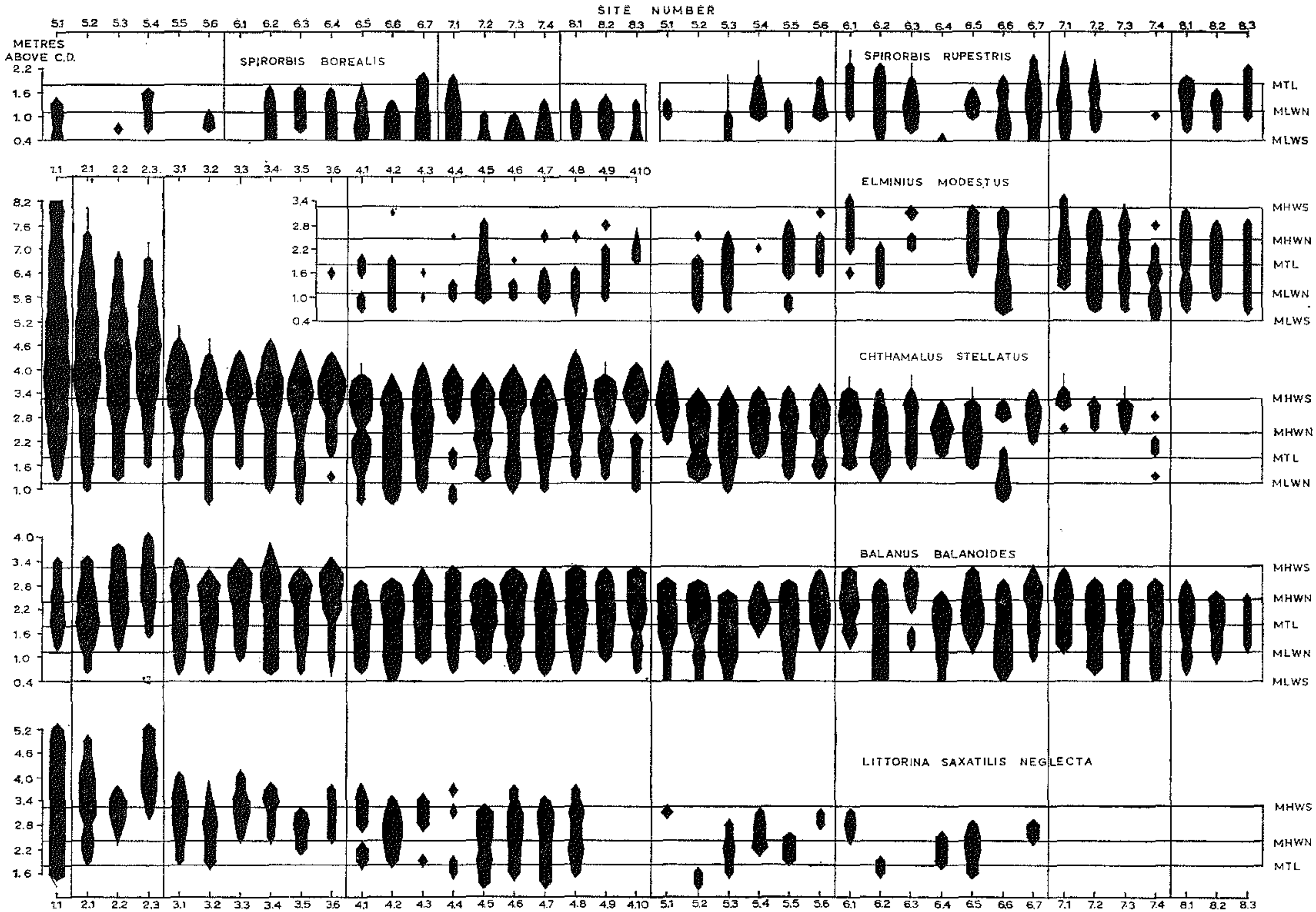

Fig. 9. Distribution of some tubeworms, barnacles and a periwinkle in Bantry Bay.

that this would act in favour of *Chthamalus* because the dogwhelks preferred to eat *Balanus*. At Crowdy Point, for instance, the levels at which *Nucella* and the lower shore *Chthamalus* were most abundant coincided. *Chthamalus* was scarce on the very sheltered shores, and absent from extreme shelter.

Balanus balanoides (Fig. 9) was subordinate to *Chthamalus* at all levels at Mizen Head, and the small number of animals found appeared to be survivors of the spring settlement a few months earlier, although growth must have been very rapid in this case. Older specimens were found on very exposed shores, where the species was usually more numerous than *Chthamalus* in the lower eulittoral zone. On exposed, semi-exposed and fairly sheltered shores *Balanus* was generally found throughout the midshore, but was most conspicuous in a belt around the MHWN level, in which the barnacles were larger rather than more numerous, although this was often noted as well. This belt lay above the zones occupied by the mussel and fucoid communities which compete with barnacles and limpets for space, and above the greatest numbers of the predatory dogwhelks, whilst above it the hardier *Chthamalus* replaced *Balanus*. With increasing shelter *Balanus balanoides* was less successful, and became very scarce under and around *Ascophyllum*. On some sheltered shores, notably at Furkeal, *Balanus* was scarce under a partial canopy of *Fucus vesiculosus*, and much of the rock surface was smooth and bare of sedentary organisms.

Balanus perforatus is believed to be absent from Ireland, and was not found in Bantry Bay.

Balanus crenatus (Fig. 10) was recorded only from the very sheltered and extremely sheltered shores.

Elminius modestus (Fig. 9) was first found in Bantry Bay in 1968, when a preliminary survey of some of the transects was made. This barnacle is believed to have established itself in Cork Harbour between 1954 and 1956, and in 1958 reached a western limit at Barloge Creek outside Lough Ine (Crisp and Southward, 1959). In 1966 *Elminius* was occasional on the harbour wall at Schull, but was not found in Glengarriff harbour (personal communication from Professor D. J. Crisp). In 1968 it was recorded as frequent on a number of transects in the Glengarriff and Bantry areas, and it therefore seems probable that *Elminius* arrived in Bantry Bay in 1966 or 1967.

The distribution of *Elminius* outside Bantry Bay was studied in February 1972 to determine whether the manner of its arrival could be deduced, and the results of visits to a number of shores are shown in Fig. 1. *Elminius* was well established in Roaringwater Bay, but it was absent from Dunmanus Bay except for a few individuals on a small pier at the head of the bay. In Bantry Bay the main concentrations were found in the inner part of the bay and around Adrigole, and *Elminius* was no more than occasional in the Castletown area. A number of shores were visited along the southern coast of the Kenmare river and at the head of this bay, but no *Elminius* was found.

