Geochemical studies of contrasing mire types using three phytometers

Alyson Wickson

GEOCHEMICAL STUDIES OF CONTRASING MIRE TYPES USING THREE PHYTOMETERS.

by

ALYSON WICKSON

September, 1974

Being a dissertation presented to the University of Durham in partial fulfilment of the requirements for the Degree of M.Sc. in Ecology by Advanced Course.

Contents

Summary

The formation of complex mire systems and their classification has been briefly described.

Three plant species, *Schoenus nigricans*, *Cladium mariscus* and *Molinia caerulea*, whose ecological ranges cover a variety of different mire types were selected for study. Their living and dead tissues were collected from a range of contrasting mire types and their tissues analysed for geochemicals. The plants were considered to be sampling the available geochemicals of each mire type.

A comparison of the relative availabilities of a range of geochemicals was made for each species between each of the mire types, as evidenced by the levels of each element detected in the tissues of each species. A comparison of the levels of each element present in the tissues from each mire type was also made between species.

Phytosociological data was collected from each site and subjected to Association-analysis in order to attempt to identify ecological gradients between the contrasting mire types as reflected in their floristic characters.

Introduction

In the sequence of mire formation and development three main ecological mire types have been described by Kulczynski, (1949) as rheophilous, transitional and ombrophilous.

Where ever the flow of water is impeded to such a degree that it can no longer carry matter in suspension, deposition of allochthonous matter will occur. A possible example would be the situation occurring where a stream bed opens into a large depression in its course, forming a pond. At such a site of reduced velocity of flow, the major geomorphological process would be the deposition of materials and the building up of the stream bed. Conditions such as these provide a template for the formation of mire systems. As the depth of the basin is reduced by the deposition of detritus, hydrophytes are able to invade the area and the process of terrestrialisation is initiated. As this process progresses, under anaerobic conditions, peat will be formed under the influence of running water which is rich in bases. Such a mire type is defined as rheophilous. This mire type receives water from three sources: the upper drainage basin in the form of stream flow; local runnoff and seepage from the immediate drainage basin; and rainwater. The major supply of water and nutrients is, however, from streamflow into the basin. If peat growth continues to such a level that the basin is blocked and the stream feeding the basin diverted, the developing mire is now fed only by runoff and seepage from the immediate area of the depression, and base poor rainwater. The loss of the base rich stream water results in the development of a more acid, base poor peat. Such a mire type is described as transitional. If peat growth continues until the level of the mire surface is raised above the local topography, then the only supply of water and nutrients to the mire surface will be from rain water. The surface of the mire will no longer be influenced by regional water table movements and flow, developing instead a perched water table of its own. The level of this water table is influenced only by the input of rain water and out put by seepage along the edges of the mire, and to the regional water table below. Conditions such as these result in the formation of a light, highly acid, base poor peat. This mire type is termed ombrophilous. As long as the input of rain water exceeds the loss of water by seepage and evapotranspiration, the surface of the mire will continue to grow upwards, as is the case in areas of high rainfall. In areas of high precipitation, mire development may continue to such an extent that the mire continues to grow untill it can no longer be contained within its own drainage basin, growing over the intervening water sheds, and thus forming a blanket mire.

Summary of mire types

Mire Type	Water Supply	Base Status	pH
Rheophilous	1. Stream flow	Base rich	High
	2. Local runoff and seepage		
	3. Rain water		
Transitional	1. Local runoff	Less base rich	acid/ neutral
	2. Rain water		
Ombrophilous	1. Rainwater	Base poor	Low

With passage westwards across the British Isles the floristic characteristics of ombrophilous mires change, until in Western Ireland the oceanic blanket bogs display closer floristic associations with rheophilous lowland mires than do ombrophilous mires of England and Scotland. Schoenus nigricans (L), Cladium mariscus (L), Pohl. and Molinia caerulea (L), Moench. are all to be found growing on ombrophilous mires in the west of Ireland, whilst throughout the rest of Europe they are confined to base rich rheophilous mires and certain flushed sites, in the cases of Schoenus nigricans and Molinia caerulea.

It was decided to investigate the geochemistry of a range of contrasting mire types using these three species as phytometers. To investigate whether, or to what extent the mineral differences between a range of mire types are reflected in the tissues of the plants found growing on them.

The method was to collect plant material from a range of mire types, covering the full ecological amplitude of the species investigated, and to analyse the plant tissues for a range of nutrient and heavy metal elements. It is argued that in this way at least some of the problem in the definition of availability would be overcome, in that at least all the geochemicals present in the tissues must have been held in available form by the plant-soil system. The 'phytometers' were thus to be used to 'sample' the available geochemicals in each mire system.

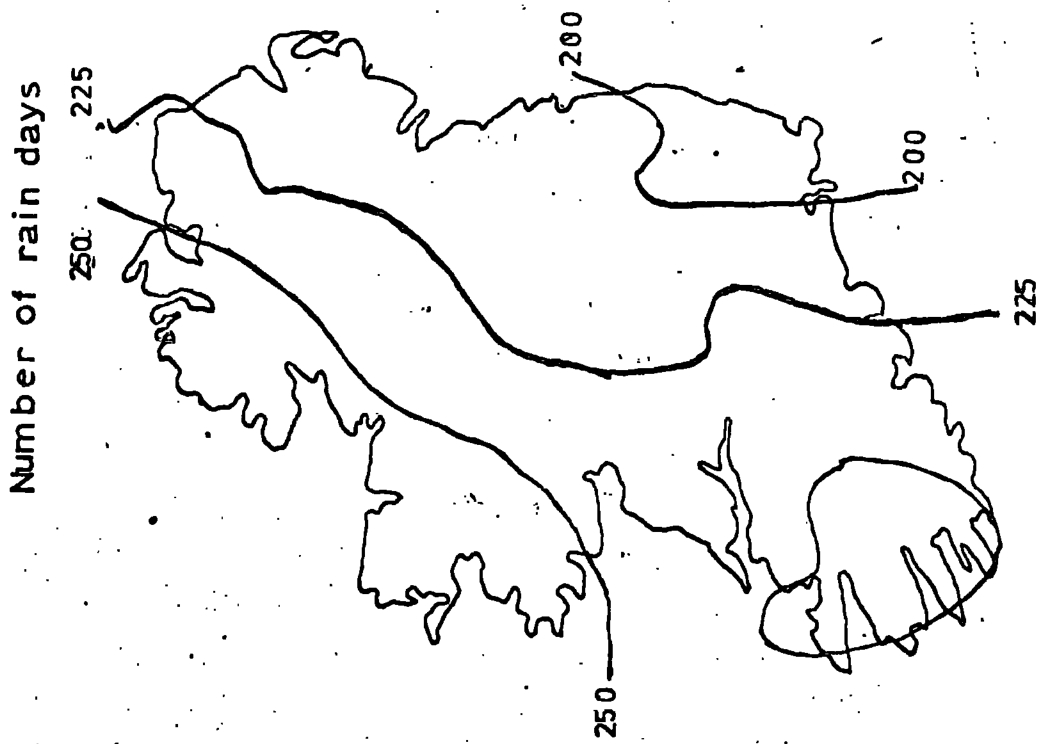
Ecology of Species

Schoenus nigricans is normally only to be found growing on base rich fen peats and certain flushed sites in Continental Europe and most of the British Isles. In Western Ireland, however, it forms one of the most important characteristic constituents of the blanket bog flora. This discrepancy in the ecology of Schoenus nigricans has been investigated by many plant ecologists. Various explanations for the occurrence of this species on Irish blanket bogs have been proposed, and will be discussed here.

