

ZONATION OF SUPRALITTORAL LICHENS ON ROCKY SHORES AROUND THE DALE PENINSULA, PEMBROKESHIRE

(with Key for their identification)

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The zonation of supralittoral lichens on the rocky shores around the Dale peninsula (Pembrokeshire, Great Britain) is described. Four reasonably distinct zones of lichens within the supralittoral arc recognized, each containing certain important indicator species, as well as a number of subordinate species. The effects of exposure and aspect on zonation are described and discussed. A brief reference is made to the zonation of supralittoral lichens on a nitrogen-rich shore on the edge of a gull colony.

INTRODUCTION

REMARKABLY little detailed attention has been paid to the zonation of lichens on rocky shores, and certainly no quantitative data is available comparable with that on seaweed and marine animal zonations (Lewis, 1964). Some early papers (Knowles, 1913, 1915 and 1929; Smith, 1921) contain descriptions of the most obvious lichen zones but few estimates of the relative importance of different species are given. Also zones are related directly to tidal levels, no account being taken of the effects of exposure. Exposure is the term used to describe the magnitude of wave and spray action, generated by the interaction of a number of physical, environmental factors, on a shore. Exposure values are more conveniently derived, however, from observations on seaweed and marine animal zonations, and are therefore biologically rather than physically based.

Some recent work contains more detailed descriptions of lichen zonation. Eliasson (1965) and Karenlampi (1966) describe the zonation on some Swedish and Finnish coastlines respectively, and used quantitative, although somewhat subjective, methods for estimating the importance of the various lichen species. Eliasson mentions the effects of aspect and high nitrogen levels, but does not consider the effects of exposure. Karenlampi includes some comments on the effects of exposure.

Sheard and Ferry describe in some detail, using data based on more objective quantitative methods, the zonation on certain shores of the Isle of May (Sheard and Ferry, 1967) and of Inishowen (Sheard, 1968). However, in both cases, too few shores (four and five respectively) were examined to allow any useful generalizations to be made.



FIG. 1.
The Dale Peninsula showing the position of the transects.

An analysis of these previous investigations indicates that, in terms of numbers of species, the upper part of the shore is the most complex ecologically, and has, proportionately, received least attention. Lewis (1964) defines this part of the shore as the supralittoral zone, its lower limit on any shore being the top of the black *Verrucaria maura* belt. Knowles (1913) lists a number of species as belonging specifically to the upper supralittoral zone, and Sheard and Ferry (1967) separate the supralittoral into three zones for shores on the Isle of May. Lewis (1964) uses *Verrucaria maura* to delimit the littoral fringe which consequently extends down to the top of the barnacles. The barnacles and the main algal zones down as far as the kelps are referred to the eulittoral zone. These biological zones are especially useful because they are constant for all shores and take account of variations in exposure.

The aim of this survey is to describe in detail, and in quantitative terms, the zonation of lichens in the supralittoral zone of the rocky shores around the Dale peninsula. Species of the littoral fringe and the eulittoral zone are omitted from this quantitative survey, partly because of the acute problems of field identification of these species, especially of extreme forms, and also because the ecology and taxonomy of these lichens is the subject of current work elsewhere. However, the lichens of these zones are included in the key mentioned below.

The zonation of the supralittoral lichens is further related to variations of exposure and aspect.

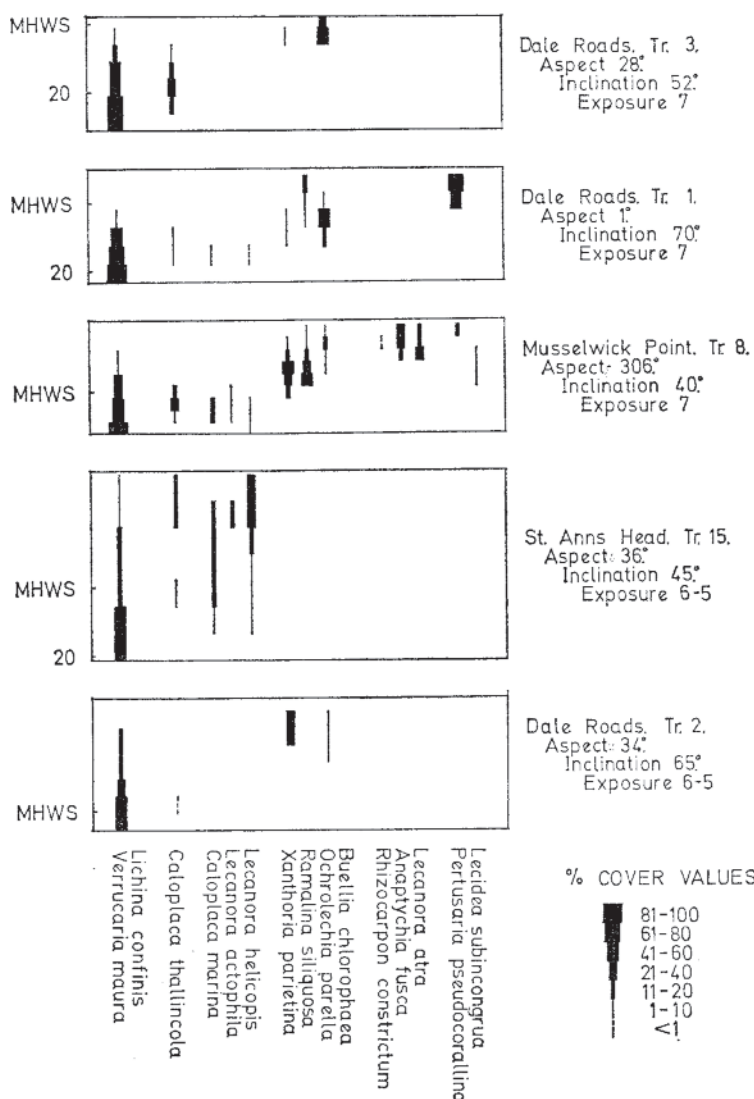


FIG. 2. The zonation of some important supralittoral lichens on sheltered north-facing shores.

(Ballantine, 1961; Moyses and Nelson-Smith, 1963), some slight modifications being made in the present paper. The exposure scale used is that of Ballantine:

1. Extremely exposed shores.
2. Very exposed shores.
3. Exposed shores.
4. Semi-exposed shores.
5. Fairly sheltered shores.
6. Sheltered shores.
7. Very sheltered shores.
8. Extremely sheltered shores.

The positions of transects on these shores, except for those at Martin's Haven and on Skomer Island, are given on the map (Fig. 1).

Percentage cover is unquestionably the best method for sampling and assessing the performance of crustose and foliose lichens which dominate the rocky shore communities. Two methods have been used by the authors to measure percentage

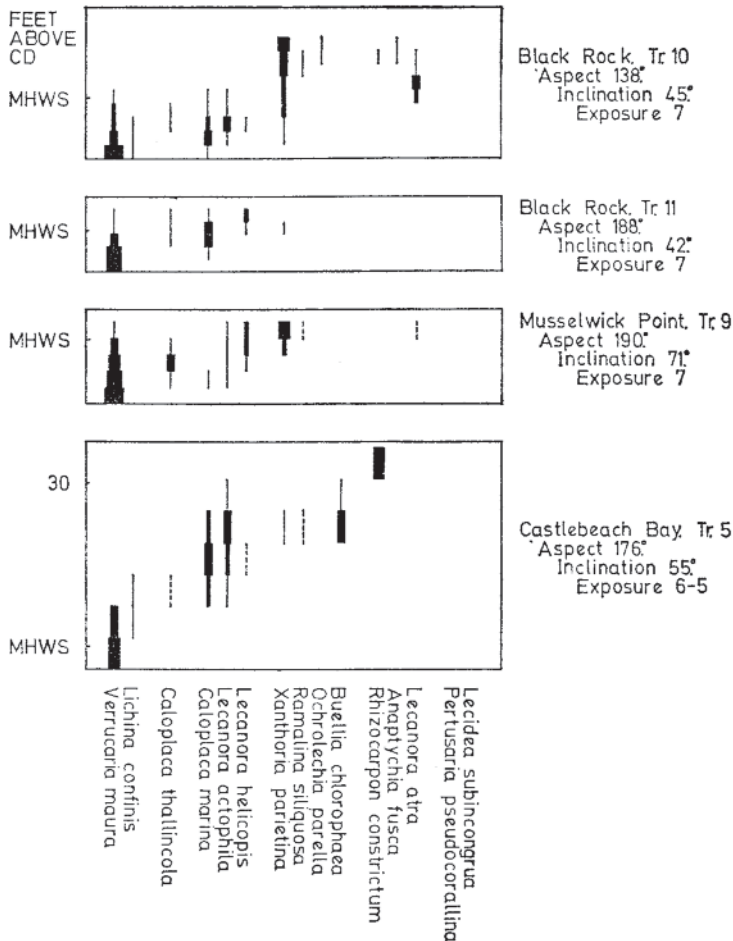


FIG. 4. The zonation of some important supralittoral lichens on sheltered south-facing shores.

