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Life Forms in the Algae

V. J. Chapman and D. J. Chapman

University of Auckland, Auckland, New Zealand

and

Department of Biology, University of California, Los Angeles, California 90 024, U.S.A.

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A review of life-form schemes in the algae is given and a new one is proposed because no previous scheme has had wide acceptance. The new scheme is intended to be a reflection of habitat requirements of response and to be applicable to both marine and freshwater algae. Biological spectra are constructed for saltmarshes, rocky coasts (temperate and tropical) and for fresh waters. A further comparison is made of different belts on saltmarsh and rocky shores. A final comparison is made of biological spectra ranging from the Arctic to the tropics and from the Atlantic to Pacific Oceans.

Introduction

Just as there have been numerous attempts to formulate life-form schemes for the flowering plants, so various workers have proposed a number of different life-form schemes for the algae. A study of intertidal algae reveals an empirical relationship of the different morphological types to the character of the habitat, e.g., rocky shore, sandy shore, saltmarsh, etc. Apart, however, from these local habitat factors there are other more general factors which must be considered in order to account for such phenomena as the dominance of large kelps in colder waters and the abundance of lime-encrusted forms in warmer waters. The former, is, of course, associated with the failure of the gametophyte generation of the large kelps to reproduce in warm waters, and the latter is regarded as related to the physiology of calcification and at a more general level the overall problem of calcification in tropical waters. It is true that large areas of calcareous algae have been reported from arctic regions but the number of species involved is small compared with those found in the tropics. In recent years this aspect of algal ecology has received very little attention. In view of the accumulating knowledge in physiological ecology and the new impetus in population ecology and "adaptive" ecology, we would like to re-examine the life-form concept with the possibility that the idea might indicate further lines along which investigations should be profitable.

An effective system, for example, should provide a quantitative picture of the vegetation in any one area or geographical region, and it would serve as an extremely useful medium for comparing floras from two different regions. Indeed it is in this respect that any system will probably make its greatest contribution. There will, of course, be much the same limitations to any life-form scheme for the algae as there are to any one for the phanerogams. The principle objections are that no life-form scheme indicates the dominant life-form nor is there any indication of the relative abundance of the different categories. The latter can be surmounted if frequency figures are available by calculating the various life-forms in terms of frequency points, as has been done for Raunkiaer's scheme for the phanerogams. At present practically no frequency data are available from algal ecological surveys, and it is probable that in future such data should be obtained. This approach might be well suited for investigation by computer methods.

The earliest attempts at life-form classification were based, as indeed were those also of the phanerogams, upon morphological criteria, though it is obvious now that this is not the most desirable basis. The main developments in this subject have been in the present century and can be regarded as stemming from Oltmann's schema of 1905 which was wholly morphological.

Little further progress in this field was made until 1926 when Setchell proposed a new system based upon his studies of coral reef algae. One advantage this new scheme possessed was that its basis was largely ecological. However, it would require very considerable modification and extension for general use because it was primarily intended for tropical and sub-tropical regions. The primary classification was based upon the response of algae to light, though in most cases there was little quantitative proof of the response. This would be essential if a scheme of this nature were to be adopted.

The following year Funk (1927) put forward another schema which was also based upon work in the waters of the Mediterranean. This system, however, returned to a morphological basis whilst at the same time some of the terms were open to difficulties of interpretation. Somewhat arbitrary units of length were selected so that it could prove difficult in some cases to decide if a species belonged to the Fine Algae or to the Microscopic Algae, nor was it made clear how one distinguished between Fine Algae and Seaweeds (Tange). There were four major groups and each one was subdivided into a number of categories.

The next classification to be proposed was that of Gislén (1930). This, too, was based upon morphological criteria. This scheme was designed to include both plants and animals in marine habitats and was therefore more ambitious, although algologically it went little further than Oltmann's.

An advance upon these purely morphological categories was proposed by Knight and Parke in 1931. They followed the terrestrial system of Raunkiaer using duration and perennation. However, only four primary groups were proposed and in order to make the scheme workable and meaningful it would have been necessary to subdivide them. The four divisions were perennials, pseudoperennials, annuals and casual annuals. The logical elaboration of this scheme was eventually put forward by Feldmann (1937) as a result of his work on the Mediterranean algae. In a more recent paper Feldmann (1966) has elaborated on this schema.

Feldmann's Scheme

A *Annuals*

1. *Ephemerophyceae*: species present throughout the year in the form of successive generations, e.g., *Enteromorpha, Ectocarpus, Polysiphonia.*
2. *Eclipsiophyceae*: macroscopic thallus present for part of successive generations.

(a) Gametophyte microscopic, e.g., *Mesogloia.*
(b) Sporophyte microscopic, e.g., *Acrosiphonia spinescens.*
(c) With microscopic plethysmothallus, e.g., *Porphyra.*

Feldmann includes *Derbesia/Halicystis* under (a) but his scheme does not seem satisfactory as the *Halicystis* generation cannot really be regarded as microscopic. Unfortunately there is no other category into which they could fit.

3. *Hypnophyceae*: macroscopic thallus present for part of the year, the unfavourable season being passed in some form of resting stage.

(a) Resting stage oospores, e.g., *Spirogyra.*
(b) Resting stage hormogones, e.g., *Rivularia.*
(c) Resting stage akinetes, e.g., *Ulothrix.*
(d) Germination followed by period of dormancy, e.g., *Dudresnaya.*

Feldmann (1966) points out that our knowledge of algae in (d) is very meagre, particularly among the Rhodophyta. This could result in species being misclassed. In the original (1937) version there was also a group for algae that persisted as spores, e.g., *Cylindrospermum.*

B *Perennials*

(a) *Frond entire throughout the year*

4. *Phanerophyceae*: Fronds erect, e.g., *Fucus, Sargassum.* These can be subdivided into plants that each year produce a new set of reproductive organs (Monocarpic phanerophyceae) and those, such as *Caulerpa*, where all the contents are transformed into gametes after which the plants die (Holocarpic phanerophyceae).
5. *Chamaephyceae*: where the frond is a perennial crust or is prostrate, e.g., *Codium adhaerens, Ralfsia, Peyssonnellia.* In 1946 Nasr proposed that algae such as *Caulerpa*, which have prostrate stolons and erect branches, should be classed as Hemichamaephyceae but Feldmann (1966) did not accept this suggestion despite its merit.

(b) *Only part of frond persisting throughout the year*

6. *Hemiphanerophyceae*: part of the erect frond disappears, e.g., *Cystoseira, Laminaria hyperborea, Delesseria sanguinea.*
7. *Hemicryptophyceae*: basal portion only of thallus persists.

(a) Basal perennating portion is a disc, e.g., *Rissoella verruculosa.*
(b) Basal perennating portion is a creeping stolon, e.g., *Petroglossum nicaeense, Caulerpa prolifera.*

Feldmann (1966) points out that some species provide considerable difficulty in classification. One such is *Acetabularia*, which is a perennial alga, but after cyst formation it behaves as Hypnophyceae and then as a Hemicryptophyceae as the sterile caps disappear each year.