The various explanations are chiefly concerned with the edaphic differences between Irish blanket bogs and English and Scottish raised bogs, on which this species is not found, and the climatic conditions experienced in the western Irish coastal areas. Most of the theories are based upon the same climatic consideration, that is, the influence of the prevailing south westerly wind, which is heavily laden with rain and salts. Clearly some aspect of mineral nutrition is important, Sparling (1967a) considers from the restriction of Schoenus nigricans on blanket bog to a narrow strip on the west coast of Ireland, that the mineral differences are directly influenced by climate. He considers that the climate could affect the plant directly through transpiration and ion uptake, and also indirectly by altering edaphic conditions, such as differences in peat formation and the supply of minerals to the peat in rain and dust. The major features of the Irish climate are shown in plate 1. The west coast of Ireland experiences a high frequency of gales, thus the salt content of the rain is increased.

Tansly (1939) was perhaps one of the first to offer an explanation for the prescence of Schoenus nigricans on Irish blanket peats, and proposed his now classical 'Sea Spray' hypothesis, suggesting that the occurrence of this plant on Irish blanket bogs may be favoured by the falling of sea spray, driven by inshore gales onto the surfaces of the bogs, thus

Plate 1


Number of rain days
225
250
200
200
225
250


Rrecipitation mm/annum
1000
1000
1250
1250
1250
1250

changing the soil reaction of the ombrophilous peat, so that it more closely resembles that of the more normal habitats of Schoenus nigricans.

Pearsall and Lind (1941), who were also concerned with the base reaction of the Irish peats, made the suggestion that the extreemly moist climate of western Ireland was preventing the blanket bog peats, in this case a Connemara bog, from reaching the same level of aeration and oxidation as those peats of raised bogs in the English Lake District. For this reason the pH levels of the Irish blanket bogs are maintained at higher general levels, normally above pH 4.7. Thus they reject the idea that additional bases from sea spray are necessary for the maintenance of higher pH values. They also noted that Schoenus nigricans growing under water-logged conditions is normally depauperate in nature.

Gorham (1953a) considered the direct effect that sea spray would have upon the nutritional status of Irish blanket bogs. He demonstrated that the pH and base status of the blanket bogs of western Ireland were greater than those of raised bogs in the English Lake District. However owing to the fact that the base saturation of the Irish peats were still lower than is usual in water-logged soils influenced by mineral soil water, he suggested that the mildness of the Irish climate was a possible factor permitting this plant to grow in the less base rich habitats.

Further to the consideration of the pH status of Irish blanket bogs and the growth of Schoenus nigricans, there does not appear to be any report of a pH value below pH 4 for any western Irish peat. Gorham (1953b) has shown that pH is related to the level of base saturation of the peat, but his values for pH of raised bogs which fall between 3 and 4 show no correlation with the base status of the peat. Sjors (1950) has also demonstrated that the pH of peat water is related to the soluble bases, as measured by conductivity. However it has been shown that the relationship between pH and available ions is far less close, if it holds at all, below pH 5. Whether therefore, the higher pH of the blanket bogs of the west of Ireland may be attributed to sea spray still seems open to some doubt. The differences in pH between a Mayo bog and a Lake District bog reported by Gorham (1953a), may or may not be as a result of the differences in the degree of base saturation.

Malmer (1962) has demonstrated, that in summer in Gotland South Sweden, the water level was low and not in contact with the upper layers of the peat. After summer when the water level rose, it came into contact with the surface layers of peat, where more oxidising conditions had been prevelent for some time, resulting in the pH of the bog being lowered. The development of acidity in Irish peats is probably being prevented by the exchange of cations from rain water with hydrogen ions present on the peat colloids, and presumably by the fact that rainfall over western Ireland is more evenly spread throughout the year than over South Sweden, hence the surfaces of the Irish peats will be less likely to dry out to the same extent as those investigated by Malmer.

With respect to the salt concentration in the rain altering the edaphic conditions of Irish blanket peats Sparling (1966) observed that divalent cations, in particular magnesium, would tend to exchange with the hydrogen ions adsorbed on the peat colloids, and that acidity decreased, much as it does in flushed sites. In view of this Sparling (1967) suggested that the lower acidity and salt supply in western Irish blanket bogs would perhaps result in a more rapid breakdown of the peat and a greater rate of release of nutrients.

Since ombrophilous bogs are dependent upon rainfall for their supply of electrolytes, the concentration of electrolytes in rain water is of great importance to the bog and its vegetation. The concentration of salts in the rain varies with distance from the sea, and also with proximity to industrial areas and other sources of dust. Boatman (1961) investigating the sources of nutrients to a bog in County Kerry, Western Ireland, found negative correlations between the exchangeable content of sodium and magnesium with distance from the sea, and concluded that the major source of these ions is from sea spray. Calcium concentrations and pH increased with distance from the sea, Boatman suggested dust as a possible source of calcium ions. Finding that the change in exchangeable calcium content of peat with distance from the sea was not quite significant, he suggested that the supply of calcium throughout the area could have been similar, but that the amount of this element retained by bogs very close to the sea is reduced through increased competition for adsorption sites with magnesium. Potassium and iron content of the peat showed no relationship with distance from the sea. Gorham (1957) analysed rain water collected from Rosscahill, 20 miles from the sea in county Galway, and found higher concentrations of electrolytes here than in samples collected from the English Lake District. Gorham calculated that 20-30% of the potassium in rain water over Oughterard in Galway was derived from the sea and suggests rock dust as a source of the rest. Gorham also demonstrated that approximately 67% of the magnesium in rain water samples from Rosscahill was derived from sea spray. He obtained, in general, similar relationships for calcium levels as he did for magnesium, however, the calcium levels exceeded 1.0 mg/l in Ireland and Great Britain only near the coasts. Sparling (1967) collected rain water samples from two stations near Glenamoy County Mayo, within ten miles of the Atlantic Ocean. The results he obtained show that the amounts of electrolytes present in rain fluctuate with season, concentrations of ions being greatest during the winter months due to stormy winter weather. Sparling considers that the amounts of major nutrients supplied to the bog must be very close to those which minerotrophic, that is rheophilous bogs, recieve. He considers this to be of interest, 'since the floristic differences between ombrophilous and minerotrophic bogs become progressively less as the bog becomes more oceanic.' The amounts of phosphorus and nitrogen which fall on the blanket bogs of Western Ireland generally appear to be lower than those which fall on English bogs, Eriksson et al (1960). This may be attributed to the association of these elements with dust particles, which are less frequent in regions of high humidity, Hutchinson (1957). Sparling (1967a) points out the fact that most ombrophilous bogs in England and Scotland are at higher elevations than Irish blanket bogs, and therefore not in areas of high electrolyte concentration in the rain. Sparling also reports that where low level bogs occur in Scotland, as for example at Laxford Bridge Sutherland, Skye and the Outer Hebrides Schoenus nigricans is found either on ombrophilous bogs or slightly flushed base poor bogs.

Boatman (1957), working on a Connemara bog, made the following observations of the distribution and growth of Schoenus nigricans on the Galway-Mayo peninsula. Firstly, in agreement with Pearsall and Lind (1941), he observed the plant to frequent suprisingly dry areas on the bog surface, producing the best growth on dry areas of peat over rocky knolls. Which suggests to the present author, that in an area of high rainfall, and under conditions of better drainage, the overall tendency would be for the soil water to percolate down through the peat, and may be effectively flushing the habitat, producing conditions more condusive to the growth of this plant. Boatman also considered that Schoenus nigricans was maintaining itself on the bog surface by means of vegetative reproduction only and was not re-seeding. Finally he makes the point that Sphagnum species, which are not on the whole very important constituents of the blanket bogs of Connemara and Mayo, may play a part in resticting the occurence of Schoenus nigricans on other bog surfaces.