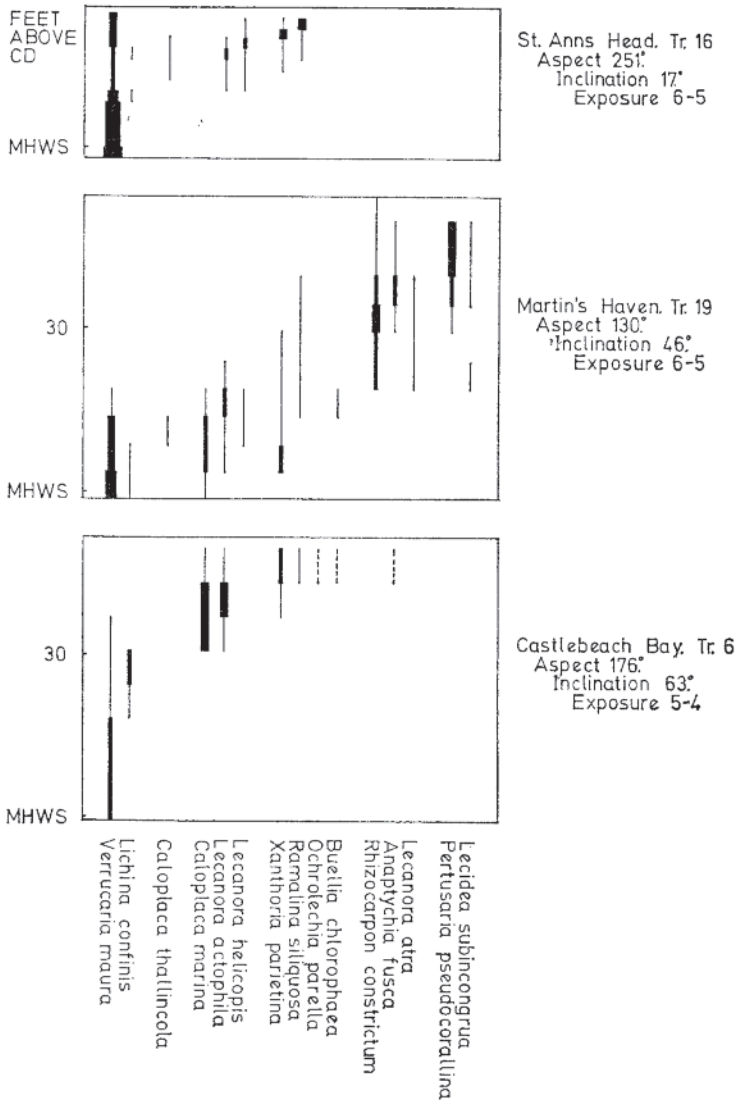


FIG. 5.

The zonation of some important supralittoral lichens on sheltered south-facing shores.

cover, both being variations of the pin-hit technique. Both are described here because they are useful under rather different circumstances.

Where lengths of reasonably uniform shore occur a method used on the Isle of May (Sheard and Ferry, 1967) can be applied. The shore is divided into horizontal belts by means of a staff and level, starting from a suitable datum line. The vertical interval for these belts depends on the exposure of the shore, varying, it is suggested, from 20 cm. for sheltered shores to 100 cm. for exposed shores. Sampling within each belt is by means of a point quadrat of suitable design. It is recommended that 25 pins, set at 5 cm. intervals, in the form of a square grid are used, and that the pins are

loose-fitting and therefore able to accommodate uneven substrata. The sensitivity of the technique obviously depends on the number of quadrats sampled for each horizontal belt of shore. Probably ten is quite sufficient to detect the distribution patterns of all but the rarer species, percentage cover values being obtained from the pooled 250 points for each belt. It is important that the quadrats be randomly distributed within each belt. This together with the initial delimiting of the belts is a time-consuming task and represents the one serious drawback of the method.

The alternative method, used when a large number of shores are to be examined or when uniform lengths of shore are absent, is less sensitive but at the same time less time-consuming, and is probably accurate enough for a general survey of the type carried out at Dale. The method involves sampling at regular intervals along a transect line starting from a suitable datum point. Sampling is by means of a metal tube, 12 cm. long, carrying 10 loosely-held pins set transversely at 1 cm. intervals, and used at right angles to the transect line. Sampling intervals should be from 5 cm. on sheltered shores to 20 cm. on exposed shores. Percentage cover values are obtained by pooling five successive sets of points. The drawback of this method clearly lies in the small number of points (50) used to estimate percentage cover and the subjectiveness of the choice of the transect line.

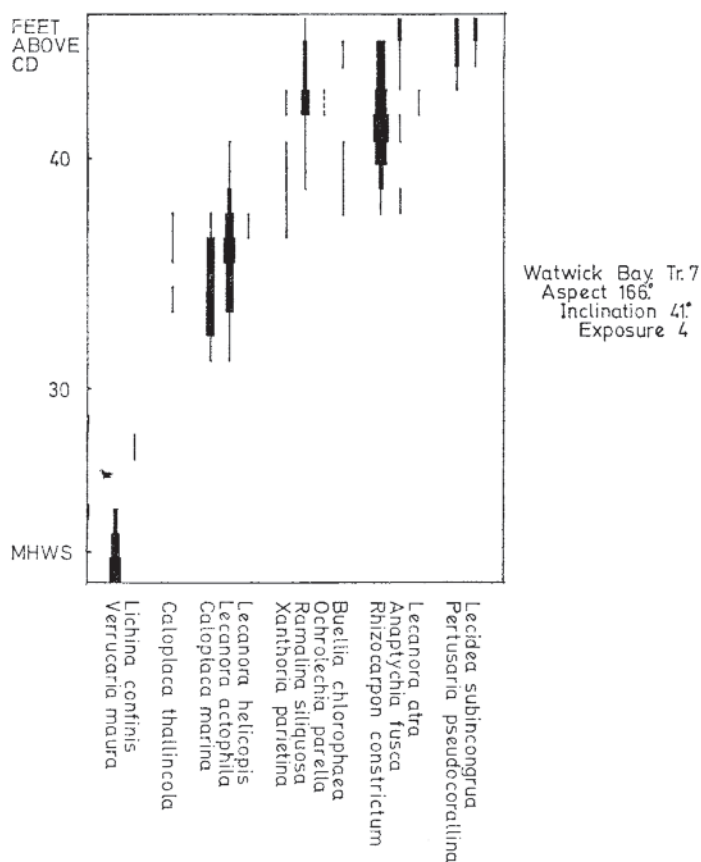


FIG. 6.

The zonation of some important supralittoral lichens on a semi-exposed south-facing shore.