Despite problems presented by algae such as the above, the scheme seems to be the most satisfactory so far produced. It does not appear, however, to give adequate consideration to the effect of the environment, and as it was based primarily on marine algae some modification would be necessary if the huge body of freshwater and terrestrial species are to be included. It is also doubtful whether the application of ideas and terminology derived from Raunkiaer's phanerogam life-form system is likely to be wholly satisfactory for such a very different group as the algae. Conditions in salt and fresh water are very much more uniform than on land and perennation or mode of survival of the unfavourable season has less significance than on land.

After Feldmann published his original classification in 1937 a further new one was proposed by Cedergren (1939) which was based essentially on the nature of the substrate, and referred more specifically to freshwater algae.

The fact that no one of the schemes outlined has so far had any wide adoption suggests that either phycologists are dissatisfied with them or that they have yet to be convinced that a suitable scheme will be useful. The present workers wish to propose a new life-form scheme and then, having done so, to examine its operation when applied to certain regions. In this last exercise some inadequacy of floras has to be accepted and also possibly some lack of information about the life-form of certain species. The resulting biological spectra are, however, sufficiently distinct to overcome any error due to the above considerations. We wish to emphasise that this is not an exercise in terminology. The terms used are of very minor importance, and are used simply to designate the life-form descriptions in a manner of convenience.

In preparing any life-form system there are certain predominant criteria:

(1) The different types should show some reflection of the habitat they occupy.
(2) It should be possible to obtain a quantitative picture for a region or a particular type of habitat, e.g., salt-marsh, estuary. If the scheme is successful a further advance would be to refer it to frequency points when algal ecology has reached the stage of regular quadrat analysis.
(3) Any scheme should be simple and easy to work with, and it should not involve additional studies before a species is assigned to a given life-form.
(4) The minimum number of morphological criteria should be used in classifying the different life-forms.
(5) It should be applicable to all algae in all habitats.

The following is an outline of our proposed scheme.

SERIES A:

Calciphykes or species with calcite or aragonite ($CaCO_3$) encrustation. Such species are grouped here irrespective of any other features. It might be objected that this is a purely morphological character but recent work by Goreau (1963) suggests that it is a physiological response to certain water conditions. The overwhelming predominance of the group in warm waters argues strongly that it is the tropical and sub-tropical conditions that result in the abundant deposition of lime. If necessary this group could be subdivided as follows:

1. *Chamaecalciphykes* (Chcp): This comprises flattened, expanded crusts, e.g., *Melobesia*, some species of *Lithophyllum* (*L. carpophylli*).
2. *Eleutherocalciphykes* (Lcp): knob-like forms lying loose on the substrate, e.g., species of *Lithothamnion.*
3. *Eucalciphykes* (Ecp): Erect branched or unbranched forms, e. g., *Cymopolia, Bossiella, Halimeda, Acetabularia, Padina, Corallina, Amphiroa, Jania.*
4. *Corallicalciphykes* (Cp): Massive lumps of coral-like algae, mostly involved in reef formation, e.g., *Lithothamnion, Goniolithon, Porolithon.*

SERIES B: Non lime or silica encrusted species

5. *Eleutherophykes* (Lp): Species with free-living thalli but which lie on the soil surface and do not float, e.g., *Pelvetia canaliculata* ecad *libera, Ascophyllym mackaii, Chaetomorpha litorea, Gracilaria secundata* f. *flagellifera, Aegagropila.*
6. *Planktophykes* (Pp): This includes all the usual marine and freshwater planktonic algae.
7. *Pleustophykes* (Psp): Floating macroscopic algae, e.g., *Enteromorpha* species, *Sargassum natans.*
8. *Geophykes* (Gp): Species wholly or partially embedded in the soil, e.g., unicellular and multicellular soil algae and species such as *Fucus vesiculosus* ecad *caespitosus.*

The next two groups represent perennial species that are attached to a solid substrate, and which at the most will only be partially denuded in the autumn. It comprises both the Phanerophyceae and the Hemiphanerophyceae of Feldmann because in many cases it is difficult to know whether denudation has in fact occurred. Two groups are recognised, based on size, because this influences shading and hence competition. Algae such as *Laminaria* are included here even though they possess a dwarf gametophyte.

9. *Megaphykes* (Mp): Macroscopic perennial attached thallus that reaches more than 5 m in length, e.g., *Macrocystis, Pelagophycus.*
10. *Mesophykes* (Msp): Macroscopic perennial attached thallus less than 5 m long, e.g., many Rhodophyceae and Phaeophyceae and some attached freshwater algae.

We realise that the delineation of these two groups is subject to criticism since it employs a somewhat arbitrary size limit. However, the assignment of such genera as *Macrocystis, Pelagophycus, Nereocystis* and *Durvillea* to the former leaves no real question as to the limitations of that group. Rhodophyta with morphologically similar generations found throughout the year are included in the Mesophykes.

The next series of groups covers those that may be considered as annuals or pseudo-perrenials.

11. *Chamaephytes* (Chp): Non-calcareous prostrate expanded crusts and gelatinous colonies, e.g., *Ralfsia, Ulvella, Cruoria.*
12. *Deciduiphykes* (Dp): These can be regarded as pseudo-perennial species attached to a solid substrate, which either persist through part of the year by means of the basal part of the thallus, e.g., *Himanthalia, Caepidium, Nemalion, Batrachospermum,* or else as a microscopic thallus. The macroscopic plant only occurs for part of the year.
13. *Therophykes* (Tp): Species attached to a solid substrate and which only occur for part of the year, the other portion being spent as a resting zygote, spore, or a unicellular generation, e.g., 'Gomontia' phase of *Urospora* and species of *Monostroma.*
14. *Epiphykes* (Ep): This consists of external epiphytes, epizoites and parasites, e.g., *Janczewskia, Elachista fucicola, Basicladia.*
15. *Endophykes* (Enp): Wholly endozoic, e.g., *Zoochlorella,* or endophytic, e.g., *Entocladia, Schmitziella.*
16. *Lithophykes* (Lip): Shell and rock boring algae, e.g., *Hyella* spp. with no other type of generation.

One major problem, for which we admit we have no immediate answer, involves those species with an alternation of generations that would normally be assigned to different groups. In the case of the Laminariales with a microscopic gametophyte we have ignored the annual gametophyte in favour of the perennial sporophyte. In the case of other alternations (e.g., *Ralfsia, Cruoria,* "Conchocelis" phase of *Porphyra*, and other Rhodophyceae, Phaeophyceae) there is a persisting problem.

Consideration of these stages of the life history would result in the algae being assigned to a group that it is totally inappropriate for the other alternating generation. It might be possible to resolve this dilemma by electing to consider the morphological dominant; the spring-summer generation (as opposed to the over-wintering generation); or either sporophyte or gametophyte. Any one of these, however, is rather arbitrary, and thus not a real solution to the dilemna. In what follows we have considered the morphological dominant.

The above scheme has been applied to floras from a variety of regions in order to see what kind of biological spectrum emerges. In all cases the plankton flora was omitted because the data were not always available. The floras selected for this initial study were as follows:

1. Scolt Head, Norfolk, England – essentially saltmarsh (Chapman, 1934).
2. Lynn salt marshes in Massachusetts (Chapman, 1940).

These two provide a comparison of two similar habitats widely separated geographically.

3. Iceland – rock coast and very cold waters (Jonsson, 1912).
4. Northeastern N. America – essentially rocky coast (Taylor, 1966).
5. Dry Tortugas – representative of a tropical flora (Taylor, 1928).