Schoenus nigricans is tolerant of a wide variety of habitats, from highly calcareous fens and magnesium rich serpentine areas, to nutrient poor blanket bogs. Occurring in situations where a single ion, such as calcium, magnesium or sodium may be dominant. The plant may also be found growing in habitats with a pH as low as 4.2, the Irish blanket bogs, or in highly calcareous situations with a pH of 8 or more. In view of this wide ecological tolerance displayed by this species, it is hardly suprising that botanists have sought to explain the absence of Schoenus nigricans from English and Scottish blanket bogs.

Conway (1958) tried unsuccessfully to transplant Schoenus nigricans onto blanket peat in the Moor House Nature Reserve.

She considered that the failure of transplants to survive indicates that conditions must be such in these habitats that Schoenus nigricans is unable to survive. Chemical analyses of bog waters Gorham (1950) and Sparling (1962) indicate that calcium levels and pH are the main factors differing consistently between fens and blanket or valley bogs.

The next approaches to be taken with a view to solving this problem were experimentally based. Sparling (1967b) grew Schoenus nigricans under different water culture treatments, and concluded that levels of calcium ions in the solutions had little effect on the plants' growth. He discovered that Schoenus plants absorb similar amounts of calcium from solutions containing high and low levels of this element. With respect to the effect of pH, he obsereved that between pH 3.9 to 7.8 the effect was slight, but below pH 3.8 root growth was strongly inhibited. Sparling demonstrated that when the major ions are considered, there can be no obstacle to the establishment and growth of Schoenus nigricans in relatively acid and base poor conditions, and considered that surface drying of Scottish and English bogs, together with subsequent increased acidity may be preventing the growth of this species. Boatman (1962) analysed plants of Schoenus nigricans from different habitats in western Ireland, and found significant correlations between magnesium, potassium and yield. After conducting experiments to test this, Boatman considered that low potassium levels in Yorkshire peat limited growth, together with some, as yet, unidentified element, which also acts to limit growth. With respect to pH, Boatman also found that in the region of pH 4 Schoenus nigricans reacts strongly to hydrogen ion concentration, resulting in failure to germinate and the stunting of root growth.

Perhaps the most popular current theory relating to the distribution of Schoenus nigricans is that relating to the susceptibility of this plant to the toxic effect of aluminium ions. Sparling (1967) investigated the effect of aluminium ions on the performance of Schoenus nigricans seedlings, and noted that at concentrations of 1 mg/l Al ions the rate of root elongation was substantially reduced. Under high calcium ion concentrations the effect of aluminium toxicity was aleviated to some degree, probably through competition for absorption sites on the root. Sparling (1962) has also shown that aluminium concentrations in waters from sites in Galway, Mayo and Kerry are generally much lower, in the region of 0.03 mg/l, than in water from blanket bogs in England and Scotland, where concentrations of aluminium in the region of 1 mg/l were reported. Sparling (1967b) suggests that the absence of aluminium from Irish peats is the factor enabling this species to grow on western Irish blanket bogs. Boatman (1972) grew Schoenus nigricans on peats collected from Sutherland in Scotland and Kerry in western Ireland. Boatman also considered that the failure of the plant to establish itself on Scottish peat was due to the fact that aluminium reached a concentration which was toxic to the roots of the plant. He also considered that the plant is surviving on Irish blanket bogs due to the fact that grazing pressure is very slight in these more remote areas of the British Isles.

From the above it can be seen that the various explanations for the anomalous occurrence of Schoenus nigricans on Irish blanket bogs concern themselves mainly with the edaphic and climatic differences between western Irish blanket bogs and English and Scottish blanket bogs, and also with the differences between Irish blanket bogs and lowland nutrient rich fens, in which Schoenus nigricans normally occurs. It was hoped that during the course of this investigation any differences in the edaphic conditions of each site visited would be reflected in the levels of nutrient and heavy metal elements present in the tissues of the plants analysed.

'Molinia caerulea is a perenial grass whose life form is considered to show adaptations to growth in fen communities rather than to that on moor and bog . . . ' Pearsall (1918). However Molinia caerulea shows as equally wide a range of ecological tolerance as does Schoenus nigricans, growing in a wide variety of different habitats. Jefferies (1915), McVean (1952) and Rutter (1955) have all shown that Molinia caerulea depends primarily upon an abundant supply of relatively fresh water. Jefferies (1915) observed that wherever stagnation becomes pronounced, so that the soil water is badly aerated and excessively acid Molinia caerulea tends to degenerate. This plant may be found growing on acid peaty soils or low lying calcareous or neutral fens. Generally under acid conditions this species is found growing either in flushes or along stream banks where water movement is more pronounced. Jefferies (1915) noted that under acid bog conditions Molinia caerulea is usually only found occupying sites where the slope is just great enough to stimulate the lateral flow of water, which results in greater oxidising conditions. On the west coast of Ireland however, this plant is to be found growing on areas of flat blanket bog, although only ever as single plants, never forming pure stands. Pearsall (1938) noted that Molinia caerulea may occur on either water logged reducing soils where the pH exceeds 4.4 or on soils of pH 3.9, these acidities only being tolerated under oxidising conditions.

James (1962) claims that this species is never to be found growing on well drained base rich or calcareous soils, showing that conditions in dry calcareous soils were such that the uptake of phosphorus by Molinia caerulea is restricted, even when this element is readily available in the soil. However, Molinia caerulea was observed during this study, growing on high calcareous glacial till in the Burren District of western Ireland, in association with Schoenus nigricans, and samples of these plants were collected for analysis. James considered that the chemical nature of calcareous soils, being dominated largely by OH^- and Ca^{++} ions, may be responsible for the restriction of phosphorus uptake.

Cladium mariscus is typically a plant of base rich fens and the shallow water zones of lakes and ponds. This species requires a water logged substratum of either peat or mineral soil rich in bases and organic matter. Apparent exceptions occur in Connemara, Praeger (1934), where this species flourishes under acid bog conditions. Pearsall (1938) examined such sites and found Cladium mariscus growing on coarse base saturated sands with a pH of 6.3. Samples have been taken from such sites for analysis and comparison with samples of this species collected from its more 'normal' habitats, the base rich fens of East Anglia.

Site Descriptions

The sites visited during the course of this study range from the base rich lowland fens of East Anglia, rheophilous mire types, to ombrophilous mire types in the west of Ireland. Each site will be described here, whilst their floristic descriptions have been referred to the appendix. Each site has been classified in accordance with the criteria of the hydrological mire type data displayed in figure 2, after Bellamy (1972).

Rheophilous Mire Sites

Lowland Sites

Foulden Common Grid Ref: TF 760000

Altitude 6.2 m.

Distance from the coast along the direction of the prevailing wind 265.5 Km.

Prevailing wind direction South Westerly.

Aspect Flat

Hydrological mire type 2.