In the inner part of Bantry Bay some evidence was noted of an increase in the distribution and abundance of *Elminius* in the interval between the making of some preliminary surveys in 1968 and 1969, and the present survey in 1971. Such increases were found at Harris Cove, Bocarnagh Bay, Reenydonagan Point and Dunnamark Point, whilst the species appeared for the first time at Illauncreeveen and Ardaturrish Bays. On the southern coast of the bay *Elminius* was absent from all transects up to February 1971, but by August a few individuals had appeared at Gerahies and Coomageragh. Therefore it seems that at present *Eliminius* is spreading slowly outwards from the sheltered shores of Glengarriff, Whiddy and Bantry harbours (Fig. 2), on which it was recorded as frequent in 1968. At present this process is slow because the adults appear to be too scarce to produce large numbers of larvae; settlement was counted throughout the summer of 1971 at Bocarnagh Bay and Reenydonagan Point, but the numbers of spat never exceeded 10 per sq. decimetre.

It is clear from these observations that it is not possible to say with absolute certainty whether *Elminius* entered Bantry Bay by marginal or remote dispersal. If larvae from Roaringwater Bay were carried out and around the exposed and unsuitable Mizen Head peninsula then the northern coast of Bantry Bay would lie within the thirty mile maximum distance for marginal dispersal suggested by Crisp (1958). However, remote dispersal through the vector of coastal shipping is more likely to be responsible, for the reasons given below.

1. Even in 1972 *Elminius* was not found at densities greater than common in Roaringwater Bay, and it is not likely that large quantities of larvae were available from this area in the mid 1960's. Thus, even if larvae from this area were carried into Bantry Bay there would probably be too few of them to establish a breeding population.

2. Larvae carried around the Mizen Head peninsula would probably enter and colonise Dunmanus as well as Bantry Bay, but *Elminius* was only found in very small numbers at the very head of Dunmanus Bay. These barnacles were almost certainly derived from a population on a small boat which visited the pier on which they were found, and the colony may be too small to become established.

3. Larvae moving northwards from Mizen Head would probably become established in the Castletown area and then spread eastwards into inner Bantry Bay (Fig. 1). The present distribution of *Elminius* suggests that the reverse of this has happened, that the species has spread westwards from the head of the bay, initially down the northern coast and latterly along the southern one as well.

It is therefore concluded that *Elminius* was probably introduced into inner Bantry Bay by remote dispersal in 1966 or 1967. This is in agreement with Crisp and Southward's (1959) expectation that the deep estuaries and bays of the western Irish seaboard would eventually support isolated populations of *Elminius* separated from each other by the intervening headlands. Enough shipping enters the bay to provide a vector of remote dispersal, including vessels from Baltimore and Cork, and it may not be a coincidence that at this time there was an increase in sea traffic associated with the construction of the oil terminal.

Littorina neritoides (Fig. 10) was found to have a distribution pattern clearly related to exposure, and was most successful at Mizen Head, where very large individuals were found in the eulittoral zone and smaller individuals extended up to 14 metres above chart datum.

Littorina saxatilis was separated into three of its subspecies, as defined by James (1968). Subspecies *tenebrosa* (Fig. 10) occupied a distribution pattern similar to that of *L. neritoides*, although it appeared to be greatly influenced by the nature of the substratum, and was scarce or absent on shores where suitable crevices were presumably absent. At Mizen Head *L. s. tenebrosa* extended up to the same high level as *L. neritoides*, and on all the shores where these two winkles occurred together the latter was usually more numerous: a contrary impression is given in Fig. 10 as a consequence of the different abundance scales used.

Subspecies *neglecta* (Fig. 9) is characteristically an inhabitant of empty barnacle shells in the eulittoral zone, and its relatively scarce and erratic distribution in Bantry Bay reflects the extent to which mussel and fucoid communities dominated this zone. Even where barnacles were dominant they were often small, providing little shelter for the periwinkles. The animals were largest and most numerous amongst the dense barnacle stands of the most exposed shores, where they extended some way above MHWS.

Subspecies *jugosa* was not separated from subspecies *rudis*, and the latter term is used for both. *L. s. rudis* (Fig. 10) was absent from the most exposed shores, being found on only three grade 3 shores. It was most numerous in the upper part of the eulittoral zone on semi-exposed and fairly sheltered shores, and usually extended some way above this level on the former, and lower on the latter. In greater shelter it became progressively scarcer.

Littorina littorea (Fig. 10) was rather erratically distributed over the five most sheltered grades of shore, and was most successful on gentle slopes under or amongst algae; on semi-exposed shores adults were entirely restricted to this kind of habitat. However, as James (1968) noted, juvenile *L. littorea* are more widely distributed than the adults, and populations consisting exclusively or very largely of juveniles are indicated by the white areas in Fig. 10, whilst the black areas indicate the more normal populations of adults and juveniles. These juvenile populations were typically found on barnacle dominated shores, and although the animals were very numerous in this habitat the populations are presumably maintained by the settlement of larvae from other areas.

Littorina littoralis (Fig. 10) has not been separated into *L. obtusata* and *L. mariae*, for practical reasons if not for taxonomic ones (James, 1968). This periwinkle was found on and under fucoid algae except under extremely exposed and very exposed conditions, and at the exposed end of its range only a small number of small animals were found on *Fucus vesiculosus* form *linearis*. In more sheltered conditions *L. littoralis* appeared to be more numerous on *Fucus* spp. than on *Ascophyllum*, and was slightly less abundant in extreme shelter.

Discussion

Vertical zonation and components of the shore population

The results may be discussed in terms of the two environmental gradients used to arrange them, the vertical zonation resulting from changes in the frequency and duration of emersion and the horizontal changes resulting from variations in the amount of wave action experienced. The scheme of vertical zonation followed here is Lewis' (1964) modification of the Stephensonian scheme, which recognises four main zones, the supralittoral zone, the littoral fringe, the eulittoral zone and the sublittoral zone. Attempts to define minor zones within these have usually encountered difficulties which arise from the variations found from one shore to another, and from the fact that no two species show precisely the same distribution. Ultimately there may be one zone for each species and the extent of this will vary from one area to another. However, it is feasible to group species with similar distribution patterns into a number of components, which makes some subdivision of the major zones feasible in a given area. Such a classification was devised by Lewis (1953, 1964) and modified by Moyse and Nelson-Smith (1963). The latter authors carried out a survey similar to the present one in the Dale area of Pembrokeshire, and from the results were able to calculate the centre of abundance of each species, this being the level which divides a diagram of the mean distribution of a species (taken over all the sites) into upper and lower parts of equal area: knowing this level it was possible to assign each species to one of a number of components with some accuracy. The components schemes of Moyse and Nelson-Smith, and Lewis may be applied to the results of the Bantry survey, and the salient features of the vertical zones and components are discussed below.