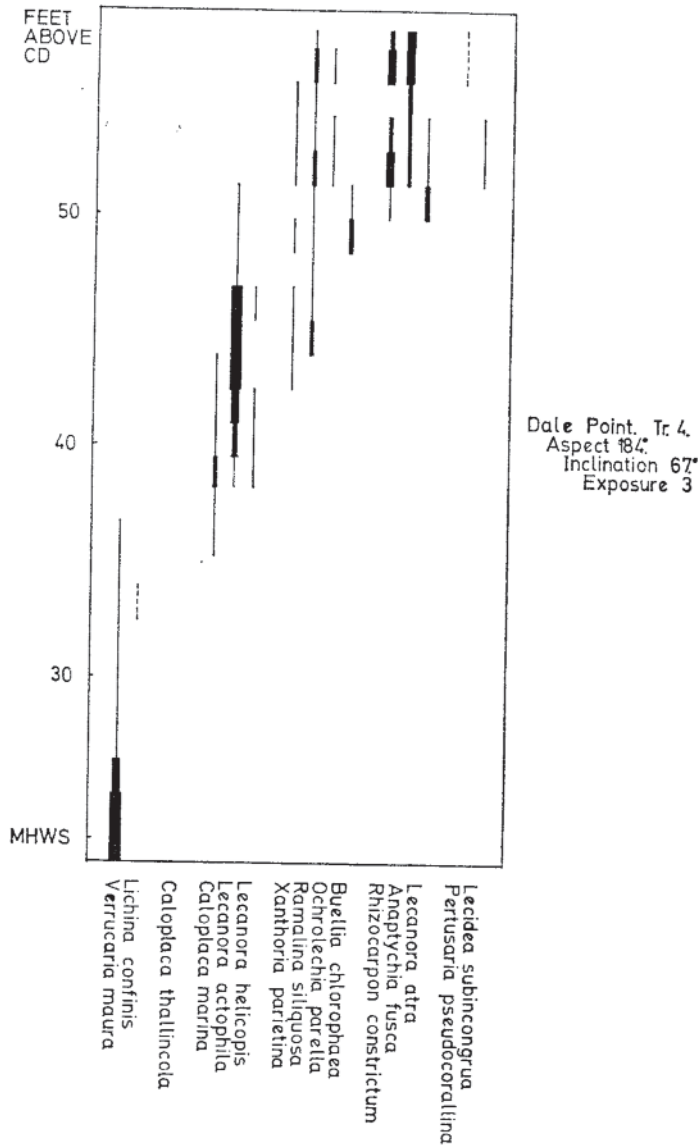


FIG. 7.
The zonation of some important supralittoral lichens on an exposed south-facing shore.

RESULTS

Nearly fifty lichens were identified and their positions described on the rocky shores of the Dale peninsula. An analysis of the results for the 21 shores examined indicates that 13 of the 50 species are particularly important because they occur regularly and occupy fairly constant positions in the supralittoral zone. The zonation of these 13 indicator species is shown for each of the shores examined in Figs 2-10.

The effects of exposure on zonation are summarized in Fig. 11. North- and south-facing shores are treated separately. None of the supralittoral lichens, with one possible exception, show a preference for shores of any particular exposure. *Caloplaca*

thallincola may possibly be restricted to more sheltered shores. The *Lichina* species of the littoral fringe and eulittoral zone, especially *Lichina pygmaea*, are known to be restricted to exposed shores. The outstanding effect of increased exposure is to raise the levels of the supralittoral lichens as shown for four of the thirteen indicator species in Fig. 11. A similar analysis of the remaining nine indicator species shows that all of the indicator species can be positioned reasonably accurately on the shore. Four zones within the supralittoral zone can be defined and are shown in Figs. 11 and 12. They are:

Zone 1. The zone nearest the littoral fringe containing, on south-facing shores, *Caloplaca marina* with *Lecanora actophila* slightly higher on the shore. Both of these species are absent from extreme north-facing shores, *Caloplaca marina* being perhaps slightly more tolerant of shade than *Lecanora actophila*. *Lecanora helicopsis* occurs in the upper part of Zone 1 on shores generally and is often the dominant species on north-facing shores. *Caloplaca thallincola* occurs in this zone. On shores of comparable exposure the lower limit of this zone, as defined by the upper limit of *Verrucaria maura*, tends to be higher on north-facing shores compared with south-facing shores.

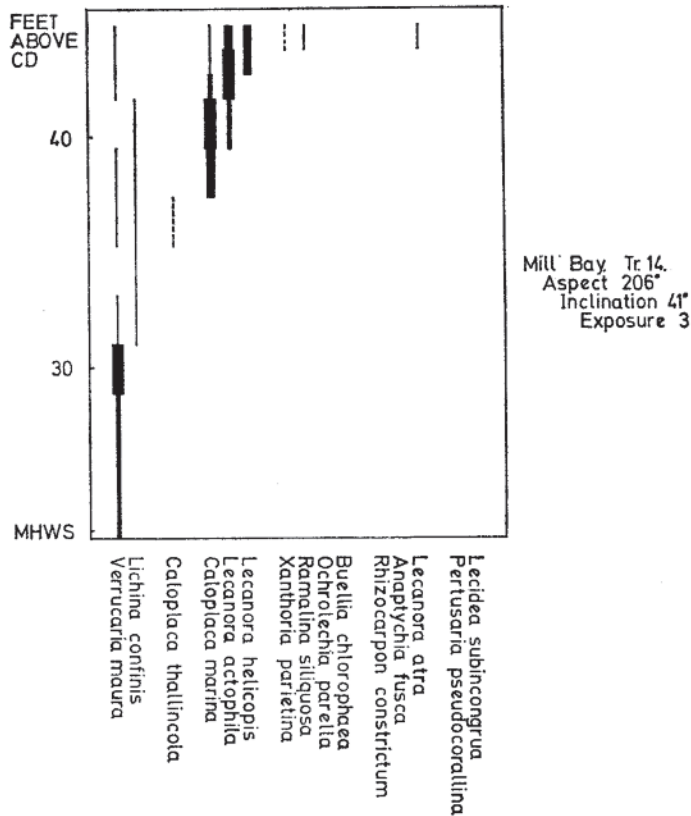


FIG. 8.
The zonation of some important supralittoral lichens on an exposed south-facing shore.

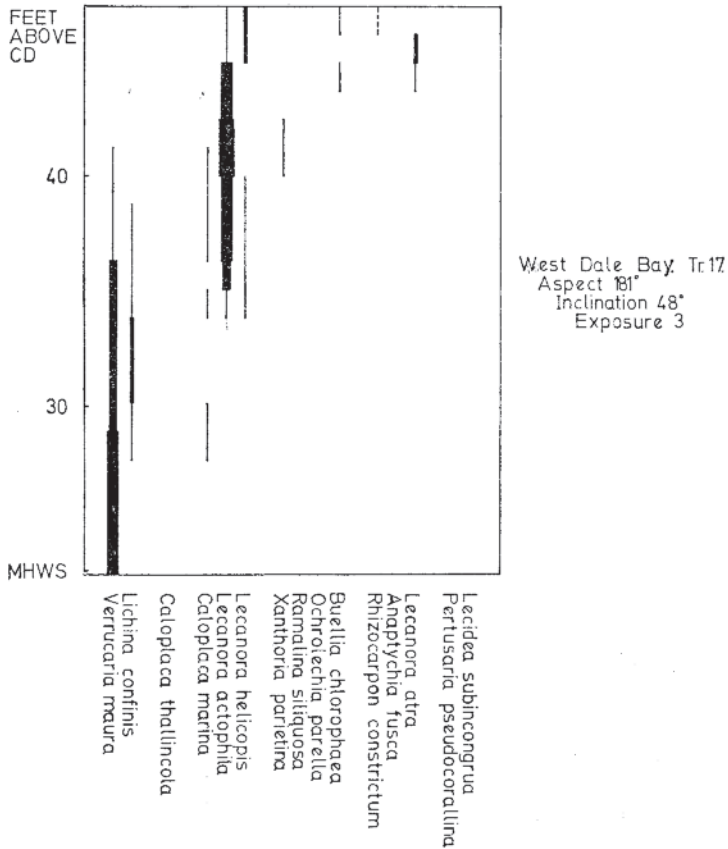


FIG. 9.

The zonation of some important supralittoral lichens on an exposed south-facing shore.

Zone 2. This zone is dominated generally on all shores by *Xanthoria parietina* and *Ramalina siliquosa*. *Buellia chlorophaea* is important on south-facing shores and appears to be completely intolerant of extreme shade. *Ochrolechia parella* on the other hand tends to be a species of shaded north-facing shores although it does occur also on south-facing shores.

Zone 3. This zone is usually dominated, on south-facing shores, by *Rhizocarpon constrictum*, a species almost completely intolerant of shaded north-facing shores. It is frequently accompanied by *Anaptychia fusca* and *Lecanora atra*, species which occur with more or less equal frequency on south- and north-facing shores.

Zone 4. This zone is the uppermost in the supralittoral and merges into the non-maritime vegetation. *Pertusaria pseudocorallina* and *Lecidea subincongrua* are species of this zone and neither appears to be restricted to shores of any particular aspect.

In describing these four zones the effects of aspect have been emphasized and it is quite clear that certain species are more or less restricted to shores of a certain aspect while others are not.