These three comprise a comparison of Atlantic ocean areas, ranging from polar to tropical waters.

In order to demonstrate the applicability of the scheme to fresh water three algal floras have been employed.

6. Cambridgeshire (West, 1899).
7. Yorkshire (West and West, 1901).
8. Great Lakes of USA (Prescott, 1962).

In a subsequent elaboration the marine floras of four countries are employed.

(a) New Zealand (Chapman, 1956; Lindauer, Chapman and Aiken, 1961; Chapman, 1961; Laing, 1926).
(b) Great Britain (Newton, 1931).
(c) Jamaica (Chapman, 1961, 1963).
(d) Peru (Dawson *et al.*, 1964).

There are of course many other regions or habitats that could have been considered. In some instances we have already done this, but have not included the results here because of space requirements.

In computing the biological spectra the subdivisions of the calciphykes have not been separated. The results for a range of floras are set out in Table 1 and Figure 1 and the following points emerge:

1. There is a high proportion of Eleutherophykes (Lp) and Geophykes (Gp) in areas 1 and 2 (saltmarsh). There is no solid substrate so that attached forms cannot survive, but the presence of such forms may be due more to the presence of phanerogams that can trap and hold them rather than to the substrate. There is a similar range of life-forms on the West Atlantic.
2. On the whole the rocky coasts are characterised by high proportions of Therophykes, Mesophykes and Epiphykes. These life-forms are present under fresh

Tab. 1. Percentage of life-forms in total floras

Area	Cp	Lp	Gp	Mp	Msp	Chp	Dp	Tp	Ep	Enp	Lip	Pp + Psp
Scolt	0.7	28.9	8.0	0	16.0	0	24.8	12.7	5.3	3.4	0.7	0
Lynn	0	54.7	13.3	0	3.9	0	3.9	14.6	7.8	1.3	0	0
Iceland	5.77	1.4	1.4	0	24.5	4.2	1.4	37	11.0	6.4	1.9	0
NE North USA	5.07	3.0	1.84	0.26	34.2	6.33	3	10.2	26.8	7.44	1.32	0.53
Dry Tortugas	19.5	5.5	0.25	0	55.6	3.75	8.25	2.75	8.25	0.5	0.75	2
Cambridge	0	0	3.0	0	0.4	0	0.8	4.5	11.1	0	0	80.3
Yorkshire	0	0	0	0	1.4	0	1.3	3.0	3.9	0.1	0	90.1
Great Lakes	0.1	0	2.6	0	10.0	0	0	0	20	0.5	0.1	66.4

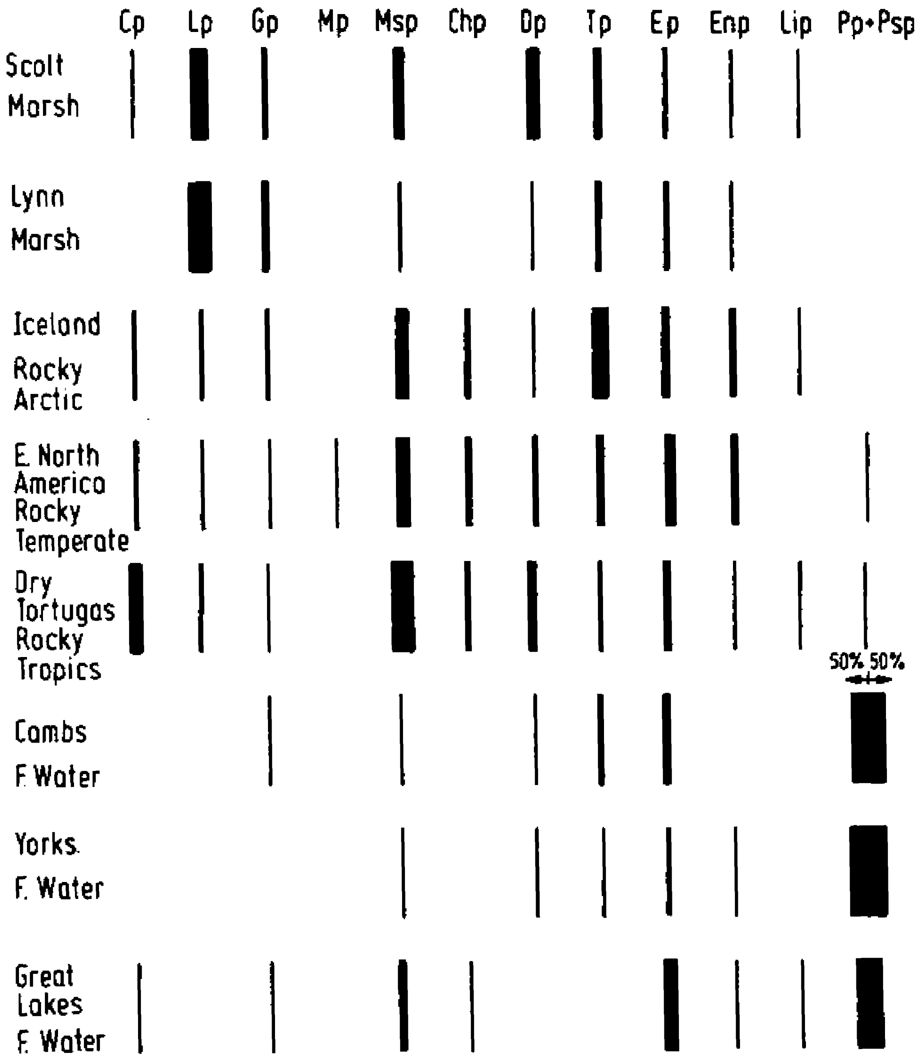

Fig. 1. Biological spectra for saltmarsh, rocky coast and fresh-water areas. (For scale cf. percentages, Table 1).

water conditions, but are overwhelmed by the dominance of Plankto- and Pleustophykes. The abundance of Therophykes could perhaps be compared with desert biological spectra in which annuals may be numerous but are not the most imposing element because they only become conspicuous under certain conditions. The reduced number of Epiphykes in some fresh waters presents more of a problem. The larger brown and red algae form admirable hosts under marine conditions, but there is an abundance of aquatic phanerogams in fresh waters. It is possible that the seasonality of the phanerogams in winter inhibits great development of epiphytes. Alternatively the surface of stem and leaves is less satisfactory as a substrate than the surface of large brown and red algae. Yet another possibility is the sheer inadequacy of information from fresh waters. This is surely a feature that justifies further study.

3. In the Dry Tortugas the Calciphykes provide the highest proportion among the life-forms and this is in agreement with the thesis that warm waters are more favourable to lime deposition. If we compare the floras of Iceland (arctic), E. North America (temperate) and the Dry Tortugas (tropical), the arctic area has a higher proportion of Therophykes than the other two. This is probably related to the short growing season. In warm waters the Mesophykes and Calciphykes assume significantly more importance than in colder waters.

Some of the issues raised above may be regarded as obvious, but the merit of a life-form schema and a biological spectrum is the translation of such obvious features into a quantitative basis.