The supralittoral zone lies above the *Littorina/Verrucaria belt,* and its upper limit merges into the non-maritime vegetation. Its characteristic inhabitants are various species of lichens. This zone was divided into four lesser ones by Ferry and Sheard (1969), working around Dale in Pembrokeshire, and for the sake of consistent nomenclature these may be described as components 1-4 here. These four components could be distinguished in Bantry Bay, as described in the results, although only the most obvious of the lichen species and neither of the dominant species of component 4 (*Pertusaria pseudocorallina* and *Lecidea subincongrua* at Dale) were studied.

The supralittoral zone apparently reflects the extent of wetting by wave spray and not by immersion, and consequently shows a greater variation in depth with different degrees of exposure than any of the other zones. The typical extent of these variations is indicated, over the eight exposure grades, in the following table, which also includes the lower limits of the littoral fringe. All the levels are given in metres and are relative to MHWS.

Exposure grade	Lower limit litt. fringe	Litt. fringe/supralittoral zone boundary	Upper limit supralittoral zone
8	—0.5	0	0.5
7	0	0.5	1.0
6	0	0.5	1.5
5	0	0.5	2.0
4	0.5	1	2.5
3	0.5	1.5	4.0
2	2.5	5-7	10-20
1	3.5	11.0	20+

These levels are only expressed in the most general terms, for exposure is only one of the factors affecting them. Thus Ferry and Sheard (1969) found that there was little evidence that any supralittoral lichens showed any preference for shores of a particular exposure grade, but that their distribution was influenced mainly by changes in aspect and other, more elusive, factors. The vertical extent of the supralittoral zone was primarily determined by the severity of wave action producing spray, but the effect of this was modified by changes in slope and aspect. On steep shores spray travels to higher levels than on gentle slopes, whilst the same level will be drier on a sunlit south facing shore than on a shaded northern one. The four components of the supralittoral zone generally overlap each other to a varying extent, and under exposed conditions there is often a considerable overlap between the supralittoral zone and the littoral fringe.

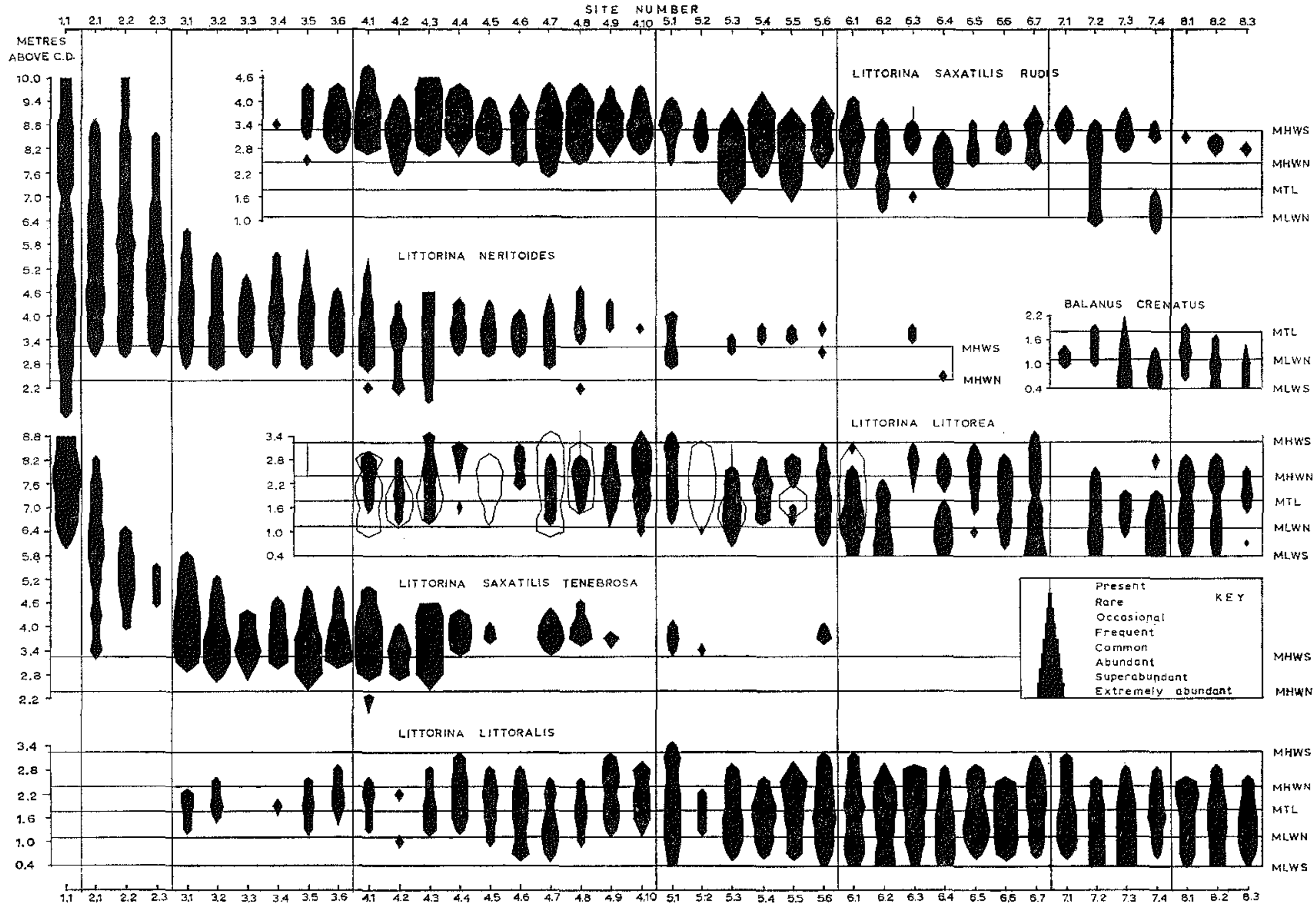

Fig. 10. Distribution of periwinkles and a barnacle in Bantry Bay.