It should be noted also that the zones overlap considerably especially Zones 2, 3 and 4, and that on some shores certain indicator species or even whole zones may be missing.

Species which were recorded in transects, besides the 13 indicator species, are listed in Table 1. The approximate positions occupied by these species within the supralittoral zone are also given.

Finally, one transect was completed on a nitrogen-rich shore on Skomer Island (Fig. 13), immediately adjacent to a Herring Gull colony. Most of the lichens typical of Zones 2, 3 and 4 of the supralittoral on normal south-facing shores are absent and are replaced by nitrophilous species such as *Caloplaca granulosa*, *Lecanora leproscens*, *Leconora poliophaea* and *Lecania aiospila*.

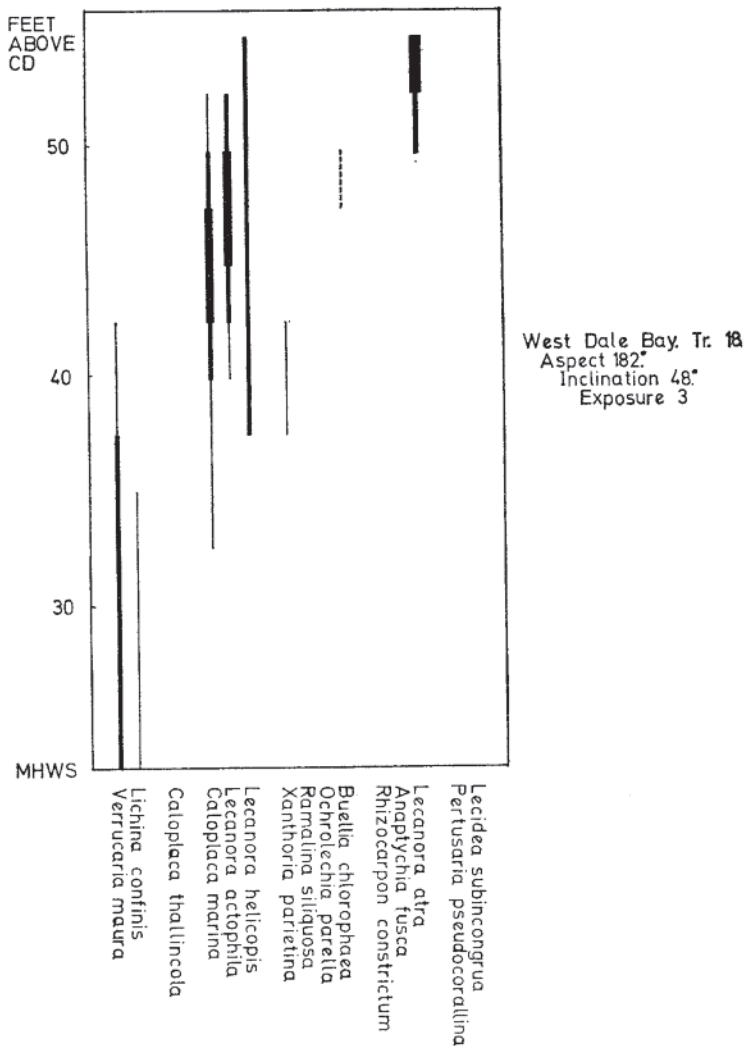


FIG. 10.
The zonation of some important supralittoral lichens on an exposed south-facing shore.

Table 1. *Species recorded from the transects together with positions in the supralittoral zone. Indicator species are not included*

Species	Zone 1	Zone 2	Zone 3	Zone 4
Catillaria lenticularis	+			
Caloplaca granulosa	+	+		
Lecania erysibe	+	+		
Opegrapha spp.	+	+		
Buellia alboatra	+	+	+	
Candelariella vitellina	+	+	+	
Catillaria chalybeia	+	+	+	+
Rinodina subexigua	+	+		
Lecania ralfsii		+		
Caloplaca ferruginea		+	+	
Lecanora dispersa		+	+	
Lecanora leproscens		+	+	
Physcia adscendens		+	+	
Lecidea albocaerulescens		+	+	+
Acarospora fuscata			+	
Lecanora caesiocinerea			+	
Buellia stellulata			+	+
Caloplaca cerina var. chlorina			+	+
Lecanora rupicola			+	+
Bacidia sp.				+
Buellia canescens				+
Buellia subdisciformis				+
Lecanora cinerea				+
Lecanora polytropa				+
Rhizocarpon geographicum				+
Verrucaria nigrescens				+

Lecania aiospila and *Lecanora poliophaea* were only found in Transect 21, the nitrogen-rich shore on Skomer Island and could not be placed accurately in the supralittoral because of the abnormal zonation.

DISCUSSION

The present results generally confirm those of previous workers. *Caloplaca marina*, *Lecanora actophila* and *Rhizocarpon constrictum* have previously been reported as species of south-facing, sunlit shores and *Buellia chlorophaea* is restricted to the sunlit sides of trees inland. The first two species are replaced, on north-facing shores, by *Verrucaria maura* which reaches a higher level here than on comparable south-facing shores. Maritime *Opegrapha* species are known to be confined to shaded north-facing shores and this is confirmed for the shores at Dale. The increased cover of *Ochrolechia parella* on north-facing shores has not previously been mentioned, although the results of Sheard and Ferry (1967) for the Isle of May and of Sheard (1968) for Inishowen indicate this to be so.

The restriction of several supralittoral lichens to south-facing shores is not easily explained. *Caloplaca marina* and *Lecanora actophila* in Zone 1 are good examples to consider. It is possible that competition exists between these two species and *Verrucaria maura* and is balanced in favour of *Verrucaria maura* on north-facing shores and in favour of *Caloplaca marina* and *Lecanora actophila* on south-facing shores. This change in the balance might be due to unequal rates of drying of the substratum, following wetting by wave or spray action, on the two shores, south-facing shores tending to dry out more rapidly. Such an explanation implies that *Caloplaca marina* and *Lecanora actophila* do not have an absolute requirement for a minimum amount of direct sunlight during the day. This may not be true and the explanation may simply be that *Caloplaca marina* and *Lecanora actophila* do require a certain amount of direct

sunlight and are therefore incapable of growing on north-facing shores. The explanation also leaves open the question of whether *Verrucaria maura* is relatively or completely intolerant of the degree of drying out that occurs at the Zone 1 level of the supralittoral on south-facing shores. Obviously the explanation is not necessarily a simple one and the same sort of comments can be applied to other species restricted to south-facing shores.

One notable point of difference exists between the present results and those of previous workers. *Catillaria chalybeia* was shown to be an important indicator species above Zone 1 of the supralittoral on the Isle of May (Sheard and Ferry, 1967) and on one shore at Inishowen (Sheard, 1968), but this is not so for any of the shores

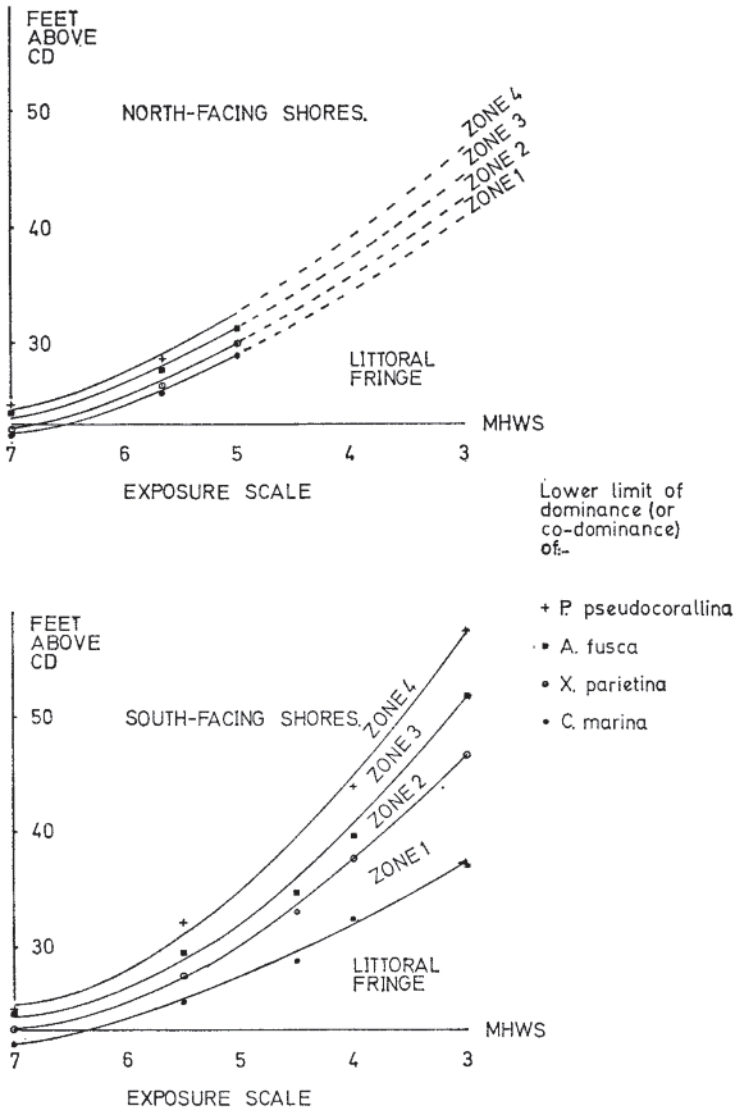


FIG. 11.