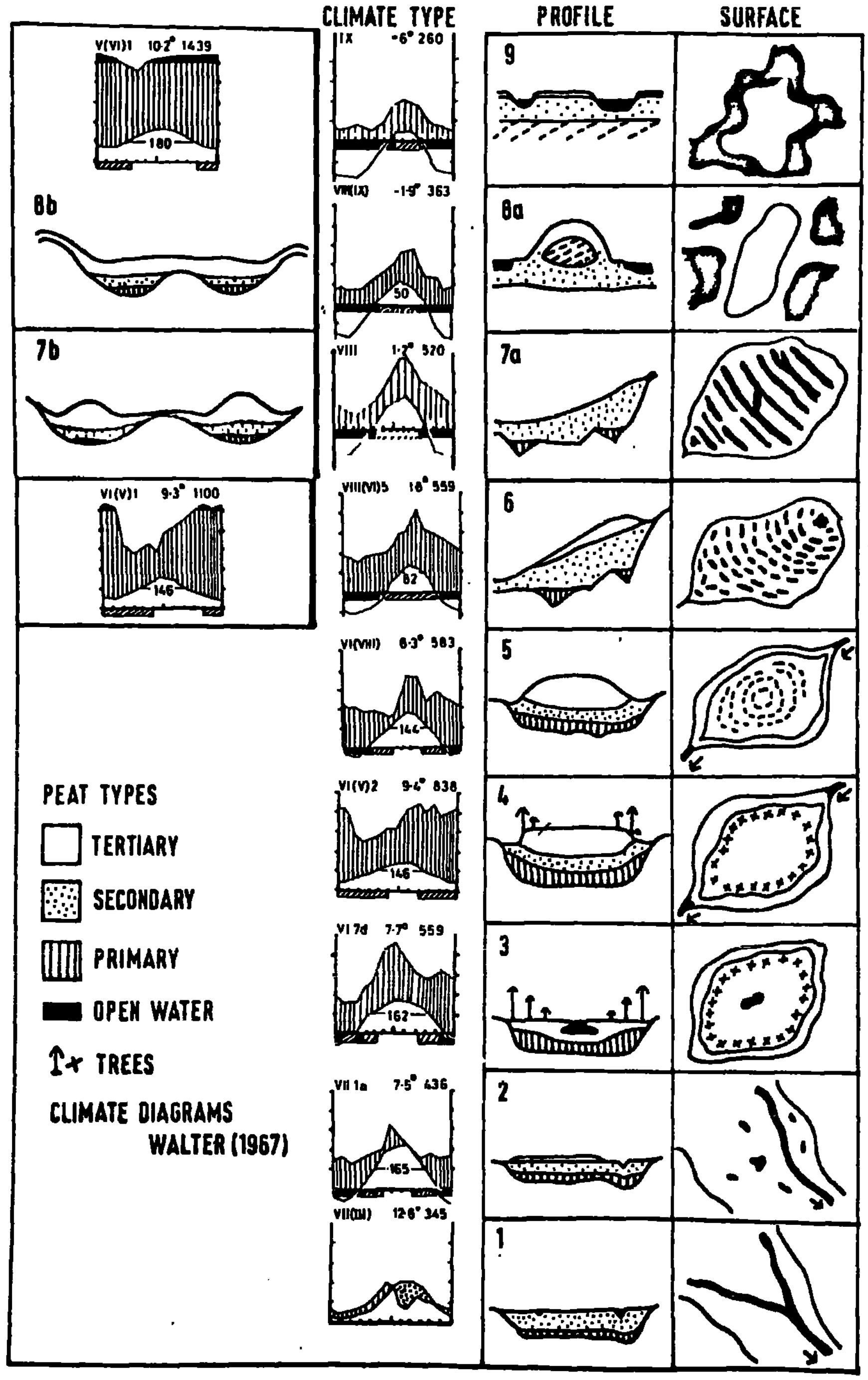
A small rheophilous mire recieving base rich drainage water from slightly higher agricultural land. The vegetation is open fen type being colonised by fen carr species around the perimeter of the mire. A depression at the centre of the fen is dominated by a large stand of Cladium mariscus with Schoenus nigricans growing in soaks around the edge of the Cladium mariscus stand.

Little Fen Grid Ref: TM 042793

Altitude 7m.

Distance from the coast along the direction of the prevailing wind 235.9 Km.

Prevailing wind direction South Westerly



CLIMATE TYPE
PROFILE
SURFACE
V(VI)1 10·2° 1439
180
8b
7b
VI(V)1 9·3° 1100
146
IX -6° 260
VIII(IX) -1·5° 363
50
VIII 1·2° 520
VIII(VI)5 1·8° 559
82
VI(VII) 6·3° 583
144
VI(V)2 9·4° 838
146
VI 7d 7·7° 559
162
VII 1a 7·5° 436
165
VII(III) 12·8° 345
9
8a
7a
6
5
4
3
2
1
PEAT TYPES
TERTIARY
SECONDARY
PRIMARY
OPEN WATER
TREES
CLIMATE DIAGRAMS
WALTER (1967)

Figure 2

A large lowland rheophilous mire complex, which once recieved base rich drainage water from the surrounding agricultural land. The water table level of the fen is now maintained by pumping in water from the surrounding area, this water is still rich in bases.

Site 1. Buckthorn carr in amongst which *Cladium mariscus* forms a dense stand, a relict of the original open fen community.

Site 2. Open fen largely dominated by *Cladium mariscus* and *Phragmites communis*.

Lough Coolreash   Grid Ref: R 3395

Altitude 27 m.

Aspect Flat.

Distance from the coast along the direction of the prevailing wind 22.5 Km.

Prevailing wind direction South Westerly

Hydrological mire type 2.

A mire formed on marley peat at the north west end of Lough Coolreash, subject to heavy grazing. The Lough has no surface inflow or outflow streams, but lying as it does in a limestone basin it must be subject to the movements of the regional water table.

Site 1. All three species were collected from the mire lying at the northern end of the Lough.

Site 2. All three species were collected from a fringing community at the edge of the Lough.

Hawes Water   Grid Ref: SD 470760

Altitude 7.9 m.

Aspect Flat

Distance from the coast along the direction of the prevailing wind 3.22 Km.

Prevailing wind direction South Westerly.

Hydrological Mire Type 1.

Plant material was collected from a pioneer fringing community of Cladium mariscus growing at the edge of a small tarn. The tarn is developed in a small depression in Carboniferous Limestone rock, therefore the vegetation is growing under highly calcareous conditions.

Upland Rheophilous Sites

Sunbiggin Grid Ref: SD 8304

Altitude 472.4 m.

Aspect South

Distance from the coast along the direction of the prevailing wind 48.3 Km.

Prevailing wind direction South Westerly

Hydrological mire type 1.

Samples of Cladium mariscus were collected from a pioneer stand of this species growing as a fringing community around the edge of the tarn at Sunbiggin. Schoenus nigricans was collected from flushes along the edge of the stream feeding the tarn. The water entering the tarn is rich in bases from the local Carboniferous Limestone and Millstone Grit series.

Cunswick Tarn Grid Ref: SD 489937

Altitude 75 m.

Aspect Flat

Distance from the coast along the direction of the prevailing wind 22.8 Km.

Prevaining wind direction South Westerly.

Hydrological Mire Type 1.

The tarn occupies a depression in the surrounding Carboniferous Limestone rock, therefore the site may be described as highly calcareous. Samples of Cladium mariscus were collected from a denso pioneer stand of this species growing as a fringing communtiy around the edge of the tarn.

Transitional Mire Lowland

Newton Rainey Moss Grid Ref: NY 478309

Altitude 183 m.

Aspect Flat

Distance from the coast along the direction of the prevailing wind 56.3 Km.

Hydrological Mire Type 5.

Site 1. An extensive area of infilled peat cuttings between slightly elevated bulks. A well defined open community with Schoenus nigricans only occuring in relatively small amounts. Scattered shrubs are invading the area, mainly Betula pubescens and Salix cinerea.

Site 2. A small shallow depression in the middle of carr vegetation, the centre of which is dominated by Cladium mariscus. The moss recieves drainage water only from the immediate areas bordering the moss.

Ombrophilous Mires

Lough Cloonagat Grid Ref: L 6946

Altitude 6 m.

Slope Flat

Distance from the coast along the direction of the prevailing wind 10 Km.

Prevailing wind direction South Westerly

Hydrological Mire Type 7.

Site 1. An ombrophilous mire with a flat surface, lying between two small loughs. The general mire surface is dominated by Schoenus nigricans.