The littoral fringe has often been referred to as the supralittoral fringe, but the prefix is discarded here for the reasons given by Lewis (1964). Perhaps the only remaining argument for its retention is that it avoids confusion with the sublittoral fringe. However, the status of the latter entity is uncertain, as discussed below, and in any case the supra- and sub- prefixes are themselves easily confused. This led Stephenson and Stephenson (1949) to adopt the otherwise unpopular term "infralittoral", but it is just as clear to refer to the littoral fringe (of the littoral zone) and the sublittoral fringe (of the sublittoral zone).

The littoral fringe contains one or two components, for Lewis (1953, 1964) distinguishes between those species which are numerous both at this and lower levels, and those which are confined to the fringe proper. Here only one component is recognised, following Moyse and Nelson-Smith (1963), and this contains those species which, although they may even be more abundant at other levels, are distinguished as being the only ones which inhabit this zone. These are *Verrucaria maura, Littorina neritoides,* and *L. saxatilis tenebrosa* (the littoral fringe is defined as the area dominated by these species or their equivalents in other places), with *Lichina confinis* in the upper levels and high level winter growths of *Porphyra umbilicalis* in the lower part. *Pelvetia canaliculata* and *Fucus spiralis* are treated as species of the eulittoral zone in Bantry Bay, although in other areas they may or may not be better regarded as belonging to the littoral fringe (see Lewis, 1964).

The organisms of the littoral fringe are generally regarded as marine rather than terrestrial, and require a certain amount of wetting. (Some of the lower members of the supralittoral zone may require regular washing with salt water, but these lichens are essentially terrestrial). Thus in extreme shelter the littoral fringe is very narrow, and does not extend above MHWS, but with increasing wave action the zone becomes higher and wider, and lies entirely above MHWS, as shown in the table given above. Here the littoral fringe is wetted only by wave splash, and in extreme exposure the elevation and widening of the littoral fringe is surpassed only by that observed in the supralittoral zone.

The eulittoral zone: upper component. Lewis (1964) uses the eu- prefix to distinguish the major part of the shore community from a "littoral zone" which includes the littoral fringe. The upper limit of the eulittoral zone is that level where barnacles or their equivalents are replaced by the littorinids and blackening organisms of the littoral fringe. This definition can lead to many practical problems, but in Bantry Bay the upper limit has been taken to be the top of the zone dominated by barnacles or by the fucoid *Pelvetia canaliculata,* which replaces the upper belt of barnacles in shelter.

The upper component of this zone consists of species which are typically most abundant at the upper levels, with centres of abundance nearer to MHWN than to MTL. It includes species which have a limited vertical range (*Pelvetia, Fucus spiralis, Catenella repens, Lichina pygmaea*), and others which may be found throughout the eulittoral zone under favourable conditions but which are most abundant at the higher levels (*Chthamalus stellatus, Littorina saxatilis rudis, L. s. neglecta, Monodonta lineata*).

The species of the upper component obviously have less need for immersion than other eulittoral forms, and those that are able to tolerate severe wave action may be found well above MHWS on the more exposed shores. The extent of this elevation may be gauged from the table given above which defines the low limit of the littoral fringe: thus at Mizen Head the presence of abundant *Chthamalus* 3.5 metres above MHWS indicates that the eulittoral zone/littoral fringe boundary is raised to this level in extreme exposure.

The eulittoral zone: midlittoral component. This contains many of the most obvious inhabitants of rocky shores, with centres of abundance lying nearer to MTL than to MLWN or MHWN. In Bantry Bay this component includes *Fucus vesiculosus, Ascophyllum nodosum, Patella vulgata, Gibbula umbilicalis, Mytilus edulis, Nucella lapillus, Actinia equina, Elminius modestus, Balanus balanoides, Littorina littorea* and *L. littoralis.*

The species of the midlittorial component appear to be much more restricted by a requirement for regular immersion in sea water than any of those found in the higher components. On the most sheltered shores they rarely extend much above MHWN, and in extreme exposure are not often found above MHWS, and thus even where wave action is very severe they are scarcely raised more than one metre above their tidal limit under sheltered conditions.

The eulittoral zone: lower component. This contains species which are most abundant at the lower levels of the eulittoral zone, with centres of abundance lying nearer to MLWN than MTL. These include *Fucus serratus, Himanthalia elongata, Gigartina stellata, Corallina officinalis, Lomentaria articulata, Laurencia pinnatifida,*

Patella aspera, Spirorbis borealis, and *S. rupestris.* All these species may extend upwards through much of the eulittoral zone under favourable conditions, and it is therefore impossible to define a clear upper limit for this component, or the extent to which such a limit might be raised under exposed conditions.

The sublittoral zone. The upper limit of the sublittoral zone is defined as that level where species of the eulittoral zone replace the kelps (or their equivalents) as the dominant species. Here only one component is recognised, containing those species which are most abundant below MLWS, but which extend above this level on many shores. This component includes *Alaria esculenta, Laminaria* spp., *Chondrus crispus,* "Lithothamnia", *Gibbula cineraria, Calliostoma zizyphinum, Paracentrotus lividus* and *Pomatoceros triqueter.* These species may extend some way into the eulittoral zone under favourable conditions, largely in pools and damp places.

The sublittoral zone is elevated by the influence of wave action to almost the same extent as the species of the midlittoral component. The top of the laminarian zone rises from MLWS on very sheltered shores to just above MLWN in extreme exposure, a difference of about one metre (see Fig. 4). In extreme shelter the sublittoral zone appears to lie entirely below MLWS, but the boundary is difficult to define in the absence of *Laminaria.*

Most schemes of zonation distinguish between the sublittoral zone and a sublittoral fringe at or above the top of the zone. This has always proved to be a difficult distinction, and schemes which place the boundary at the physical level of extreme low water of spring tides (for instance, that of Stephenson and Stephenson, 1949) are unsatisfactory, for the way in which wave action affects zonal levels is clear from the account given above. Lewis (1964) considers that it is often possible to distinguish a fringe dominated by species which are confined to the top of the sublittoral zone, such as *Alaria esculenta* and *Laminaria digitata,* but the lower limit of such a fringe is usually inaccessible from the shore, and is difficult to define with confidence.

The separate existence of a littoral fringe component is not recognised in the zonation scheme adopted here, on the grounds that insufficient information is available to define one, and the question is best left open until more is known of distribution patterns throughout the sublittoral zone.