The exposure curves of the lower limits of four indicator species used to divide the supralittoral into four zones.

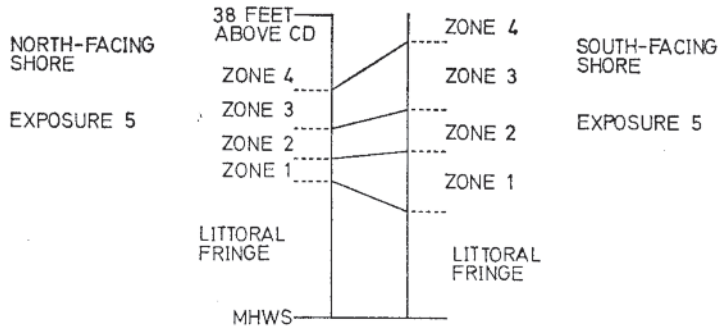


FIG. 12.
A comparison of zonation on south- and north-facing shores of comparable exposure.

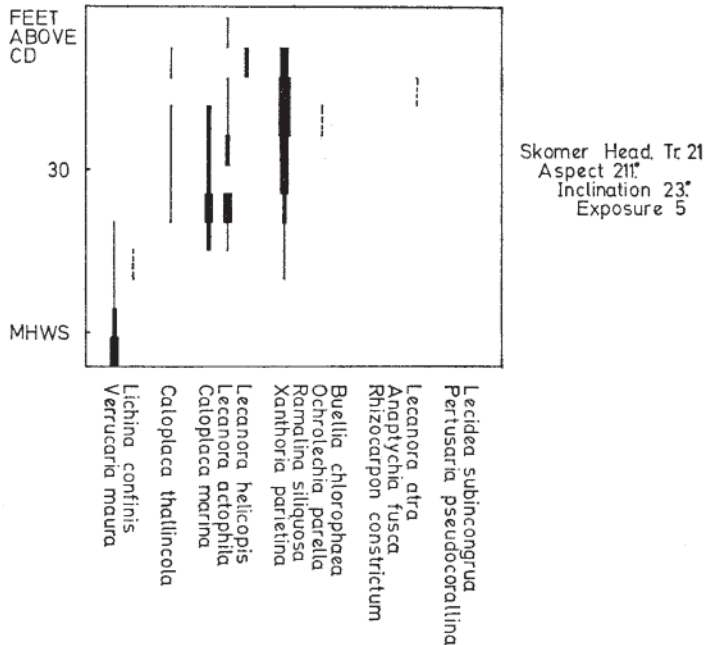


FIG. 13.
The zonation of some important supralittoral lichens on a nitrogen-rich shore.

examined at Dale. This species is distributed throughout the supralittoral at Dale and is never dominant or co-dominant. Sheard (1968) suggests that it might replace *Lecanora helicopsis* in Zone 1 of the supralittoral in damper situations, but even where *Lecanora helicopsis* is sparse or absent on north-facing shores at Dale, *Catillaria chalybeia* does not become important. No attempt was made at Dale to assess the importance of dryness or dampness of the substratum on zonation. Obviously such factors as the aspect, inclination, microtopography and porosity of the substratum would need to be considered.

Without doubt the basic pattern of zonation of the supralittoral lichens reflects different degrees of tolerance to salt water, species of the upper supralittoral,

especially Zone 4, being the least tolerant. The most tolerant species, in Zone 1, are actually subject to immersion by salt water at high tides on the more sheltered shores. There is a possibility, which on the basis of our present knowledge of lichen physiology cannot be discounted, that some maritime lichens need regular washing with salt water. Requirements for certain minerals present in sea water may be involved. Finally it would seem reasonable to suppose that the pattern of zonation is, in part, the result of competition between species with similar tolerances to salt water.

A KEY TO THE MARINE AND MARITIME LICHENS

(with a glossary)

- | | |
|---|--|
| 1. Thallus crustose | 2 |
| Thallus foliose, placoid or squamulose | 52 |
| Thallus fruticose | 63 |
| 2. Fruit a disc (apothecium) | 3 |
| Fruit a globose receptacle (perithecium) | 42 |
| Fruit elongate or stellate | 48 |
| Fruits absent or, if present, then thallus always with isidia or soredia .. | 49 |
| 3. Thallus golden- or orange-yellow | 4 |
| Thallus yellowish-green, pale green or dark green | 6 |
| Thallus whitish or some shade of grey | 10 |
| Thallus brownish | 34 |
| Thallus blackish | 37 |
| Thallus absent | 38 |
| 4. Thallus K + purple. Spores colourless, polarilocular, septum third spore length | 5 |
| Thallus K —. Usually thin, sometimes thick, effuse, granular, yellow, usually with a few small yellowish apothecia. Spores colourless and simple. A supralittoral species, frequently lining cracks. | |
| | <i>Candelariella vitellina</i> (Hoffm.) Mull. Arg. |
| 5. Thallus thin or thick, effuse, entirely sorediate, yellow or yellowish-green. Apothecia rare, small and yellow. A supralittoral species, more common on calcareous substrata. | |
| | <i>Caloplaca citrina</i> (Hoffm.) Th. Fr. |
| Thallus thick, effuse, sometimes with a distinct squamulose margin, areolate, orange. More rarely of scattered yellow granules. Apothecia small and orange, rarely yellow. An important supralittoral species in Zone 1 on all but north-facing shores. | |
| | <i>Caloplaca marina</i> Wedd. |
| 6. Apothecia yellowish, flesh coloured or reddish-brown | 7 |
| Apothecia dark brown or olive | 8 |
| Apothecia black | 9 |

7. Thallus, thin, granular, yellowish- or greyish-green. K+ yellow. Apothecia small, yellowish or flesh coloured with non-persistent thalline margins. Spores colourless and simple. An upper supralittoral species.
Lecanora polytropha (Hoffm.) Rabenh.
 Thallus usually thin, effuse, granular or cracked, greenish- or greyish-olive or brownish. K—. Apothecia small, pale brown or reddish-brown with non-persistent thalline margins. Spores colourless, 1-septate when mature. A mid-supralittoral species. *Lecania erysibe* (Ach.) Mudd.
- Thallus thin, effuse, granular, yellowish-green. K—. Apothecia few or lacking, small, yellowish, Spores colourless and simple. A supralittoral species, frequently lining cracks. *Candelariella vitellina* (Hoffm.) Mull. Arg.
- Thallus thin or thick, effuse, entirely sorediate, yellowish-green. K+ purple. Apothecia rare, small, yellow. Spores colourless, polarilocular, septum third spore length. A supralittoral species, more common on calcareous substrata. *Caloplaca citrina* (Hoffm.) Th. Fr.
8. Thallus usually thick, markedly areolate, forming distinct islands overlying a black hypothallus, greyish- or greenish-yellow or greenish-brown. K+ yellow. Apothecia small, plane, dark brown to greenish-black. Spores colourless and simple. An upper supralittoral species.
Lecanora intricata (Ach.) Ach.
 Thallus thick, sulphurous-green. K+ yellowish-brown. Apothecia smallish, plane, olive or greenish-black, pruinose. Spores colourless and simple. An upper supralittoral species. *Lecidea sulphurea* (Hoffm.) Wahlenb.
9. Thallus thick, dull pale green. Apothecia convex, small, black with distinct thalline margins. Spores colourless and simple. An important supralittoral species in Zone I on all but north-facing shores.
Lecanora actophila Wedd.
 Thallus thick, areolate, bright yellowish-green. Apothecia small, plane, black without thalline margins. Spores brown and muriform at maturity. An upper supralittoral species. *Rhizocarpon geographicum* (L.) DC.
- Thallus thin, minutely areolate, yellowish-green. C+ orange. Apothecia very small, black without thalline margins. Spores brown and septate at maturity. A supralittoral species. *Buellia verruculosa* (Sm.) Mudd
10. Apothecia pale orange to deep rusty-red. K+ purple. 11
 Apothecia pruinose 12
 Apothecia not as above 16
11. Thallus thin or thick and areolate, grey or occasionally pale grey. Apothecia small, deep rusty-red, sometimes paler, without thalline