Site 2. A reed swamp at the northern edge of one of the small loughs, a small area of vegetation dominated by Cladium mariscus rooted in firm peat fringing the lough at the head of a flush.

Lough in Connemara Grid Ref: L6946

Altitude 6m.

Aspect Flat.

Distance from the coast along the direction of the prevailing wind 10 Km.

Hydrological Mire Type 7.

A small lough developed on the surface of an ombrophilous mire close to Lough Cloonagat. Cladium mariscus forms a fringing community along the shore of the lough growing in 18 inches of peaty water.

Ombrophilous Mire Connemara

Altitude 6m.

Slope Flat

Distance from the coast along the direction of the prevailing wind 10 Km.

Prevailing wind direction South Westerly.

Hydrological Mire Type 7.

A large area of flat ombrophilous mire dominated by Schoenus nigricans with Molinia caerulea also present.

Minerotrophic Sites

River Cahor Valley Grid Ref: R 140085

Altitude 94.5 m.

Slope 85 degrees

Aspect South

Distance from the coast along the direction of the prevailing wind 2 Km.

Prevailing wind direction South Westerly

Highly clacareous lateral morain has been deposited along the northern edge of the river valley. These deposits have been undercut deeply by the stream flowing through the valley, this action together with the previous glacial activities has resulted in the formation of a shear sided flat bottomed valley. The local geology of the area is Carboniferous Limestone series, the moraine on which the mineral soils are developed are therefore highly calcareous.

Site 1. A *Schoenus nigricans* dominated community developed at the top of the valley side, just over the edge of the surface of the morain, inaccessible to grazing animals - domestic.

Site 2. *Schoenus nigricans* and *Molinia caeruloa* growing in association, in a similar situation to site 1.

Materials and Methods

Chemical Analysis of Plant Tissues

Living and dead leaf tissues of each of the species under investigation was collected at each of the sites visited, when available. In the cases of Schoenus nigricans and Cladium mariscus dead leaf tips were collected, whilst in the case of Molinia caerulea the previous years' leaf litter was collected. Owing to the fact that the growing season on the west coast of Ireland starts earlier in the year than in the rest of the British Isles, it was not possible to sample all the sites concurrently. The Irish sites were sampled during the the last week in April, and the English sites sampled during the first and second weeks in June. All the sites were sampled just after the beginning of the growing season, it was considered that all the plant tissues would be in similar physiological conditions.

Although the relative proportions of various mineral nutrients may differ in the leaves of some plants with age, Guttler (1941); Baumeister (1958). The changes in the mineral composition of leaves with age in species investigated by Jefferies and Willis (1964) did not appear to be very pronounced. Their analyses of leaves collected in the spring did not differ markedly from those of leaves collected in the summer. The differences in sampling time experienced in this study are not considered to be important.

Analysis was carried out on leaf tissues, which were regarded as giving a better index of the nutrient status of the plant than roots, where complete removal of soil particles is rarely achieved, or stems, where many of the cells are dead xylem elements.

Triplicate samples of the living and dead leaf tissues of each species were collected from each site in order to account for site variation to some degree.

The leaves were washed in distilled water and then dried for forty eight hours at 80°C. The dried leaves were then milled down to a fine powder. One gram of each sample was digested in a Kjeldahl flask, to which was added 20 ml of concentrated nitric acid and 5 ml of 60% w/v perchloric acid (sg. 1.54). Analar chemicals were used throughout. The problem of foaming was overcome by adding the nitric acid 12 hours before adding the perchloric acid, after which all the excess acid was boiled off until only a little perchlorate remained. The neck of the flask was then washed down with distilled water and the contents filtered through Whatman No. 42 paper, which had previously been soaked in 10% perchloric acid to removed trace elements, filtration removes any trace elements from the paper. The filtrate was then made up to 100 ml.

Calcium, magnesium, potassium, sodium, aluminium, zinc, lead, manganese and iron levels were then determined with the use of a Perkin Elmer 403 Atomic Absorption Spectrophotometer. The instrument was set up as described in the instruction manual. The wavelengths used, together with their theoretical sensitivity for 1% absorption are quoted in table 1.

All the phosphorus present in plant tissues is converted to phosphate phosphorus during the process of digestion used here. Phosphate levels were estimated by means of the ammonium molybdate ammonium metavanadate method, which depends upon the formation of a yellow phospho-molybdate complex under acid conditions. This method covers a wide range of phosphate

concentrations, and is less susceptible to interference.
The reagent was made up as follows:
50 ml concentrated nitric acid were added to 50 ml of distilled water.
0.312 gm of ammonium metavanadate were added to 100 ml of cooled nitric acid
12.5 gm of ammonium molybdate were added to 100 ml distilled water.
The two solutions were mixed together and made up to 250 ml using distilled water.
To 40 ml of each digestant 5 ml of the above reagent was added and left for five minutes for the colour complex to form, after which time the solutions were made up to 50 ml and the colour intensity read on an Eel Spectrophotometer, which had previously been calibrated, at 470 mu wavelength.

Table 1.

Element	Wavelength	Sensitivity (ugm/1 = 1% absorbance)
Magnesium	285.6 UV	0.007
Calcium	211.7 Vis.	0.08
Potassium	383.4 Vis.	0.04
Sodium	294.7 Vis.	0.015
Zinc	214.3 UV	0.018
Iron	248.8 UV	0.12
Manganese	279.9 UV	0.005
Aluminium	309.6 UV	1.0
Lead	283.5 UV	0.5

Vegetation Analysis

An area, generally 10 metres by 10 metres, of what was considered to be homogenous vegetation has been described for each site. The cover value of each species present has been expressed according to the Braun Blanquet cover scale, see table 2a.

Table 2a.

Value	Percentage Cover
+	less than 1%
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-100%

The second number given to each species indicates the sociability index of each species, see table 2b.

Table 2b.

Sociability	
1	Growing once in a place, singly.
2	Grouped or tufted.
3	In troops, small patches or cushions.
4	In small colonies, extensive patches or forming carpets.
5	In great crowds or pure populations.

Thus an adequate description of each vegetation type is achieved.

An association analysis, after Williams and Lambert (1960, 61) was selected for the analysis of the vegetation data. This method was selected in order to apply simple measurement of the relative similarities of sample composition, thus giving rise to a situation which enables the arrangement of the sample areas along axes which may correspond to underlying environmental gradients.

In order to carry out the analysis the cover data was transformed into simple presence and absence data. Analysis was carried out on an IBM computer. The method employed uses positive and negative correlations for the division of the data in an hierarchical manner. Williams and Lambert (1959,60) demonstrate that there are a number of alternative subdivisions which will produce the method's objective, and for this purpose introduce the concept of efficient subdivision. The division occurs on the species which produces the smallest total number of significant correlations in each of the dichotomous pairs of division. χ^2 is used as a measure of correlation, both groups resulting from a division are retained. The hierarchical procedure thus employed poses the problem of significance. The relative importance of the different subdivisions at the same level may vary considerably. One subdivision may reduce the residual heterogenity by a large amount, whilst a parallel subdivision on the other side of the hierarchy may cause only a small reduction in the residual heterogenity. In order to record this disparity Williams and Lambert used the highest individual χ^2 value within the data as the criterion for the termination of subdivision. Subdivision ceases when no individual χ^2 value exceeds 3.84, corresponding to a probability of 0.05.