The Ballantine exposure scale in Bantry Bay

Exposure to wave action was estimated by applying the biological exposure scale of Ballantine (1961a) to the results from each shore, as described earlier. In some respects this scale did not work very well in the Bantry area; these discrepancies are discussed below and some of them are illustrated in Figs. 11 and 12. Basically these diagrams are very simple, and of a commonly used pattern (see, for instance, Lewis 1964). They show the area occupied by a species in terms of a two dimensional grid, which has height above chart datum and the degree of exposure to wave action as its axes. The black area shows the distribution pattern in Bantry Bay, the white area that found around Dale in Pembrokeshire, the source area of the Ballantine scale, whilst the stippled area shows the overlap between the two. (This does not apply to the barnacle dominance diagrams in Fig. 11, which are explained later). However, the diagrams have been carefully drawn to accurate limits, and the means of doing this needs to be explained in some detail.

Firstly, the information from the Dale area has been taken from the transect results of Moyse and Nelson-Smith (1963) and Nelson-Smith (1967a), although in the latter case the estuarine sites (Milford Haven from Angle Point upwards) were omitted. This gives one site of grade 1, two of grade 2, seven of grade 3, three of grades four and five, five of grade 6, two of grade 7 and none of grade 8, to compare with the Bantry sites listed in Table 1.

Secondly, if one of the earlier figures (3-10) is examined, it is clear that on these a series of contour lines could be drawn linking points of equal abundance. This has been done for Figs. 11 and 12, but for the sake of clarity only one abundance contour has been drawn, enclosing the area where the species is found at that or greater abundance. Although the contour used has been selected subjectively, this is valid for comparative purposes, and in any case the use of the abundance categories tends to minimise the real differences found, so that these are, if anything, underemphasised.

Thirdly, the mean spring tidal range in Milford Haven is 6.3 metres, whilst it is 2.9 m in Bantry Bay. The vertical scales have been adjusted to compensate for this, so that tidal levels in the two areas coincide on the diagrams. However, the influence of wave action in raising zonal levels is largely independent of tidal range, and in the case of species which extend some distance above MHWS (*Chthamalus stellatus, Littorina neritoides, L. saxatilis tenebrosa*) the scales have been equalised from this level upwards.

Fourthly, there are a different number of shores in each exposure category in the two areas, and so the horizontal axis is arranged to give an equal interval to each exposure category, regardless of the number of shores represented in each. However, grade one is allotted only a half interval, for only one such shore was studied in each area, and grade eight is omitted because shores of this grade were absent from the Dale area.

It is unnecessary to attempt to rewrite the Ballantine exposure scale so that it applies more accurately to the exposure transition observed in the Bantry area, for this would in most cases be a repetition of information given in the results above, and it is those respects in which the two schemes differ that are of interest. Therefore the account that follows is designed as a series of corrections to the exposure scale, arranged under the same headings as Ballantine's (1961a) descriptions; the Bantry transition is briefly described only where it differs from these. It is suggested that shores in south west Ireland may be classified by Ballantine's method provided that these corrections are applied.

1. *General comments.* On the Atlantic coast of Ireland it is reasonable to expect that extremely exposed shores will be found on many headlands, and such shores will be neither as rare or as isolated as in the Dale area.

2. *The kelps. Alaria* was abundant and dominant on two shores classified as very exposed, and could be found in locally favourable conditions even on semi-exposed shores. As was described earlier, *Laminaria saccharina* does not become progressively more abundant in shelter in Bantry Bay; a belt of *L. digitata* was generally found on sheltered and very sheltered shores, whilst in extreme shelter the sublittoral zone appeared to be dominated by a turf of red algae.

3. *The fucoids. Pelvetia* may be frequent or common on exposed shores, generally forms a distinct zone on semi-exposed shores, and is usually abundant or superabundant in fairly sheltered conditions. The plants do not actually tolerate greater exposure around Bantry (Fig. 11), but are much more abundant at the exposed end of their range. *Fucus spiralis* extends into greater exposure in Bantry Bay as form *nanus*, which is absent to frequent on very exposed shores and occasional to abundant on exposed ones. Form *spiralis* is occasional to superabundant on semi-exposed and fairly sheltered shores, but although it is usually absent from such shores at Dale, some plants may be found tolerating these conditions (Fig. 11). In the Bantry area *Fucus vesiculosus* is an important eulittoral species, whilst around Dale it is not (Fig. 11). Ballantine's description of the distribution of this species may be replaced by that given in the results section above, but it should be noted that in both areas the boundary between form *linearis* and form *vesiculosus* is found on semi-exposed shores. *Fucus serratus* was less successful on exposed shores in the Bantry area, being absent more often than occasional (Fig. 11). *Ascophyllum nodosum* is found on shores of the four most sheltered grades in both the Bantry and Dale areas, but is more successful on fairly sheltered and sheltered shores in the Bantry area, on which it may be locally abundant or superabundant (Figs. 4 and 11).

4. *Other algae. Corallina officinalis* occupies similar distribution patterns at Dale and Bantry (Fig. 11).

5. *Lichens.* The effects of wave action on the height and extent of the supralittoral zone, described earlier, are similar in the Dale and Bantry areas, and this is a more reliable guide to exposure than lichen abundance. Although the distribution of the supralittoral lichens becomes erratic on the most sheltered shores, this appears to result from the extreme compression of the available habitat, and there is no evidence of a decline in abundance as described by Ballantine.

Lichina pygmaea extends slightly further into shelter in Bantry Bay (Fig. 11); it is rare to frequent on rough, sunlit rocks on both fairly sheltered and some sheltered shores. The species is found at higher tidal levels on the Bantry shores, and this is probably due to elevation by wave action, which is effectively greater over the smaller tidal range, and the replacement of suitable barnacled habitats at lower levels by mussel and fucoid communities.

6. *Barnacles.* Ballantine describes the exposure transition in terms of the relative abundance of *Balanus balanoides* and *Chthamalus stellatus.* In most respects the Dale descriptions apply to Bantry, except with regard to *Chthamalus* in shelter (Fig. 12), but the relative abundance of the two species is more clearly expressed in terms of the midlittoral and upper littoral components of the eulittoral zone (Ballantine's midlittoral zone).