18. Thallus dark grey, with a greenish tinge, on a white hypothallus. Apothecia brown with distinct thalline margins. Spores colourless and simple. A species of nitrogen-rich shores.
Lecanora poliophaea (Wahlenb. ex Ach.) Ach.
 Thallus pale grey or pale brownish-grey, on a dark hypothallus. Apothecia brown with thalline margins. Spores colourless, 1-septate when mature. A species of nitrogen-rich shores.
Lecania aipospila (Wahlenb. ex Ach.) Th. Fr.
19. Apothecia large 20
 Apothecia small 21
20. Thallus pale grey on a black hypothallus. K + yellow. Apothecia black with thalline margins. Epithecium violet. Spores colourless and simple. An upper supralittoral species. *Lecanora atra* (Huds.) Ach.
 Similar to *L. atra* but epithecium greenish-brown. *Lecanora gangaleoides* Nyl.
21. Apothecia with persistent thalline margins 22
 Apothecia with non-persistent thalline margins 25
22. Apothecia pale, yellow to rich brown 23
 Apothecia dark, olive, brown or black 24
23. Thallus pale grey. K —. Apothecia pale or rich brown. Spores colourless and simple. A mid- and upper-supralittoral species.
Lecanora dispersa (Pers.) Sommerf.
 Thallus yellowish-grey. K + yellow. C + orange. Apothecia yellowish. Spores colourless and simple. A supralittoral species. *Lecanora fugiens* Nyl.
24. Thallus grey, tending to form scattered segments among crowded, dark brown or black apothecia. Spores brown, 1-septate (polarilocular). A supralittoral species. *Rinodina subexigua* (Nyl.) Oliv.
 Thallus dark, lead grey, shiny, of convex areolae, each areola often with a dark central spot. Apothecia dark olive, brown or black. Spores colourless, 1-septate when mature. A mid-supralittoral species.
Lecania ralfsii (Salwey) A. L. Sm.
25. Thallus thick and areolate, thin or occasionally lacking, pale to dark grey. K —. Apothecia brown to black. Spores colourless and simple. An important supralittoral species in Zone 1 on many shores.
Lecanora helicopsis (Wahlenb. ex Ach.) Ach.
 Thallus thin or thick and areolate, whitish, pale grey or grey. K —. Apothecia plane becoming convex, black. Spores brown and pseudomuriform at maturity. A mid-supralittoral species.
Buellia alboatra (Hoffm.) Deichm. Br. & Rostr.

Thallus thin or more rarely thick and areolate, pale grey or grey, usually tinged yellowish. K + yellow then red. Apothecia plane quickly becoming convex, black. Spores brown and pseudomuriform at maturity. An important supralittoral species in Zone 3 on all but north-facing shores.

Buellia chlorophaea (Hepp ex Leight.) Lett.

- | | |
|---|----|
| 26. Apothecia markedly convex, large | 27 |
| Apothecia immersed or plane, perhaps becoming convex at maturity, small | 28 |
| Apothecia immersed, becoming concave at maturity, small | 33 |

27. Thallus smooth, whitish to pale grey. K —. P + orange. Apothecia black, often pruinose. Spores simple and colourless. An upper supralittoral species. *Lecidea albocaerulescens* (Wulf.) Ach.
Thallus thin, sometimes thick, smooth, cracked or areolate, pale grey. P —. K —. Apothecia black. Spores colourless and simple. An upper supralittoral species. *Lecidea macrocarpa* (DC.) Steud.

Thallus thick, areolate, grey, brownish- or creamy-grey. K + yellow then red. Apothecia black, often pruinose. Spores brown and septate at maturity. An upper supralittoral species. *Buellia subdisciformis* (Leight.) Vain.

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|--------------------------------|----|
| 28. Thallus C + orange | 29 |
| Thallus C — | 30 |

29. Thallus pale grey. K + yellow. Apothecia immersed becoming convex, dark brown or black. Spores brown, 1-septate (polarilocular). An upper supralittoral species. *Rinodina atrocineria* (Dicks.) Korb.
Thallus thick, areolate, purplish-grey. K —. Apothecia plane becoming convex, dark brown. Spores brown, 1-septate (polarilocular). An upper supralittoral species. *Rinodina luridescens* (Anzi) Arnold

- | | |
|---|----|
| 30. Thallus K — or K faint + yellow | 31 |
| Thallus K + yellow or K + yellow then red | 32 |

31. Thallus finely areolate, grey or brownish-grey. K —. Apothecia plane, black. Spores brown and muriform at maturity, 20–38 by 10–17 microns. An important supralittoral species in Zone 3 on all but north-facing shores. *Rhizocarpon constrictum* Malme.
Thallus finely areolate, grey or brownish-grey. K faint + yellow. Apothecia plane, black. Spores brown and muriform at maturity, 24–50 by 12–18 microns. An upper supralittoral species, much less frequent than *R. constrictum*. *Rhizocarpon obscuratum* (Ach.) Massal.

32. Thallus small, areolate, whitish or pale grey. K + yellow. Fimbriate black hypothallus often evident. Apothecia plane, black, numerous and regularly distributed, so as to produce a distinctly mottled black and

white thallus. Spores brown and 1-septate at maturity. An upper supralittoral species. *Buellia stellulata* (T. Tayl.) Mudd

Thallus effuse, finely areolate, grey or brownish-grey. K+ yellow then red. Hypothallus black. Apothecia immersed becoming almost plane, dark brown. Spores brown and 1-septate at maturity. An upper supralittoral species. *Buellia aethalia* (Ach.) Th. Fr.

33. Thallus smooth, cracked, grey or brownish-grey. K+ yellow then red. Apothecia black. Spores colourless and simple. An upper supralittoral species. *Lecanora cinerea* (L.) Sommerf.

Thallus thick, coarsely areolate, bluish-grey. K—. Apothecia black. Spores colourless and simple. An upper supralittoral species. *Lecanora caesiocinerea* Nyl. ex Malbr.

Thallus never areolate, pale somewhat dirty grey. K—. Apothecia black. Spores colourless and simple. A species of nitrogen-rich shores. *Lecanora leproscens* Sandst.

Thallus thick, deeply cracked, whitish. Apothecia grey, minute, remaining immersed and tending to crowd at the centre of the thallus. Spores brown, 4-7-septate. A supralittoral species of dry overhangs. *Sclerophyton circumscriptum* (T. Tayl.) Zahlbr.

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|---|----|----|----|
| 34. Apothecia convex from the first, without thalline margins | .. | .. | 35 |
| Apothecia immersed at first, opening into minute discs | .. | .. | 36 |

35. Thallus rather granular, pale khaki-brown, tinged with yellow or green. C+ orange. Apothecia large, black. Spores colourless and simple. An important supralittoral species in Zone 4 on many shores. *Lecidea subincongrua* Nyl.

Thallus thick, grey-brown or brown, subdivided by black lines of hypothallus. C—. Apothecia small, nearly plane, black with dark brown flexuous margins. Spores colourless, simple and bean-shaped. An upper supralittoral species. *Lecidea cyathoides* (Ach.) Ach.

36. Thallus thick, coarsely areolate with a squamulose margin, brown. C+ red. Apothecia reddish-black. Spores colourless and simple, many in each ascus. An upper supralittoral species. *Acarospora fuscata* (Nyl.) Arnold.

Thallus areolate or of scattered squamules, yellowish-brown. C—. K+ yellow then red. Apothecia black. Spores colourless and simple, many in each ascus. An upper supralittoral species. *Acarospora smaragdula* (Wahlenb. ex Ach.) Massal.