In Figure 2 the algal floras of Scolt Head and Port Erin (Knight and Parke, 1931) are divided into the principal

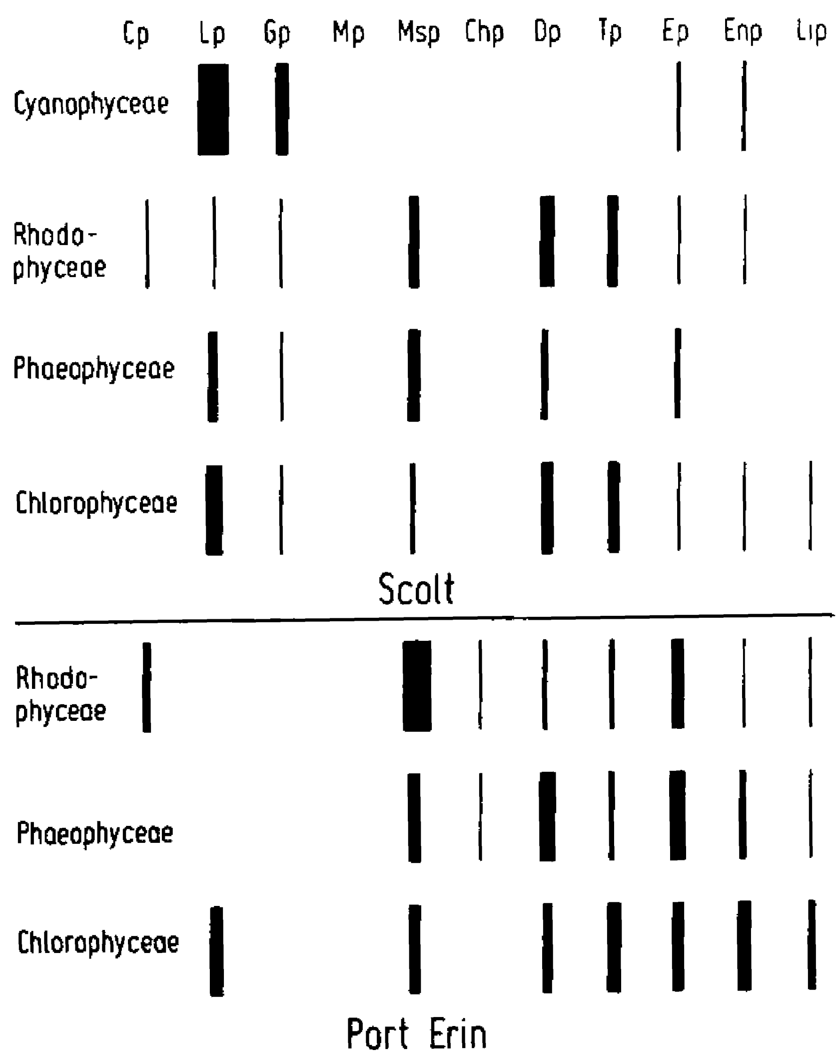

Fig. 2. Biological spectra for major algal divisions of Scolt and Port Erin floras (Scale as for Fig. 1).

component algal groups and individual biological spectra calculated for each. In neither area do the Rhodophyceae present any striking feature. Among the Chlorophyta there is a greater development of Epiphykes, Endophykes and Lithophykes under rocky shore conditions (Port Erin) than under saltmarsh conditions. The presence of rock certainly promotes the last named group.

In Figures 3 and 4 a study has been made of biological spectra at different levels on the shore, using the marshes of Scolt Head Island and the rocky shore flora of Mt Desert Island, Maine (Johnson and Skutch, 1928). In the latter the influence of the rock pools has also been considered in order to determine what effect their vegetation could exert upon the spectra.

In Figure 3 (Scolt Head Island), which includes algae from the saltmarshes, creeks, channels, and a breakwater, it will be evident that the spectra differ at each level. At higher levels Eleutherophykes and Geophykes predominate, the former persisting down to the middle levels. At the middle levels there is a significant proportion of Mesophykes, Deciduiphykes and Therophykes.

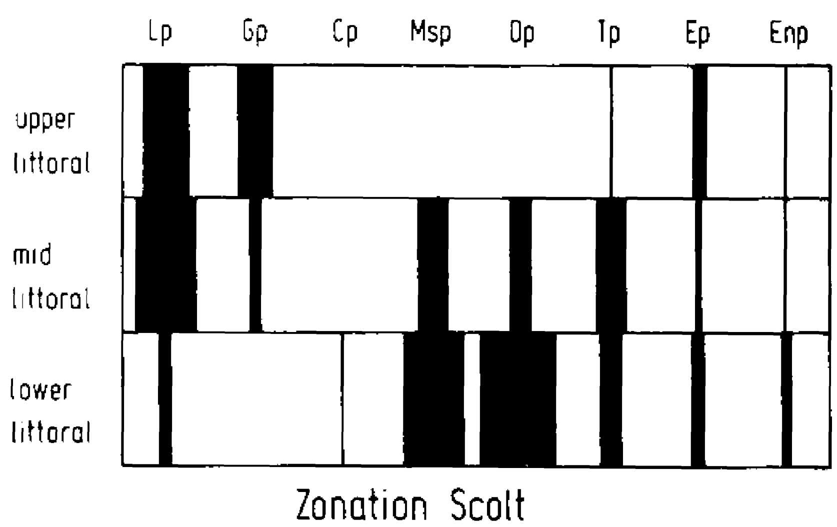

Fig. 3. Biological spectra for upper, middle and lower littoral at Scolt. (Scale as for Fig. 1, × 4).

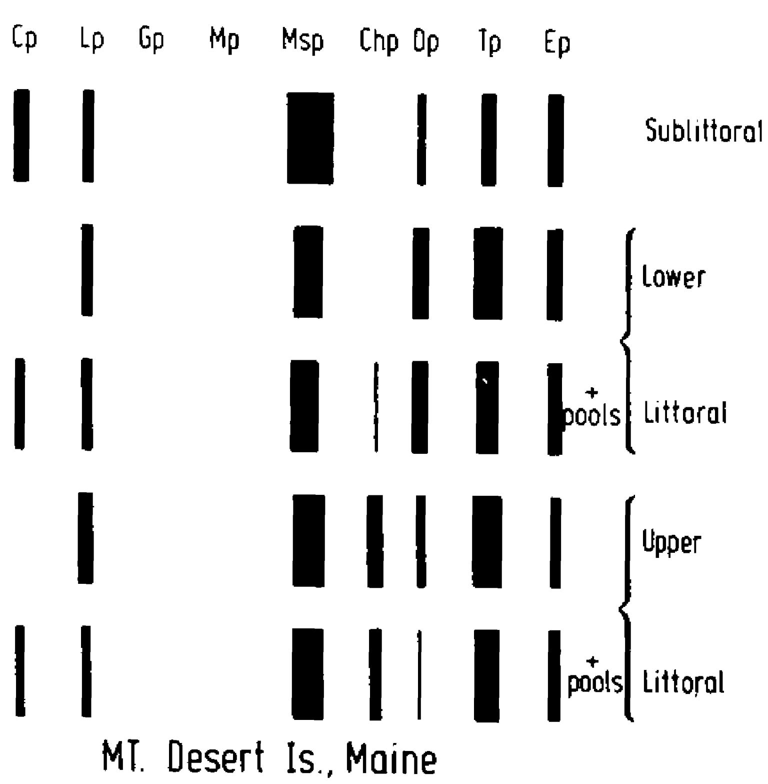

Fig. 4. Biological spectra for upper, lower and sublittoral at Mt Desert Island, Maine (Scale as for Fig. 1, × 2).