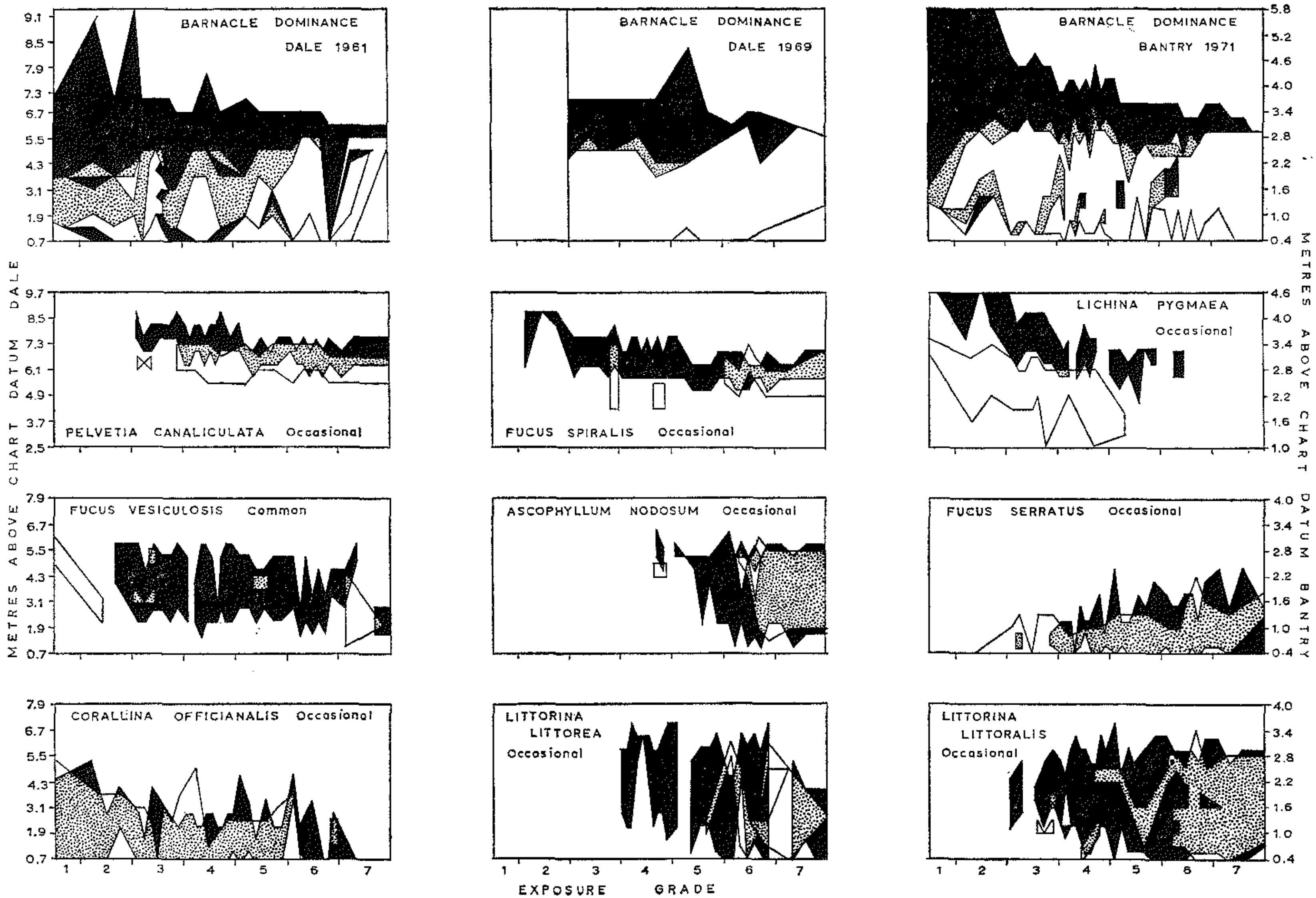

Fig. 11. The distribution patterns of various species in Bantry Bay compared with those found around Dale, Pembrokeshire. Barnacle dominance diagrams for the two areas are shown in the top row.

This is illustrated in the barnacle dominance diagrams in Fig. 11, which are drawn in the same fashion as the others, except that the black area represents the area over which *Chthamalus* is the dominant barnacle, the white area the area of *Balanus* dominance, and the stippled area the area of co-dominance. *Chthamalus* is the dominant barnacle of the upper littoral component, in which it is absent in extreme shelter, frequent to common on very sheltered shores, common on sheltered shores, and abundant to extremely abundant in greater exposure. With increasing exposure the area occupied by the upper littoral component becomes very much wider, whilst that occupied by the midlittoral component remains at almost the same width, as described in the discussion of vertical zonation. *Chthamalus* dominates an increasing proportion of the eulittoral zone with greater wave action, but this is mainly due to the expansion of the upper littoral component, and not to an invasion of the midlittoral one, as shown in Fig. 11. Such an invasion was only observed in extreme exposure, and on other shores *Chthamalus* is only irregularly dominant in the midlittoral component, under the conditions described in the account of the results.

In using the relative abundance of these two species as an index of exposure, care must be taken to allow for the fact that the balance between them is profoundly influenced by temperature changes, whether comparing different areas at the same time or the same area at different times (Southward and Crisp, 1954, 1956). Under warmer conditions *Chthamalus* may be the dominant species in the midlittoral component, but at present numbers of *Balanus* are increasing in response to cooler conditions (Southward, 1967), and at Dale conditions have changed since the exposure scale was devised. This is illustrated in Fig. 11, where a barnacle dominance diagram for 1961 has been drawn from the results of Moyse and Nelson-Smith (1963) and Nelson-Smith (1967a). At this time the situation at Dale was very similar to that found around Bantry in 1971, with *Chthamalus* dominant or co-dominant over small parts of the midlittoral area. (The extent of the co-dominant area is probably exaggerated in the figure, for both species were abundant over much of it, and as the higher abundance categories were not used the true dominant cannot be distinguished, although it is clear from the comments of Moyse and Nelson-Smith that it was usually *Balanus*). In 1969 a number of the Dale transects (but not the very exposed or extremely exposed sites) were resurveyed by Crapp (1971), and the diagram in Fig. 11 shows that by then *Chthamalus* dominance was restricted to the upper littoral component (again the higher abundance categories of superabundant and extremely abundant were not used). This type of change may be expected in the Bantry area, with *Chthamalus* retreating from the midlittoral area, where it is competing with *Balanus*, before its upper littoral distribution is affected.

The distribution patterns of *Chthamalus* at Dale and Bantry are compared in Fig. 12. The species extends to lower levels at Dale, and this is attributed to the prevalence of mussel and fucoid communities in the lower midlittoral area around Bantry. On the most exposed Bantry shores the upper limit of *Chthamalus* is much higher than at Dale, even after allowing for the tidal range disparity.

7. *Limpets. Patella depressa* was not found in the Bantry area, and the distribution of *P. aspera* was described in the account of the results. This species has a similar exposure range in the Dale and Bantry areas, and the fact that it extends to higher levels in the latter area (Fig. 12) may be attributed to the disproportionate effects of wave action over the two tidal ranges.