Thallus of small, angular, swollen areolae, pale to dark fuscous-brown. C—. K—. Apothecia black with violet-blue epithecia. Epithecium K+ sky blue. Spores colourless and simple. An upper supralittoral species. *Lecidea tenebrosa* Flot.

37. Thallus thin, brownish-black or black. Apothecia very small, black, without thalline margins. Hypothecium pale. Spores colourless, mostly 1-septate. A lower supralittoral and littoral fringe species.
Catillaria lenticularis (Ach.) Th. Fr.
 Thallus thin, greenish-black or black. Apothecia very small, black with shiny margins and without thalline margins. Hypothecium dark. Spores colourless, mostly 1-septate. A common supralittoral species.
Catillaria chalybeia (Borr.) Massal.
38. Apothecia yellow to brown, small 39
 Apothecia dark brown to black, small 40
39. Apothecia pale or rich brown. Persistent thalline margins K—. A mid- and upper-supralittoral species. *Lecanora dispersa* (Pers.) Sommerf.
 Apothecia yellowish. Persistent thalline margins K+ yellow, C+ orange. A supralittoral species. *Lecanora fugiens* Nyl.
40. Apothecia without thalline margins 41
 Apothecia with non-persistent thalline margins, brown to black. Spores colourless and simple. An important supralittoral species in Zone 1 on many shores. *Lecanora helicopsis* (Wahlenb. ex Ach.) Ach.
 Apothecia with persistent thalline margins, dark brown or black. Spores brown, 1-septate (polarilocular). A supralittoral species. *Rinodina subexigua* (Nyl.) Oliv.
41. Apothecia very small, black. Hypothecium pale. Spores colourless mostly 1-septate. A lower supralittoral and littoral fringe species.
Catillaria lenticularis (Ach.) Th. Fr.
 Apothecia very small, black, with shiny margins. Hypothecium dark. Spores colourless, mostly 1-septate. A common supralittoral species.
Catillaria chalybeia (Borr.) Massal.
42. Thallus dark brown or black 43
 Thallus dark olive-green 47
 Thallus creamy-grey, thick and papillate. K+ yellow then red. Apothecia immersed in worts, open only at tips. Spores colourless and simple, usually two in each ascus. An upper supralittoral species.
Pertusaria microstictica (Sm.) Erichs.
43. Algal cells green, alga unicellular. Spores colourless and simple .. 44
 Algal cells yellowish-green, alga filamentous. Thallus thin, brownish. Perithecia small, slightly immersed. Spores colourless 3-septate. A supralittoral species of shaded places. *Porina chlorotica* (Ach.) Mull. Arg.
 Algal cells blue-green (*Hyella caespitosa*). Thallus usually thin, shiny brownish-black on acid rocks, absent on shells of barnacles and limpets.

Perithecia minute, black, immersed or partly immersed. Spores colourless, unequally 2-celled. A species of the eulittoral zone and littoral fringe, often on shells. *Arthopyrenia halodytes* (Nyl.) Arnold

44. Thallus black, cracked, never areolate, often partly or wholly ridged. Species of the eulittoral zone or lower littoral fringe 45
 Thallus dark brownish or dull black and areolate. Species of the littoral fringe or supralittoral zone 46
45. Thallus typically continuous, delicately ridged, shiny. Perithecia prominent with flat or crateriform tips. Spore length greater than 11 microns. *Verrucaria amphibia* R. Clem.
 Thallus continuous or reduced to ridges. Perithecia prominent and usually shiny. Spore length less than 11 microns. *Verrucaria microspora* Nyl. (atypical form).
 Thallus of ridges. Perithecia prominent with flat tips. Spore length less than 11 microns. *Verrucaria striatula* Wahlenb. ex Ach. (atypical form).
46. Thallus typically coarsely areolate, sometimes finely cracked or smooth, dull black. Perithecia immersed but may be prominent in forms lacking a thallus or with the thallus reduced to ridges. Spore length greater than 11 microns. The main littoral fringe species. *Verrucaria maura* Wahlenb. ex Ach.
 Thallus thin and scurfy, greyish-brown. Perithecia usually prominent and shiny. Spores with blunt ends, length greater than 11 microns. A species of the upper littoral fringe. *Verrucaria prominula* Nyl.
 Thallus finely areolate, brownish-black. Perithecia semi-immersed. Spore length greater than 11 microns. An upper supralittoral species. *Verrucaria nigrescens* Pers.
47. Thallus thick, smooth, gelatinous, on a white hypothallus. Perithecia completely immersed. Spores colourless and simple, less than 11 microns long. A species of the culittoral zone. *Verrucaria striatula* Wahlenb. ex Ach.
 Thallus thinner than in *V. mucosa*, smooth, gelatinous. Perithecia prominent and shiny. Spores colourless and simple, less than 11 microns long. A species of the eulittoral zone and lower littoral fringe. *Verrucaria microspora* Nyl.
 Thallus thin, dark olive-green with coarse black ridges. Perithecia prominent with flat tips. Spores colourless and simple, less than 11 microns long. A species of the eulittoral zone. *Verrucaria striatula* Wahlenb. ex Ach.
48. Thallus thin or evanescent, scurfy, yellowish-grey or brownish. Apothecia single or stellate, black. Spores colourless, 3-septate. A supralittoral species. *Opegrapha saxicola* Ach.

Thallus very thin, grey. Apothecia tending to form heaps towards the centre of the thallus. Spores colourless, 3-septate. A supralittoral species.

Opegrapha confluens (Ach.) Stiz.

Thallus white to pale violet-grey. Apothecia single or stellate, black. Spores colourless, 5-septate with a large end cell. A supralittoral species, common in dry crevices.

Opegrapha cesareensis Nyl.

49. Thallus whitish, pale or creamy-grey 50
 Thallus yellow, yellowish- or greyish-green 51

50. Thallus thick, deeply cracked, whitish, appearing greyish due to the presence of numerous minute immersed apothecia towards the centre. Spores brown, 4-7-septate. A supralittoral species of dry overhangs.

Sclerophyton circumscriptum (T. Tayl.) Zahlbr.

Thallus pale somewhat dirty grey. K —. A species of nitrogen-rich shores.

Lecanora leproscens Sandst.

Thallus creamy-grey, thick and papillate. K + yellow then red. An upper supralittoral species.

Pertusaria pseudocorallina (Liljeb.) Arnold

51. Thallus golden-yellow or yellowish-green, entirely sorediate. K + purple. A supralittoral species, more common on calcareous substrata.

Caloplaca citrina (Hoffm.) Th. Fr.

Thallus thin, greenish-grey, with yellowish soralia. C + orange. A supralittoral species.

Lecidea scabra T. Tayl.

Thallus thick, papillate, greenish-grey. C —. A supralittoral species.

Bacidia scopulicola (Nyl.) A. L. Sm.

52. Thallus foliose 53
 Thallus placoid 57
 Thallus squamulose 59

53. Thallus grey 54
 Thallus brownish 55
 Thallus yellow 56

54. Thallus deeply lobed, pruinose, attached to substratum at central point, lacking rhizinae. Perithecia immersed in thallus. An upper supralittoral species.

Dermatocarpon miniatum (L.) Mann.

Thallus lobed, with ciliate margins, attached to substratum by rhizinae.

K + yellow. Soralia present under helmet-shaped ends of lobes. A mid- and upper-supralittoral species.

Physcia adscendens (Th. Fr.) Oliv. em. Bitt.

55. Thallus lobed, brown, attached to substratum by rhizinae. Apothecia large, blackish, with thalline margins. Spores brown, 1-septate. An important supralittoral species in Zone 3 on many shores.

Anaptychia fusca (Huds.) Vain.

Thallus lobed, becoming transversely wrinkled away from margins, pale olive-brown, pale or dark brown, shiny, attached to the substratum by rhizinae. An upper supralittoral species. *Parmelia prolixa* (Ach.) Carroll.

Thallus lobed, pale olive-brown, with isidia in patches, attached to the substratum by rhizinae. An upper supralittoral species. *Parmelia loxodes* Nyl.

56. Thallus of broad lobes, attached to the substratum by rhizinae. K+ purple. Apothecia large, orange, abundant. Spores colourless, 1-septate. An important supralittoral species in Zone 2 on nearly all shores.

Xanthoria parietina (L.) Th. Fr.