Whilst the presence of the phanerogams or the nature of the substrate may be important there is also the possibility that absence of spray and lack of any swash may restrict some of these life-forms. At the lowest levels the greatest percentage of the life-forms is occupied by the Deciduiphykes. There is little doubt that the increased frequency of flooding is at least partly responsible, but there are other factors, such as supply of nutrient salts and light intensity, that could be involved. At present very little is known about the physiological requirements of species belonging to the Eleutherophykes and Geophykes, and these require study.

The panflora of the Norfolk marshes consist of about 40 species (Chapman, 1937). 55 % of these are Eleutherophykes, 17.5 % Therophykes and 15 % Geophykes. In other words, although the substrate is either soft mud or a phanerogamic plant, the mere presence of water in pans during most of the year enables a significant number of Therophykes to exist at high levels. Substrate therefore, is not the sole factor, and on rocky coast inundation or spray could be equally important.

From Figure 4 it is at once evident that on a rocky shore variation in level does not produce profound differences comparable to those found on saltmarshes. There are, however, certain features of interest. The Calciphykes, which collectively as a group demand long or perpetual submergence, are restricted to the sublittoral or pools. The Megaphykes also decrease with increasing exposure, and it can be suggested that at upper levels the length of time they are covered cannot be sufficient for them to obtain the necessary nutrient salts. The effect of the rock pool vegetation in the lower littoral and upper littoral upon the biological spectra is also very evident, particularly in the addition of Calciphykes.

Finally the proposed life-form scheme has been applied to four other regions. For this purpose the floras of New Zealand, Britain, Peru and Jamaica were used (the first two temperate and the second two tropical) and they were also divided into the three major algal divisions. A comparison has also been made with the earlier Feldmann scheme. As far as possible the published revisions of the New Zealand Flora were used, but some of the Rhodophyceae were selected from Laing's (1926) list and unpublished observations of the existing herbaria and field observations. In order to simplify the analysis only a sample of each flora has been analysed.[1]) This has had the merit that any species could be omitted where doubt existed over its life-form. Despite this limitation the results illustrate significant differences (Tab. 2).

Using the Feldmann scheme (Fig. 5) and comparing the total flora for Britain, New Zealand and Jamaica, it is evident that in Jamaica there is an absence of Eclipsio-

[1]) We are grateful to Dr. F. I. Dromgoole for the analysis.

Tab. 2. **Percentage of life-forms in four floras**

Flora	Cp	Lp	Gp	Mp	Msp	Chp	Dp	Tp	Ep	Enp	Lip
New Zealand	3	2	2	4	22	1	15	26	16	0	0
Great Britain	2.5	6.8	3.4	0	16.4	5.1	16.1	32.2	13.5	2.5	0.8
Jamaica	16	5	0	0	49	5	5	15	4	0	0
Peru	8.1	1.4	0	1.4	60	2.8	3.6	6.6	11.0	5.1	0.7

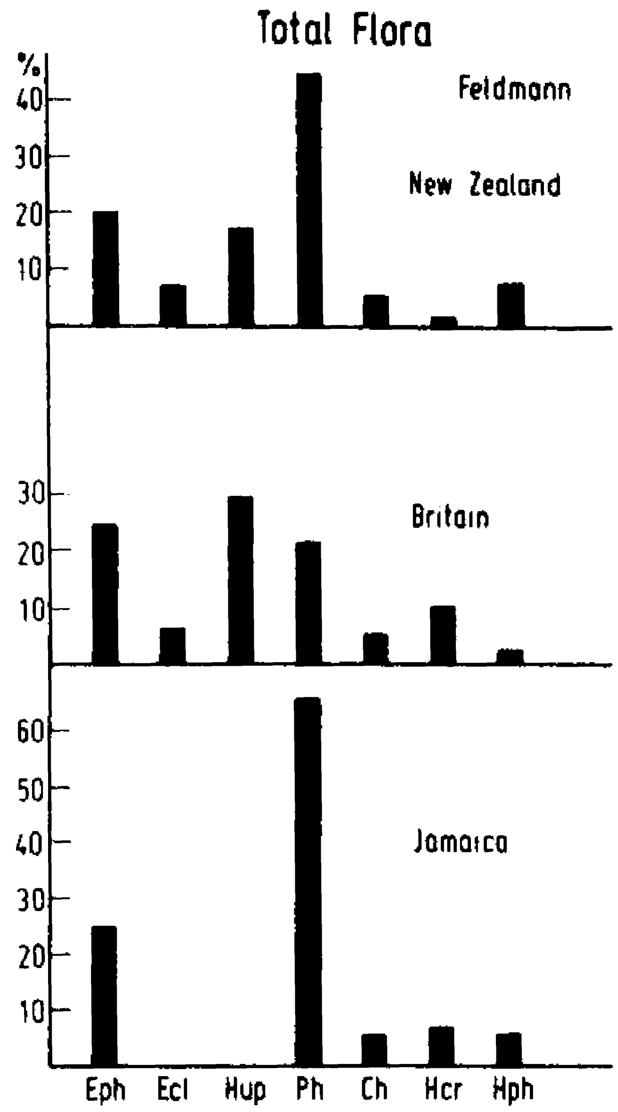

Fig. 5. Biological spectra on Feldmanns Scheme for New Zealand, Britain and Jamaican algal floras.