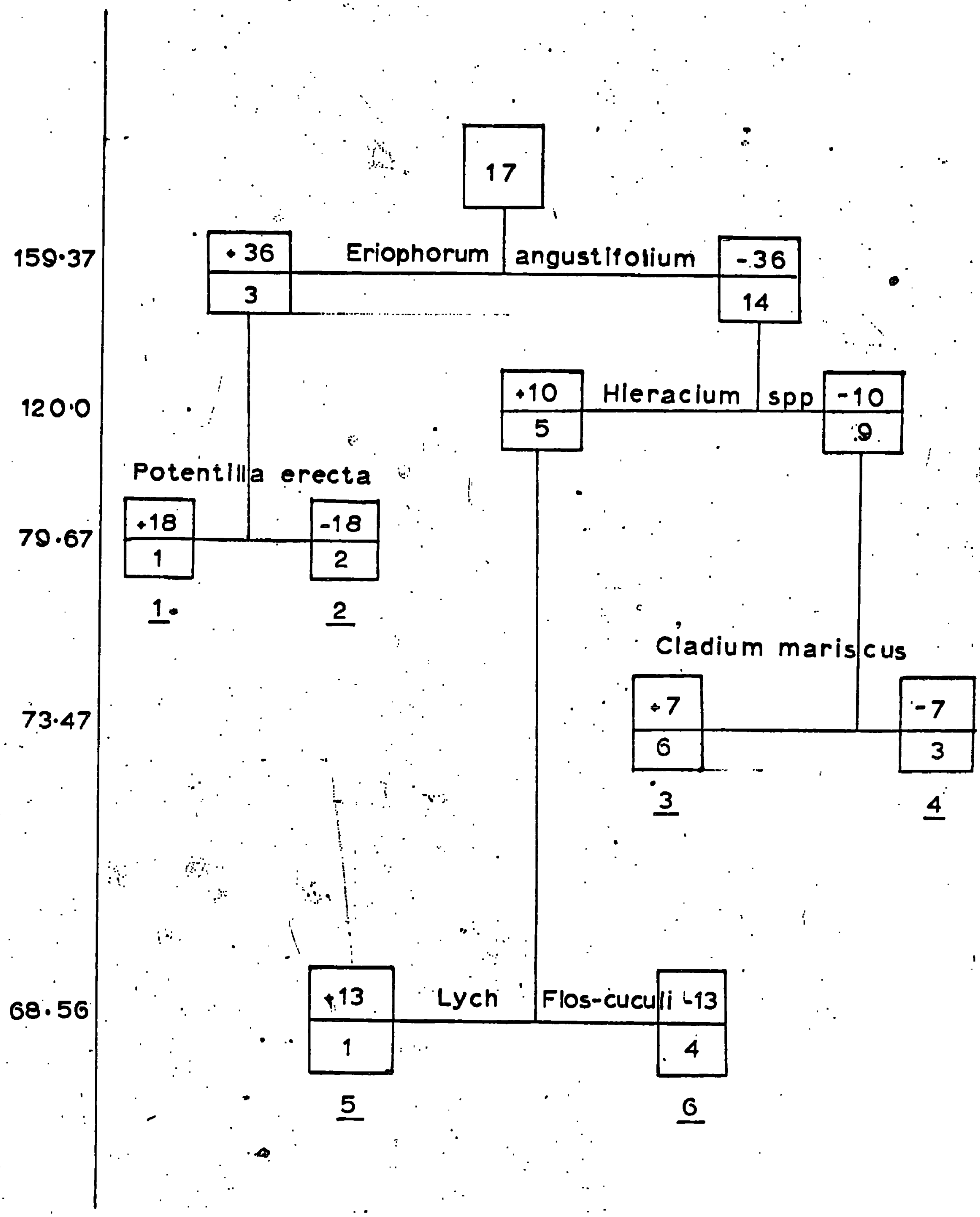
Owing to the fact that data for only 17 quadrats was being analysed, the computer was instructed to terminate analysis after six sub-groups had been formed. Thus individual χ^2 values may exceed 3.84.

Results

Vegetation Analysis

The results of the vegetation analysis are presented on Plate 2.

Of note is the fact that on the first division the ombrophilous mire in Connemara and the transitional mire at Newton Rainey Moss have been separated by the presence at these sites of *Eriophorum angustifolium*, an acid bog species. Ombrophilous sites where this species is absent, Lough Cloonagat and the Lough in Connemara subsequently fall into clusters along with rheophilous sites, indicating the closer floristic similarities of these sites. The χ^2 coefficient of each of the final divisions indicate that a great deal of heterogenity still exists within the final clusters. It was thought that further subdivisions would perhaps reduce this heterogenity and may result in the separation of ombrophilous and rheophilous sites into separate clusters. However further analysis merely resulted in the separating out of individual rheophilous sites without reducing the residual heterogenity to any real degree, an inherent drawback when floristicaly rich data is subjected to such an analysis. However the analysis does serve to illustrate the floristic similarities between some of the ombrophilous sites and the rheophilous sites. Floristic data was not available for Sunbiggin.



159·37
120·0
79·67
73·47
68·56
17
+36
3
Eriophorum angustifolium
-36
14
+10
5
Hieracium spp
-10
9
Potentilla erecta
+18
1
-18
2
1
2
Cladium mariscus
+7
6
-7
3
3
4
+13
1
Lych Flos-cuculi
-13
4
5
6

Plate 2

Association Analysis - Final Cluster Groups

Group 1

Ombrophilous mire in Connemara

Group 2

Newton Rainey Moss Site 1	Transitional Mire
Newton Rainey Moss Site 2	

Group 3

Hawes Water	Rheophilous Mire
Lough Coolreash	Rheophilous Mire
Foulden Common Site 2	Rheophilous Mire
Wicken Fen Site 1	Rheophilous Mire
Lough Cloonagat Site 2	Ombrophilous Mire
Lough in Connemara	Ombrophilous Mire

Group 4

River Caher Site 1	Minerotrophic
River Caher Site 2	Minerotrophic
Lough Cloonagat Site 1	Ombrophilous

Group 5

Cunswick Tarn	Rheophilous

Group 6

Little Fen	Rheophilous
Foulden Common Site 1	Rheophilous
Redgrave Fen	Rheophilous
Wicken Fen Site 2	Rheophilous

Table 3. Analyses of leaves of *Schoenus nigricans* live tissue.

The results are expressed as mg/g dry tissue.

Each value is a mean of three separate determinations.

Site	Mg	Ca	K	PO_4	Na
Foulden Common	1.11	4.87	11.06	1.51	0.18
Little Fen	0.83	5.15	14.0	1.82	0.19
Redgrave Fen	1.31	4.89	14.3	1.22	0.22
Sun Biggin	1.32	2.86	4.93	1.92	0.26
Newton Rainey Moss	2.01	4.65	5.70	1.89	0.40
Lough Cloonagat	2.32	1.84	7.70	0.90	0.72
Connemara Bog	2.21	1.80	8.40	0.84	0.50
Lough Coolreash Site 1.	1.41	5.0	12.8	1.72	1.30
Lough Coolreash Site 2.	1.62	4.26	5.8	1.42	1.60
River Caher Site 1.	2.0	4.26	9.45	1.01	0.71
River Caher Site 2.	2.18	5.15	9.90	1.43	0.66
Mean and S.E.	1.57 ±0.52	4.07 ±1.28	9.46 ±3.02	1.43 ±0.45	0.61 ±0.23

Table 4. Analyses of leaves of *Cladium mariscus* live tissue.

The results are expressed as mg/g dry tissue.

Each value is a mean of three separate determinations.