8. *Littorinids. Littorina neritoides* does not extend quite so far into shelter in the Bantry area as at Dale, and is usually absent from sheltered shores. As shown in Fig. 12, it occupies a much narrower belt over many of the Bantry shores, and this is probably due to the replacement of its barnacled habitat by mussels and fucoids at the lower levels, and to more gentle supralittoral slopes at the upper ones: around Dale this zone is generally steeper than at Bantry and presumably splash travels to higher levels. The distribution pattern of the subspecies of *Littorina saxatilis*, described earlier, agrees with Ballantine's general account of the species, and subspecies *tenebrosa* shows a restricted upper distribution similar to that of *L. neritoides* (Fig. 12). Subspecies *neglecta*, which replaces *tenebrosa* in the eulittoral zone, also resembles *L. neritoides* in being much less successful at the lower levels of Bantry shores.

L. littoralis and *L. littorea* extend into greater exposure around Bantry than they do at Dale (Fig. 11), and this is probably related to the greater abundance of fucoids, which may provide local shelter. *L. littoralis* is rare to frequent on exposed shores, occasional to common on semi-exposed shores, occasional to superabundant on fairly sheltered and sheltered shores, and common to abundant under very sheltered and extremely sheltered conditions. *L. littorea* is occasional to abundant on semi-exposed shores, common to abundant on fairly sheltered and sheltered shores, frequent to abundant on very sheltered shores, and frequent to common in extreme shelter.

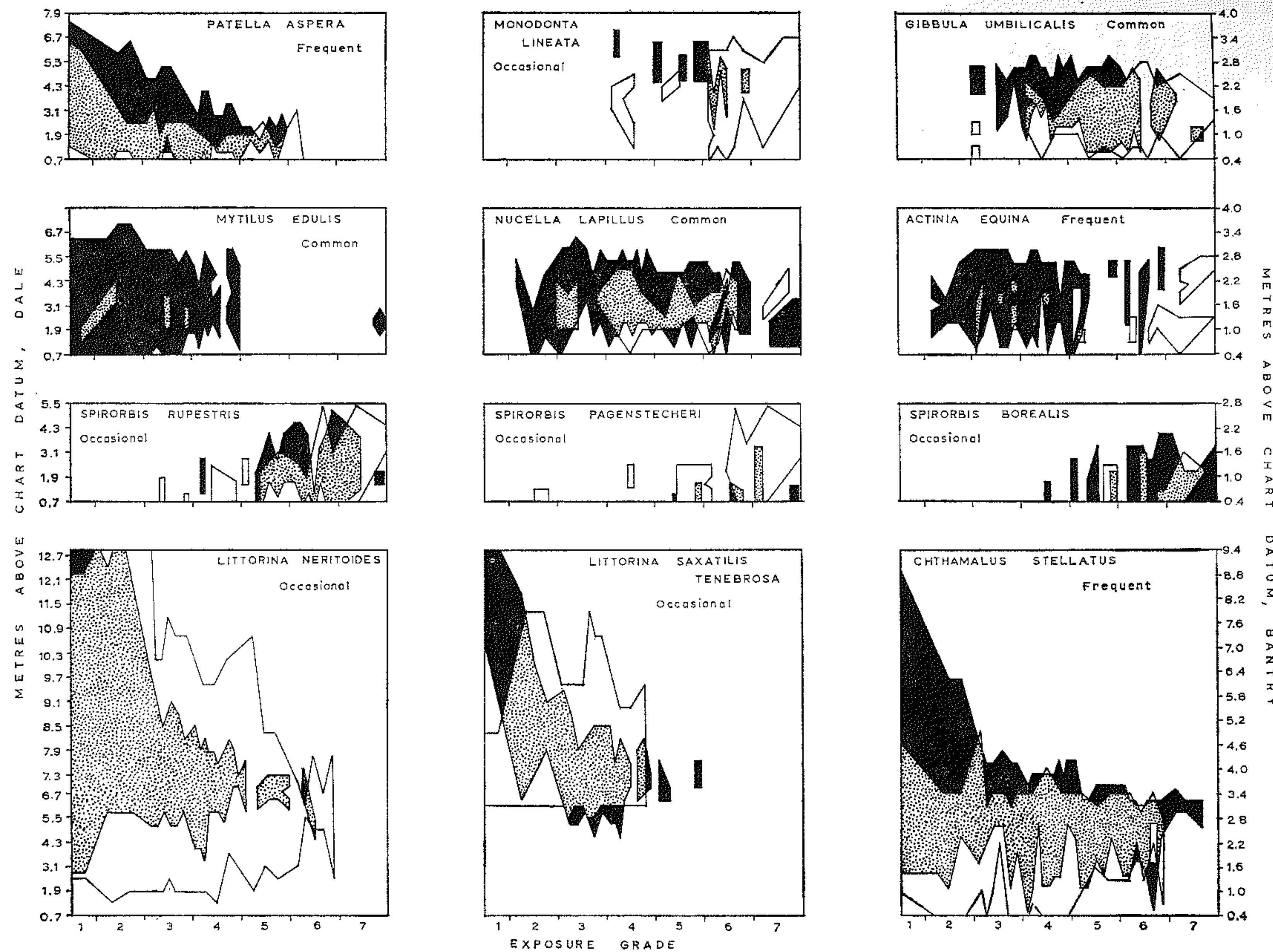

Fig. 12. The distribution patterns of various species in Bantry Bay compared with those found around Dale, Pembrokeshire.

9. *Top-shells. Gibbula umbilicalis* appeared to be more successful in exposure in Bantry Bay, but less so in shelter, although its absolute limits of distribution are similar in the Dale and Bantry areas (Fig. 12). Thus the species is locally abundant under fucoids on exposed shores, and common to superabundant on semi-exposed ones, but on very sheltered shores it is frequent to common, and in extreme shelter is no more than rare or occasional.

The sparse and irregular distribution of *Monodonta lineata* in Bantry Bay (Fig. 12) has been described in the account of the results.