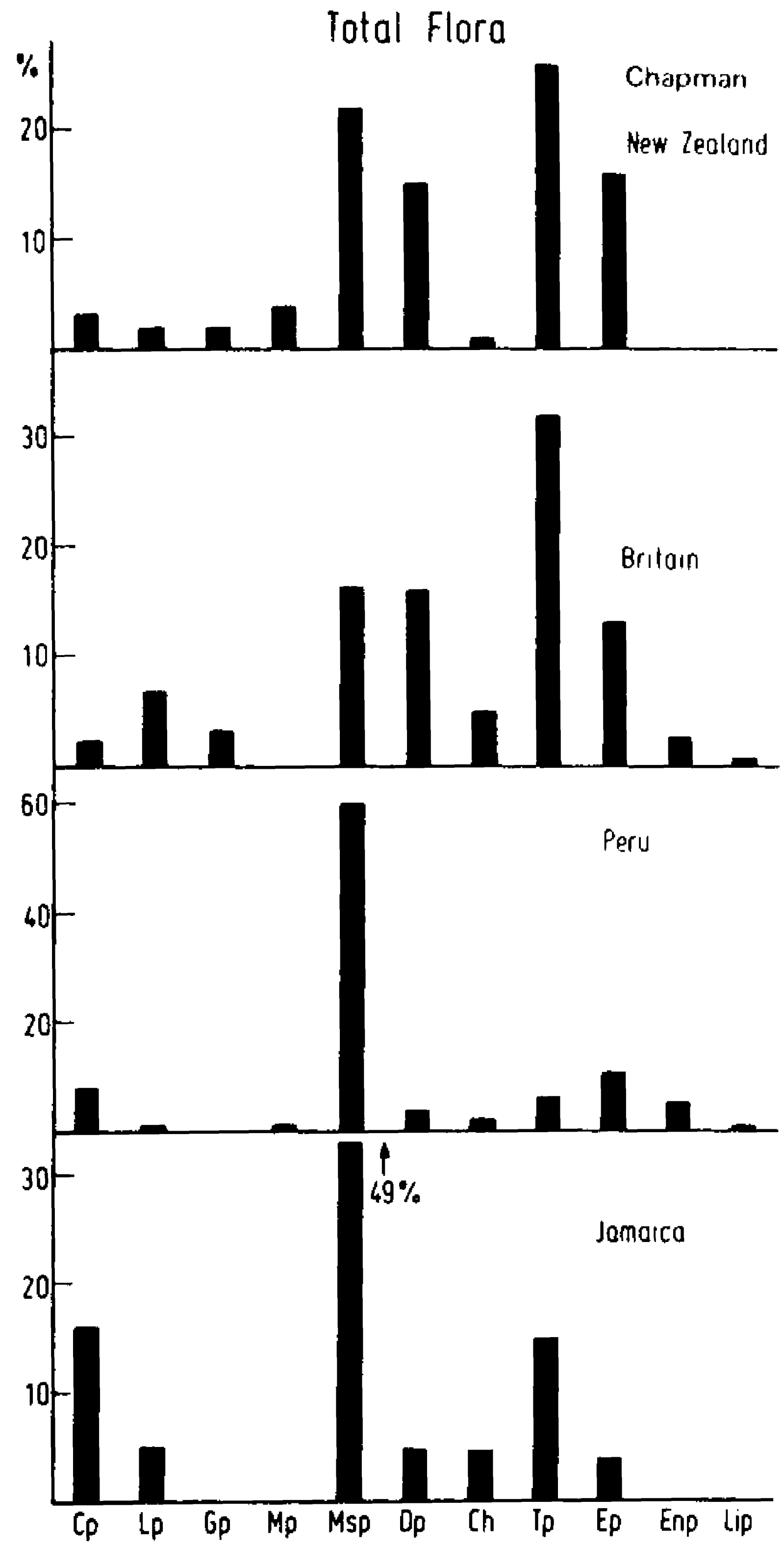

Fig. 6. Biological spectra for New Zealand, Britain, Jamaica and Peru algal floras.

phyceae and Hypnophyceae and a very high proportion of Phanerophyceae. In general the spectra for the two temperate areas are similar, but in New Zealand there is twice the percentage of Phanerophyceae.

On the scheme proposed in this paper (Fig. 6) there is again a similarity in the spectra for the two temperate areas and there is also some similarity between the two tropical areas. When the temperate spectra are compared with the tropical floras the following differences emerge:

1. Large increase in the proportion of Calciphykes. This is more pronounced with Jamaica than Peru where the cold Humboldt Current has undoubtedly exerted a significant influence.
2. Great increase in proportion of Mesophykes. This is probably associated with the probability that only small bushy algae can survive on the littoral during the period of exposure.
3. A great decrease in the proportion of Deciduiphykes. Since there is little difference between the seasons this could be expected.
4. A decrease in the proportion of Therophykes and Epiphykes. The more equable climate would account for the former but the latter is interesting and warrants study.

5. Comparing the Atlantic and Pacific tropical floras there is the difference in proportion of Calciphykes as well as differences in Therophykes, Epiphykes and Endophykes.

It seems, therefore, that this scheme brings out more differences between temperate and tropical floras than does Feldmann's and this suggests it should be more useful.

Using the proposed scheme (Fig. 7) the main features that emerge from an analysis of the Rhodophyceae component are:

1. The large percentage of Calciphykes in Jamaica, though they are present in both Great Britain and New Zealand. The Peruvian percentage is intermediate between Jamaica and the temperate regions.
2. The small proportion of Mesophykes in the British flora, and the very high proportion in the Jamaican and Peruvian floras.
3. The very low proportion of Deciduiphykes in the Jamaican and Peruvian floras.
4. The high percentage of Therophykes in the British flora and the very low percentage in the Jamaican flora, and apparent absence in Peru.
5. The very low proportion of Epiphykes in the Jamaican flora as compared with the other three. This may be related to the effect of heat and desiccation during periods of exposure, or alternately the plants may grow under the warmer conditions at a rate that inhibits epiphytes or parasites from being established. In view of the difference between Peru and Jamaica this would seem to be a life-form aspect worthy of further study.

Using the new proposed scheme (Fig. 8) the main features that emerge for the Phaeophycean element are:

1. The presence of a Calciphyke element only in Jamaica. This is probably directly related to water temperature, the cold Humboldt Current inhibiting tropical Calciphykes in Peru.
2. The presence of Geophykes (saltmarsh component) in the British flora and its absence in the other two. Salt-