Site	Mg	Ca	K	PO_4	Na
Foulden Common	0.40	2.03	8.95	1.90	0.33
Wicken Fen Site 1.	0.91	2.42	8.16	4.04	0.94
Wicken Fen Site 2.	1.15	2.89	3.68	1.77	0.33
Little Fen	0.45	1.50	10.50	2.08	0.26
Redgrave Fen	0.44	1.68	10.27	1.27	0.31
Cunswick Tarn	1.02	2.3	2.46	1.52	1.28
Hawes Water	1.04	3.42	3.87	2.33	1.34
Sun Biggin Tarn	1.05	3.15	7.20	2.46	1.76
Newton Rainey Moss	1.48	3.73	7.70	1.98	2.12
Lough Cloonagat	0.52	1.2	7.76	1.44	1.21
Lough in Connemara	0.62	1.6	6.5	1.82	1.04
Lough Coolreash Site 1.	0.99	5.25	4.60	1.94	1.92
Lough Coolreash Site 2.	0.74	3.13	4.26	1.73	1.28
Mean and S.D.	0.83 $\pm$0.25	2.64 $\pm$0.8	6.61 $\pm$1.97	2.02 $\pm$0.59	1.09 $\pm$0.35

Table 5. Analyses of leaves of *Molinia caerulea* live tissue. The results are expressed as mg/g dry tissue. Each value is a mean of three separate determinations.

Site	Mg	Ca	K	PO_4	Na
Little Fen	0.71	1.98	14.6	1.93	0.11
Rodgrave Fen	0.79	2.31	14.9	2.88	0.13
Lough Cloonagat	1.04	1.32	15.7	5.12	0.83
Connemara Bog	1.12	1.30	14.0	3.16	0.30
Lough Coolreash Site 2.	1.0	3.4	22.0	7.09	0.26
River Caher Site 2.	1.21	2.4	20.5	7.08	0.22
Mean and S.E.	9.78 ±0.41	2.12 ±0.92	16.95 ± 4.80	4.54 ±2.07	0.31 ±0.17

Table 6. Analyses of leaves of *Schoenus nigricans* dead tissue.
The results are expressed as mg/g dry tissue.
Each value is a mean of three separate determinations.

Site	Mg	Ca	K	PO_4	Na
Foulden Common	0.19	2.47	0.80	0.73	0.10
Little Fen	0.30	3.75	2.49	0.61	0.18
Redgrave Fen	0.30	4.03	1.60	0.97	0.30
Sun Biggin	0.27	2.40	0.36	0.40	0.25
Newton Rainey Moss	0.48	5.88	0.74	0.59	0.24
Lough Cloonagat	0.59	1.26	0.46	0.21	0.48
Connemara Bog	0.42	1.03	0.16	0.30	0.48
Lough Coolreash Site 1.	0.73	10.40	1.56	0.40	0.30
Lough Coolreash Site 2.	0.30	7.60	0.40	0.38	0.30
River Caher Site 1.	0.76	3.45	1.0	0.34	0.33
River Caher Site 2.	0.73	2.83	0.56	0.32	0.26
Mean S.E.	0.459 ±0.15	4.1 ±1.5	0.92 ±0.35	0.48 ±0.16	0.29 ±0.095

Table 7. Analyses of leaves of *Cladium mariscus* dead tissue.

The results are expressed as mg/g dry tissue.

Each value is a mean of three separate determinations.

Site	Mg	Ca	K	PO_4	Na
Foulden Common	0.16	1.80	0.23	0.54	0.10
Wicken Fen Site 1.	0.35	1.91	0.55	0.97	0.14
Wicken Fen Site 2.	0.16	2.54	0.48	1.36	0.23
Little Fen	0.19	2.99	0.30	0.69	0.08
Redgrave Fen	0.22	2.52	0.26	0.51	0.13
Cunswick Tarn	0.29	2.74	0.19	0.67	0.19
Hawes Water	0.39	3.42	0.40	0.73	0.31
Sun Biggin Tarn	0.39	2.26	0.42	1.53	0.36
Newton Rainey Moss	1.07	4.76	1.10	1.78	0.95
Lough Cloonagat	0.69	1.20	1.14	0.54	1.87
Lough in Connemara	0.77	1.78	0.23	0.13	0.80
Lough Coolreash Site 1.	0.28	8.86	0.24	0.28	0.19
Lough Coolreash Site 2.	0.26	10.0	0.36	0.36	0.13
Mean and S.D.	0.40 $\pm$0.15	3.60 $\pm$ 1.26	0.45 $\pm$0.15	0.78 $\pm$0.26	0.42 $\pm$0.18

Table 8. Analyses of leaves of *Molinia caerulea* dead tissue. The results are expressed as mg/g dry tissue. Each value is a mean of three separate determinations.

Site	Mg	Ca	K	PO_4	Na
Little Fen	0.12	1.95	0.68	0.44	0.08
Redgrave Fen	0.13	1.09	1.04	1.02	0.12
Lough Cloonagat	0.29	0.54	0.24	0.21	0.24
Connemara Bog	0.23	0.52	0.24	0.30	0.23
Lough Coolreash Site 1.	0.25	7.08	0.39	0.35	0.22
Lough Coolreash Site 2.	0.30	7.64	0.53	0.46	0.32
River Caher Site 2.	0.59	3.20	0.48	0.36	0.15
Mean and S.E.	0.27 $\pm$0.85	3.15 $\pm$1.65	0.51 $\pm$0.19	0.45 $\pm$0.19	0.18 $\pm$0.07

Table 9. Analyses of leaves of *Schoenus nigricans* Heavy metals. The results are expressed as mg/g dry tissue.
Each value is a mean of three separate determinations.

Site		Al	Zn	Pb	Fe	Mn
Fouldon Common	Live	0.015	0.035	0.007	0.17	0.023
	Dead	0.088	0.068	0.037	0.25	0.027
Little Fen	Live	0.020	0.047	0.009	0.18	0.030
	Dead	0.083	0.075	0.023	0.34	0.044
Redgrave Fen	Live	0.016	0.062	0.013	0.18	0.036
	Dead	0.118	0.105	0.047	0.433	0.088
Sun Biggin	Live	0.045	0.137	0.064	0.14	0.090
	Dead	0.135	0.105	0.104	0.15	0.094
Newton Rainey Moss	Live	0.024	0.062	0.035	0.10	0.090
	Dead	0.105	0.078	0.053	0.15	0.094
Lough Cloonagat	Live	0.024	0.026	0.005	0.119	0.026
	Dead	0.090	0.022	0.028	0.231	0.007
Connemara Bog	Live	0.020	0.031	0.015	0.13	0.015
	Dead	0.097	0.023	0.003	0.177	0.003
Lough Coolreash Site 1.	Live	0.038	0.034	0.005	0.21	0.134
	Dead	0.077	0.056	0.014	0.204	0.081
Lough Coolreash Site 2.	Live	0.050	0.022	0.008	0.183	0.039
	Dead	0.126	0.049	0.020	0.231	0.050
River Caher Site 1.	Live	0.012	0.042	0.022	0.10	0.020
	Dead	0.10	0.038	0.041	0.314	0.020
River Caher Site 2.	Live	0.031	0.048	0.023	0.168	0.025
	Dead	0.110	0.064	0.044	0.30	0.081

Table 10. Analyses of leaves of *Cladium mariscus* Heavy metals.
The results are expressed as mg/g dry tissue.
Each value is a mean of three separate determinations.