Thallus of narrow ascending lobes, minutely sorediate on the margins. K+ or - purple. Rarely fertile. A species of nitrogen-rich shores.

Xanthoria candelaria (L.) Th. Fr.

57. Thallus yellow or greenish-yellow. K+ purple. 58

Thallus whitish or pale grey, often sorediate, rarely with small black apothecia. K-. An upper supralittoral species. *Buellia canescens* (Dicks.) DNot.

58. Thallus with long, crowded, convex marginal lobes. Apothecia orange with non-persistent thalline margins. Spores colourless, polarilocular, septum half spore length. An important supralittoral species in Zone 1 on most shores.

Caloplaca thallicola (Wedd.) Du Rietz.

Thallus with long, crowded, convex marginal lobes, the centre granulate with isidia. Apothecia rare. A lower supralittoral species, important on nitrogen-rich shores.

Caloplaca granulosa (Mull. Arg.) Jatta.

59. Thallus brown 60

Thallus orange, usually effuse, sometimes with a distinct squamulose margin, thick and areolate. K+ purple. More rarely of scattered yellow granules. Apothecia small and orange, rarely yellow. Spores colourless, polarilocular, septum third spore length. An important supralittoral species in Zone 1 on all but north-facing shores.

Caloplaca marina Wedd.

Thallus whitish, of minute, scattered or massed squamules. Apothecia minute, plane, brown. Spores colourless, 1-septate. A supralittoral species.

Solenopsora vulturicensis Massal.

60. Apothecia convex from the first 61

Apothecia immersed at first, opening into minute discs 62

61. Thallus of somewhat imbricate squamules, brown. K-. C-. Apothecia small, dark brown with non-persistent thalline margins. Spores colourless, 1-septate. A supralittoral species.

Solenopsora holophaea (Mont.) Samp.

Thallus of squamules, dark brown. K—. C—. Apothecia small, dark brown without thalline margins. Spores colourless and simple. A supralittoral species.

Lecidea lurida (With.) Ach.

62. Thallus thick, coarsely areolate with a squamulose margin, brown. C+ red. Apothecia reddish-black. Spores colourless and simple, many in each ascus. An upper supralittoral species. *Acarospora fuscata* (Nyl.) Arnold

Thallus areolate or of scattered squamules, yellowish-brown. C—. K+ yellow then red. Apothecia black. Spores colourless and simple, many in in each ascus. An upper supralittoral species.

Acarospora smaragdula (Wahlenb. ex Ach.) Massal.

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| 63. Thallus brownish-black | .. | .. | .. | .. | .. | .. | .. | 64 |
| Thallus green | .. | .. | .. | .. | .. | .. | .. | 65 |

64. Thallus a branched tuft about 1 cm. high, branches rather flattened. A species of the eulittoral zone. *Lichina pygmaea* (Lightf.) C. Ag.

Thallus a branched tuft barely 5 mm. high, branches rounded. A species of the upper littoral fringe.

Lichina confinis (O. F. Mull.) C. Ag.

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| 65. Thallus greyish-green, tinged yellowish | .. | .. | .. | .. | .. | .. | .. | 66 |
| Thallus greyish, tinged bluish never yellowish | .. | .. | .. | .. | .. | .. | .. | 68 |

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|--------------------|----|----|----|----|----|----|----|----|
| 66. Soredia absent | .. | .. | .. | .. | .. | .. | .. | 67 |
|--------------------|----|----|----|----|----|----|----|----|
- Soredia present laterally on tufted thallus. K+ red. A mid-supralittoral species. *Ramalina subfarinacea* (Nyl. ex Cromb.) Nyl.

67. Thallus of flattened branches, green at the base. Apothecia sometimes present, laterally on branches. An important supralittoral species in Zone 2 on most shores. *Ramalina siliquosa* (Huds.) A. L. Sm.

Thallus of nearly rounded branches, black at the base. A mid-supralittoral species.

Ramalina curnowii Cromb. ex Nyl.

68. Thallus a tuft of flattened branches, longer than 5 cm. C—. Soredia along margins, C+ red. A supralittoral species. *Roccella fuciformis* DC

Thallus a tuft of rounded branches, shorter than 5 cm. C+ orange. Soredia in globose heads, C—. A supralittoral species.

Roccella phycopsis (Ach.) Ach.

GLOSSARY TO THE KEY

APOTHECIUM (pl. APOTHECIA). An open disc-shaped fruiting body, if less than 1 mm. diam. then SMALL, if greater than 1 mm. diam. then LARGE.

AREOLA (pl. AREOLAE, adj. AREOLATE). A small area of thallus completely isolated by cracks. A thallus may be cracked without being areolate.

- ASCUS (pl. ASCI). A sac-shaped cell containing spores.
- C TEST. One drop of 50 per cent calcium hypochlorite or "Domestos" added to the thallus may elicit a colour change, designated positive (+) or negative (-).
- CALCAREOUS. Containing lime (a substratum).
- CILIUM (pl. CILIA, adj. CILIATE). A hair on the thallus or fruit.
- CONCAVE. Forming a shallow pit in a thallus (an apothecium).
- CONVEX. Raised above the level of the thallus (an apothecium).
- CRATERIFORM. Crater like (a perithecium tip).
- CRUSTOSE. Forming a crust closely adhering to the substratum (a thallus).
- EFFUSE. Indeterminate and spreading (a thallus).
- EPITHECIUM. The upper layer of an apothecium, consisting of the tips of the asci and paraphyses.
- EULITTORAL ZONE. The zone of shore delimited by the upper edge of the *Laminaria* seaweeds and the upper limit of the barnacles.
- FIMBRIATE. Fringed (a hypothallus).
- FLEXUOUS. Wavy (an apothecium margin).
- FOLIOSE. Leafy and more or less prostrate (a thallus).
- FRUTICOSE. Upright or pendulous, attached to the substratum at a single point (a thallus).
- GLOBOSE. Spherical (a perithecium).
- GRANULAR. Formed of minute granules (a thallus).
- HYPOTHALLUS. A layer of hyphae underlying the thallus proper.
- HYPOTHECIUM. The layer of hyphae below the asci and paraphyses in an apothecium.
- IMBRICATE. Overlapping (parts of a thallus).
- IMMERSED. Embedded in a thallus (apothecia or perithecia).
- ISIDIUM (pl. ISIDIA, adj. ISIDIATE). A coral-like outgrowth of the thallus, which does not disrupt the cortex of the thallus.
- K TEST. One drop of 50 per cent potassium hydroxide added to the thallus may elicit a colour change, designated positive (+) or negative (-).
- LITTORAL FRINGE. The zone of shore delimited by the upper edge of the barnacles and the upper limit of *Verrucaria maura*.
- MICRON. 0.001 mm. (used in spore measurements).
- MURIFORM. With transverse and longitudinal septa (a spore).
- P TEST. One drop of paraphenylenediamine solution (a crystal in a drop of meths.) added to the thallus may elicit a colour change, designated positive (+) or negative (-).
- PAPILLA (pl. PAPILLAE, adj. PAPILLATE). A small protruberance (of a thallus).
- PERITHECIUM. A globose fruiting body with an apical pore.
- PLACOID. With well-developed marginal lobes closely adpressed to the substratum (a thallus).
- PLANE. Flat and level with the thallus (an apothecium).
- POLARILOCULAR. With a thick central septum containing a small tube-like passage connecting two cells (a spore).
- PRUINOSE. Covered with a powdery bloom.
- PSEUDOMURIFORM. With transverse and longitudinal pseudosepta (a spore). Not easily distinguished from muriform.
- RHIZINA (pl. RHIZINAE). A root-like strand.
- SEPTUM (pl. SEPTA, adj. SEPTATE). A wall dividing one cell from another.
- SIMPLE. Non-septate (a spore).
- SORALIUM (pl. SORALLA). A cluster of soredia forming a plaque.
- SOREDIDIUM (pl. SOREDIA, adj. SOREDIATE). A granule erupting through the surface of a thallus and disrupting the cortex.
- SQUAMULOSE. Minutely lobed at the margin (of a crustose thallus).
- STELLATE. Radiating from a central point (of a group of apothecia in *Opograpta* spp.).
- SUPRALITTORAL ZONE. The zone of shore above the upper limit of *Verrucaria maura*.
- THALINE MARGIN. An apothecial margin the same consistency and colour as the thallus.
- THALLUS (pl. THALLI). The vegetative part of a lichen.

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