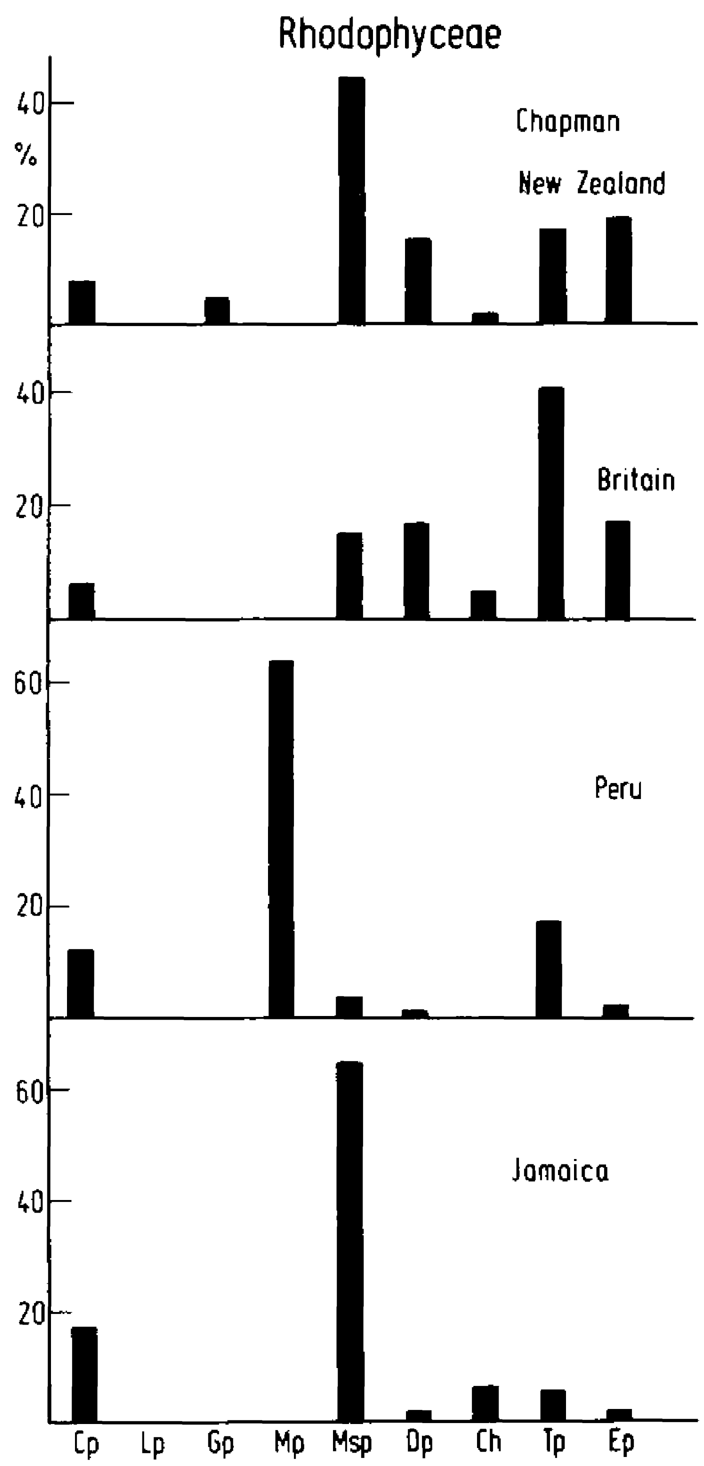

Fig. 7. Biological spectra for Rhodophycean component of algal floras of New Zealand, Britain, Jamaica and Peru.

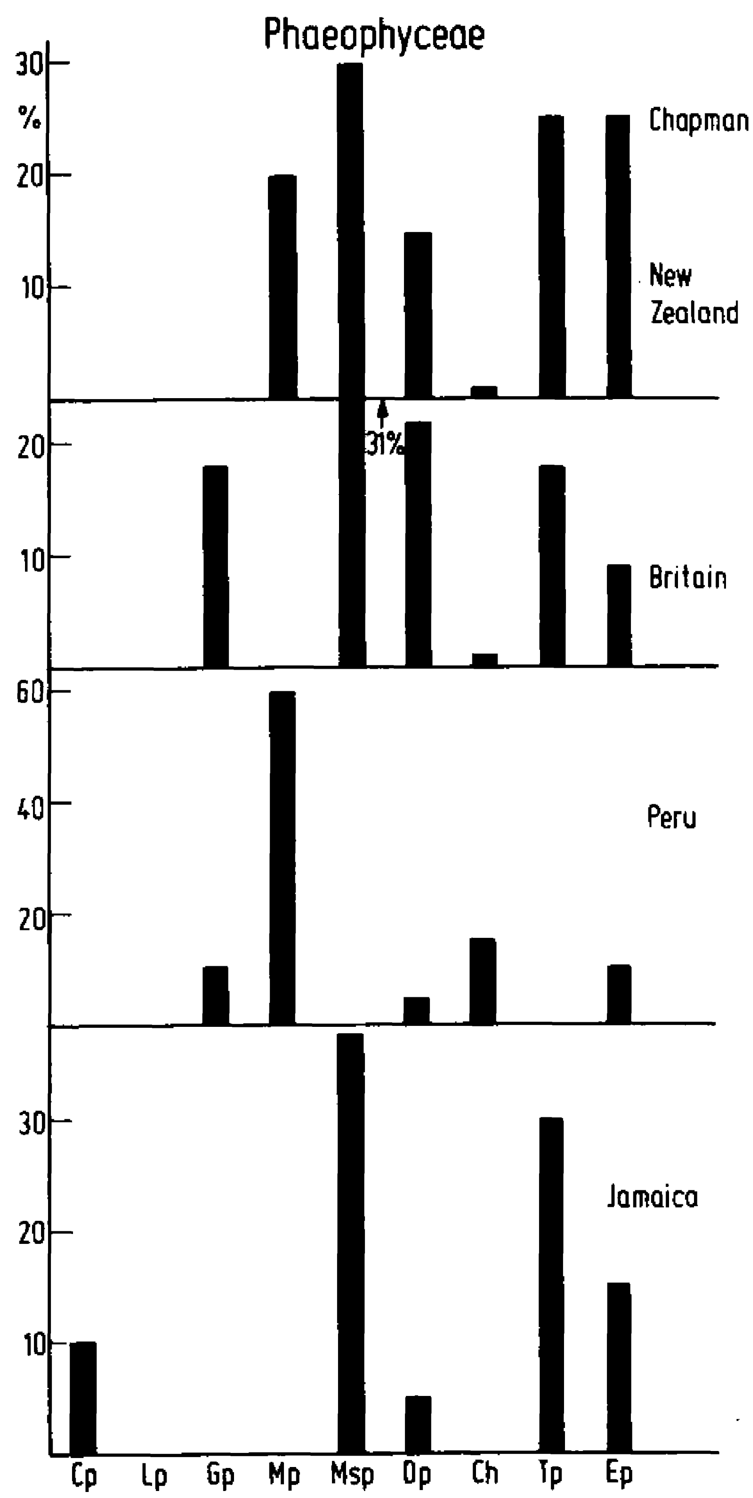

Fig. 8. Biological spectra for Phaeophycean component of algal floras of New Zealand, Britain, Jamaica and Peru.

marsh is present in New Zealand but Geophykes do not appear to have developed, nor have they developed in the mangrove habitat of the tropics.

3. The presence of Megaphykes only in the New Zealand and Peruvian floras. These very large algae have a distinct regional limitation.
4. The high proportion of Therophykes and Epiphykes in Jamaica as compared with Peru.
5. The relative absence of Deciduiphykes in Jamaica and Peru (see above for Rhodophyceae).
6. There is an interesting variation in the proportion of Epiphykes between all four floras.

Finally in the Chlorophycean element of the floras the main features using the new proposed scheme (Fig. 9) are:

1. The high proportion of Calciphykes in the Jamaican flora. Thus all three algal divisions have contributed to this element. Calciphykes are also present in Peru but here the Phaeophyceae make no contribution to this element.
2. The small proportion of Eleutherophykes in the New Zealand and Peruvian floras as compared with the other two floras.
3. The high percentage of Mesophykes in the Jamaican and Peruvian floras (see above in the Rhodophyceae and the Phaeophyceae).
4. The high and rather surprising proportion of Deciduiphykes in the New Zealand flora.
5. The great disparity in the proportions of Thereophykes in all four floras, though Peru and Jamaica are very comparable.
6. The lack of Epiphykes in the Jamaican and Peruvian floras.
7. The presence of Endophykes and Lithophykes in the British and Peruvian floras. This result is partly due to sampling because a very few of both of these lifeforms do occur in the New Zealand flora.

When the total floras are compared the scheme proposed in this paper provides significant differences and can therefore be regarded as meaningful. Perhaps the most useful application is to floras associated with different levels on the shore. A future study is needed in order to compare the biological spectra of lakes with those of rivers.