10. *Other animals. Mytilus edulis* is an important eulittoral species around Bantry, but not at Dale (Fig. 12), and Ballantine's descriptions must be abandoned for that given in the account of the results earlier. *Nucella lapillus,* on the other hand, has essentially similar distribution patterns in the two areas, but is generally more numerous on Bantry shores (Fig. 12) and the Ballantine descriptions would be improved here by the addition of one or two abundance categories in each case, although the species was absent from Mizen Head. *Actinia equina* is much more successful in exposed conditions in Bantry Bay, although it is absent from the very sheltered conditions in which it is often found at Dale (Fig. 12). Also shown in Fig. 12 are the distribution patterns of three species of *Spirorbis. S. rupestris and S. pagenstecheri* are more numerous and more tolerant of exposure in the Dale area, but the opposite applies to *S. borealis.*

The major pitfall of the comparison made here between the Dale and Bantry areas is obvious: the distribution patterns of the species are compared relative to the eight exposure grades, and yet it is these patterns which are used to define the exposure grades. This is an extension of the circular argument which underlies the use of a biological exposure scale in the first place; the implications of this have been discussed by Ballantine (1961a) and Lewis (1964), and there is no need to repeat the arguments here. Essentially the case against biological exposure scales is that in practice they may be invalidated by biological changes which are dependent on factors other than exposure. The case for the scales is that they attempt to define in consistent terms a concept which is implicit in almost any study of the shore, and that by doing so they can lead to a better understanding of distribution and abundance, which at present cannot be achieved in any other way. The comparisons which have been made here are based on the latter argument, but because of the defects of the exposure scale the following comments should be noted.

1. It is assumed that shores assigned to the same exposure grade are exposed to approximately the same intensity of wave action in the Dale and Bantry areas. This appears to be reasonable, for there is no evidence of a consistent shift in one direction or the other. Some of the changes observed do suggest that, for instance, a Bantry grade 5 shore might be equivalent to a grade 6 shore at Dale (thus *Littorina neritoides* extends further into shelter at Dale), but other changes suggest that the opposite happens (and *L. saxatilis tenebrosa* extends further into shelter at Bantry).

2. The estimation of exposure is subjective, complex, and qualitative, and at this level appears to be valid. It is not possible, at present, to carry out a more rigorous analysis, for at least two reasons. Firstly, some species are probably less affected by changes in exposure than others, but the extent of this cannot be quantified. For example, *Pelvetia* is more successful in exposure in the Bantry area, but this is matched by a greater abundance of *Fucus serratus* on exposed shores around Dale. Are these changes of equal significance in assessing exposure, and if not, what is their relative importance? Secondly, many of the differences observed between the two areas do not seem to reflect a real change in tolerance to wave action, but are probably related to the replacement of the barnacle and limpet communities of Dale by the mussel and fucoid communities of Bantry.

3. The estimates of exposure made here would be much improved if reliable physical measurements of wave action could be made. This remains an extremely difficult task, but the technique devised by Jones and Demetropoulos (1968), in which spring balances secured to the shore record the maximum wave pull experienced over a given period, would probably be feasible. This method could profitably be attempted on the Bantry transects, where biological information is now available for correlation with physical results. However, this would occupy a fairly long and difficult investigation, and in the short term the results are only comparable over a small area, for the values recorded will depend on the sea and weather conditions experienced during the period of the study. Long term averages would be necessary for comparisons between distant areas, and in any case, no such figures are available for the Dale area.

Conclusion

Although a considerable number of rocky shore surveys have been carried out, there has been little evidence of the development of any form of standard method, and this is probably the result of working in a habitat where the surface is usually broken and irregular, containing very many diverse microhabitats. The method adopted for the present survey perhaps represents the nearest approach which has been made to a suitable standard method, but has not gained a very wide acceptance since it was developed by Moyse and Nelson-Smith (1963) from the abundance scales of Crisp and Southward (1958) and Ballantine (1961a). In conclusion, therefore, some of the advantages and disadvantages of the method are briefly described in relation to the three main purposes of the present survey.

The first purpose of the survey was to provide the basis of the general description of the shores of Bantry Bay, which is given in this paper. Various alternative methods could have been used to do this, and in particular a series of maps of various shores could have been made, or quadrat counting used on transects, or detailed notes could have been written from observations made on a number of shores. Each of these methods has its disadvantages. Mapping in detail takes far too long in a general survey, whilst even on a smooth transect site a large number of quadrat counts are necessary to obtain reliable average figures, and on rough and broken shores the method becomes practically impossible. Descriptive notes are fairly quick to make, but it is not always easy to arrange the results in a meaningful way, or to compare results from different times or places.

The abundance scale and transect method is a mixture of the quadrat-transect and the descriptive notes approach. The high accuracy of the quadrat method is lost, but surveying can be carried out rapidly, even on very rough and broken shores. A standard format is provided for making notes on distribution and abundance, ensuring that all records are directly comparable, but on the other hand observations must be modified to fit this format where necessary, and many details may go unrecorded.

This method is not always the most suitable for making a general survey, but in the present case it has been possible to define the principal features of vertical zonation and the exposure transition in Bantry Bay, and to compare these with those recorded around Dale in Pembrokeshire. This comparison is made because the survey method has only been used in these two areas, but it illustrates the way in which the distribution patterns found in various places can be compared if this method is used. In fact it is clearly shown that whereas around Dale barnacles and limpets dominate most shores, around Bantry mussel and fucoid communities are much more important. Why this should be so is not clear, but this sort of change has already been described by Lewis (1964), who points out that the latter situation is usually associated with Atlantic coasts and a mild climate.

The second purpose of the survey is to provide a basis for detecting future changes in the littoral fauna and flora. For this purpose the method is ideal in a general survey, since it is quick to carry out, and the results are easily compared even when different workers are making surveys at different times. Although the method is only semi-quantitative it is still possible to detect most changes because of the large number of shores surveyed. As was explained earlier, the diagrammatic and sometimes selective account of the results given here is not the best basis for making a comparison, and attention is again drawn to the notes which have been deposited with the Fisheries Division and the Department of Zoology at Cork.

The survey method provides semi-quantitative information on distribution patterns which may be used to record changes in these. It would be possible to obtain more accurate figures in a fully quantitative survey, but this would take up a great deal of time, and little new information would be obtained: measuring changes in space or time more accurately would not help to explain them. Such an explanation is best sought through an understanding of the processes by which littoral populations are established and maintained, and these are at present being studied in Bantry Bay. An essential requirement in this work is a scheme of reference by which one population can be related to another, and this is provided in terms of vertical zonation and exposure to wave action by the survey results. Although other factors beside these two are important, the influence of these can be more easily understood once the two dimensional grid has been constructed, and in fact the exposure scale itself was defined as an aid to a study of limpet population dynamics (Ballantine, 1961b). The definition of this scheme of reference for further studies is the third purpose of the survey.

Acknowledgments

The work was carried out while the author was the holder of a Junior Fellowship, established by the Fisheries Division of the Department of Agriculture and Fisheries, and financed by Gulf Oil Terminals (Ireland) Ltd. Facilities for the work were provided by the Fisheries Division of the Department of Agriculture and Fisheries, the Department of Zoology of University College, Cork, and Gulf Oil Terminals (Ireland) Ltd. at Whiddy Island.

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