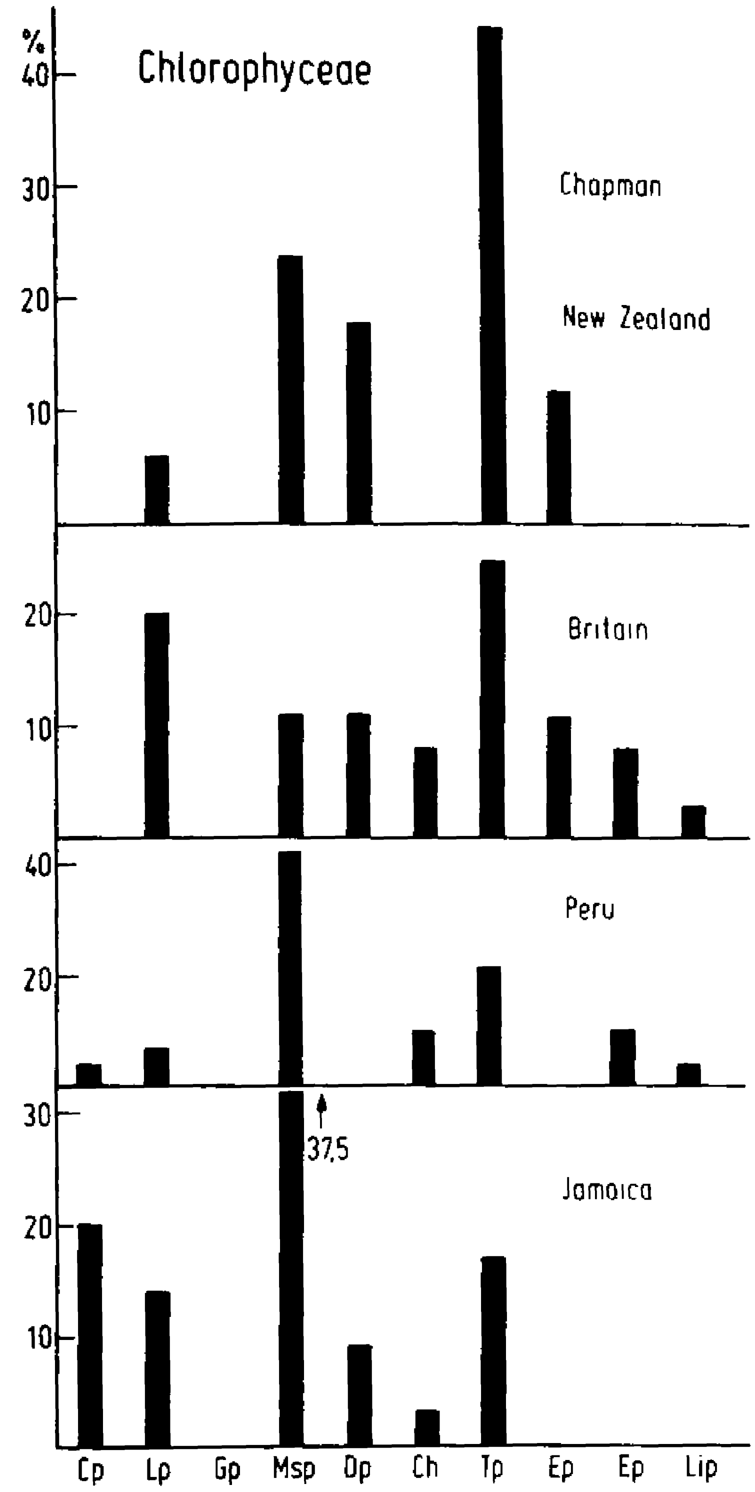

Fig. 9. Biological spectra for Chlorophycean component of algal floras of New Zealand, Britain, Jamaica and Peru.

This study has presented only a few selected floras and habitats. Furthermore the comparisons have considered only species numbers, a crude measure of diversity. No attempt has been made to conduct comparisons with other systematic levels (e.g. genera). More importantly this study makes no consideration of the relative abundance of the individual taxa. It might prove very interesting to try to quantitate such a study by some other factor than simply number of species or genera, etc.

References

Cedergren, G. R., 1939. Aerofila Alger. *Bot. Notiser* 1939: 97–111.

Chapman, V. J., 1934. The vegetation. *In*: Scolt Head Island. Ed. J. A. Steers, Camb. Univ. Press.

Chapman, V. J., 1937. A revision of the marine algae of Norfolk. *J. Linn. Soc. Bot. 51*: 205–63.

Chapman, V. J., 1940. Studies in saltmarsh ecology VI and VII. *J. Ecol. 28*: 118–152.

Chapman, V. J., 1956. Revision of the marine algae of New Zealand I. Cyanophyceae and Chlorophyceae. *J. Linn. Soc. Bot. 55*: 333–499.

Chapman, V. J., 1961. Marine algae of Jamaica. Part I. *Bull. Inst. Jamaica 12* (I): 5–159.

Chapman, V. J., 1963. Marine algae of Jamaica. Part II. *Bull. Inst. Jamaica 12* (II): 6–201.

Chapman, V. J., 1968. Revision of the marine algae of New Zealand. III. Bangiophycideae and Florideophycidae, Nemalionales, Gelidiales and Bonnemaisoniales. Cramer 113pp.

Dawson, E. Y., C. Acleto and N. Foldvik., 1964. The seaweeds of Peru. *Nova Hedwigia 13*: 1–96.

Feldmann, J., 1937. Recherches sur la vegetation marine de la Mediterranée. La Côte des Albères. *Rev. Algol. 10*: 1–339.

Feldmann, J., 1966. Les types Biologiques d'algues marines benthique. *Mem. Soc. Bot. France.* 45–60.

Funk, G., 1927. Die Algenvegetation des Golfs von Neapel. *Publ. Staz. Zool. Napoli, 7* (Suppl.): 1–507.

Gislèn, T., 1930. Epibioses of the Gullmar Fjord. II. *Skr. K. Sv. Vetens. Krist. Zool. Stat. 3*: 1–12; *4*: 1–38.

Goreau, T. F., 1963. Calcium carbonate deposition by coralline algae and crab in relation to their roles as reef builders. *Ann. NY. Acad. Sci. 109*: 127–167.

Johnson, D. S. and A. F. Skutch, 1928. Littoral vegetation on a headland of Mount Desert Island, Maine. *Ecology 9*: 118–215, 307–338.

Jonsson, H., 1912. Marine algae. *In*: Botany of Iceland IX. Copenhagen.

Knight, M. and M. Parke, 1931. Manx algae. Liverpool Univ. Press.

Lindauer, W. V., V. J. Chapman and M. Aiken, 1961. Revision of the marine algae of New Zealand. II. Phaeophyceae. *Nova Hedwigia 3*: 129–350.

Nasr, A. H., 1947. Synopsis of the marine algae of the Egyptian Red Sea Coast. *Bull. Fac. Sci. 26*: 1–155 Fouad I Univ., Cairo.

Newton, L., 1931. Handbook of British seaweeds. Brit. Mus. Lond.

Oltmanns, F., 1905. Morphologie und Biologie der Algen. Jena.

Prescott, G. W., 1962. Algae of the Western Great Lakes Area. Rev. Ed. Iowa.

Setchell, W. A., 1926. Phytogeographical notes on Tahiti. Part II. Marine Vegetation. *Univ. Cal. Pub. Bot. 12*: 291–324.

Taylor, W. R., 1928. Marine algae of the Tortugas. *Carn. Inst. Wash. Publ. 379*: 1–219.

Taylor, W. R., 1966. Marine algae of the north eastern coast of North America. 2nd Ed. Univ. Mich. Press.

West, G. S., 1899. The algal flora of Cambridgeshire. *Journ. Bot. 1099*: 49.

West, W. and G. S. West, 1901. The algal flora of Yorkshire. *Trans. Yorks. Nat. Union. 5.*