Site		Al	Zn	Pb	Fe	Mn
Foulden Common	Live	0.026	0.138	0.028	0.12	0.062
	Dead	0.095	0.085	0.028	0.17	0.042
Wicken Fen Site 1.	Live	0.021	0.034	0.006	0.13	0.086
	Dead	0.054	0.085	0.020	0.167	0.054
Wicken Fen Site 2.	Live	0.026	0.138	0.004	0.117	0.080
	Dead	0.129	0.081	0.062	0.347	0.046
Little Fen	Live	0.017	0.017	0.006	0.093	0.030
	Dead	0.107	0.063	0.058	0.283	0.046
Rodgrave Fen	Live	0.012	0.020	0.007	0.083	0.062
	Dead	0.091	0.065	0.048	0.306	0.059
Cunswick Tarn	Live	0.013	0.013	+	0.103	0.062
	Dead	0.048	0.026	0.041	0.15	0.057
Hawes Water	Live	0.016	0.017	0.006	0.113	0.128
	Dead	0.033	0.015	0.022	0.123	0.164
Sun Biggin Tarn	Live	0.017	0.054	0.018	0.074	0.083
	Dead	0.095	0.097	0.064	0.216	0.046
Newton Rainey Moss	Live	0.045	0.055	0.031	0.122	0.099
	Dead	0.087	0.063	0.043	0.20	0.135
Lough Cloonagat	Live	0.026	0.020	0.002	0.358	0.193
	Dead	0.037	0.016	0.016	0.418	0.113
Lough in Connemara	Live	0.018	0.021	0.006	0.126	0.30
	Dead	0.055	0.020	0.017	0.399	0.28
Lough Coolreash Site 1.	Live	0.014	0.024	0.005	0.217	0.30
	Dead	0.047	0.025	0.013	0.141	0.048
Lough Coolreash Site 2.	Live	0.027	0.022	0.006	0.116	0.034
	Dead	0.062	0.026	0.011	0.126	0.037

Note. + = trace.

Tablo 11. Analyses of leaves of *Molinia caerulea* Heavy metals.
The results are expressed as mg/g dry tissue.
Each value is a mean of three separate determinations.

Site		Al	Zn	Pb	Fe	Mn
Little Fen	Live	0.026	0.083	0.007	0.137	0.045
	Dead	0.155	0.059	0.041	0.347	0.042
Redgrave Fen	Live	0.026	0.046	0.005	0.177	0.059
	Dead	0.242	0.047	0.049	0.753	0.042
Lough Cloonagat	Live	0.032	0.115	0.012	0.157	0.146
	Dead	0.076	0.029	0.018	0.367	0.015
Connemara Bog	Live	0.040	0.115	0.004	0.126	0.192
	Dead	0.076	0.029	0.020	0.270	0.006
Lough Coolreash Site 2.	Live	0.152	0.080	0.022	0.264	0.118
	Dead	0.154	0.045	0.014	0.183	0.117
River Caher Site 2.	Live	0.037	0.073	0.006	0.181	0.074
	Dead	0.169	0.077	0.030	0.40	0.028

Table 12. Mineral elements of dead leaf tissues of *Schoenus nigricans* expressed as a percentage of live values.

Sites	Mg	Ca	K	PO_4	Na
Foulden Common	17.8_1	48.7	7.2_5	48.4_{10}	55.5
Little Fen	36.0_9	72.8	17.8_{11}	33.5_7	94.7
Redgrave Fen	22.9_5	82.0	11.0_8	79.5_{11}	136
Sun Biggin	20.5_4	83.9	7.3_6	20.6_1	96.0
Newton Rainey Moss	23.9_6	126.5	13.0_{10}	31.2_5	60.0
Lough Cloonagat	25.4_7	68.5	6.0_3	23.0_3	66.7
Connemara Bog	19.0_3	57.2	1.9_1	35.7_9	96.0
Lough Coolreash Site 1.	51.8_{11}	208.8	12.2_9	23.2_4	23.1
Lough Coolreash Site 2.	18.5_2	178.4	6.9_4	26.6_6	18.8
River Caher Site 1.	38.0_{10}	81.0	10.6_7	33.7_8	46.5
River Caher Site 2.	33.5_8	55.0	5.7_2	22.4_2	39.4

Table 13. Heavy metal levels of dead tissue expressed as a percentage of live tissue levels for *Schoenus nigricans*

Sites	AL	Zn	Pb	Fe	Mn
Foulden Common	587.0_3	194.0	514.0_2	147.0_7	117.4
Little Fen	421.0_6	159.6	256.0_5	191.0_4	146.7
Sun Biggin	300.0_9	76.6	162.5_9	104.4_{10}	244.4
Redgrave Fen	737.0_2	169.0	370.6_3	240.6	104.4
Newton Rainey Moss	438.0_5	126.0	151.0_{10}	150.0_6	104.0
Lough Cloonagat	357.0_7	84.6	575.5_1	194.0_3	26.9
Connemara Bog	485.0_4	74.2	20.0_{11}	136.2_8	20.0
Lough Coolreash Site 1.	202.6_{11}	164.7	306.4_4	97.1_{11}	60.4
Lough Coolreash Site 2.	252.0_{10}	222.7	247.5_6	126.2_9	128.2
River Caher Site 1.	833.3_1	90.5	186.4_8	314.0_1	100.0
River Caher Site 2.	354.8_8	133.3	188.8_7	178.6_5	324.0

Table 14. Nutrient levels of dead tissue expressed as a percentage of live tissue levels for *Cladium mariscus*

Sites	Mg	Ca	K	PO_4	Na
Foulden Common	4.0_{2}	90.0	2.6_{3}	28.4_{5}	33.3
Wicken Fen Site 1.	8.2_{3}	79.0	6.8_{8}	24.0_{4}	14.9
Wicken Fen Site 2.	1.4_{1}	86.5	1.3_{1}	77.0_{12}	70.0
Little Fen	42.0_{9}	199.0	2.8_{4}	33.0_{7}	30.8
Rodgrave Fen	50.0_{10}	150.0	2.5_{2}	40.0_{9}	42.0
Cunswick Tarn	28.0_{4}	119.0	7.7_{9}	44.0_{10}	14.8
Hawes Water	37.5_{8}	100.0	10.3_{11}	31.6_{6}	23.0
Sun Biggin Tarn	37.1_{7}	71.7	5.8_{7}	62.2_{11}	20.5
Newton Rainey Moss	72.3_{11}	127.6	14.3_{12}	89.9_{13}	44.8
Lough Cloonagat	132.7_{13}	100.0	14.7_{13}	37.5_{8}	154.5
Lough in Connemara	93.3_{12}	124.2	3.5_{5}	7.1_{1}	76.9
Lough Coolreash Site 1.	28.3_{5}	168.8	5.2_{6}	14.4_{2}	9.9
Lough Coolreash Site 2.	35.1_{6}	319.5	8.5_{10}	20.8_{3}	10.2

Table 15. Heavy metal levels of dead tissue expressed as a percentage of live tissue levels for *Cladium mariscus*

Sites	Al	Zn	Pb	Fe	Mn
Foulden Common	365.0_{6}	61.5	100.0_{13}	141.5_{8}	67.7
Wicken Fen Site 1.	254.0_{9}	470.0	323.0_{8}	128.0_{9}	62.8
Wicken Fen Site 2.	495.0_{4}	59.0	1550.0_{2}	296.0_{3}	67.7
Little Fen	662.0_{2}	370.0	967.0_{3}	304.0_{2}	153.3
Redgrave Fen	771.0_{1}	325.0	685.0_{5}	368.0_{1}	95.2
Cunswick Tarn	367.0_{5}	200.0	$-_{1}$	146.0_{7}	91.3
Hawes Water	210.0_{11}	88.0	374.0_{6}	109.0_{12}	132.3
Sun Biggin Tarn	559.0_{3}	179.6	356.0_{7}	292.0_{4}	55.4
Newton Rainey Moss	193.4_{12}	114.5	138.7_{12}	163.9_{6}	135.9
Lough Cloonagat	142.3_{13}	80.0	762.0_{4}	116.8_{10}	58.5
Lough in Connemara	305.5_{8}	95.2	296.0_{9}	183.9_{5}	93.3
Lough Coolreash Site 1.	335.7_{7}	104.2	256.0_{10}	111.9_{11}	100.0
Lough Coolreash Site 2.	229.6_{10}	118.2	186.4_{11}	108.8_{13}	108.6

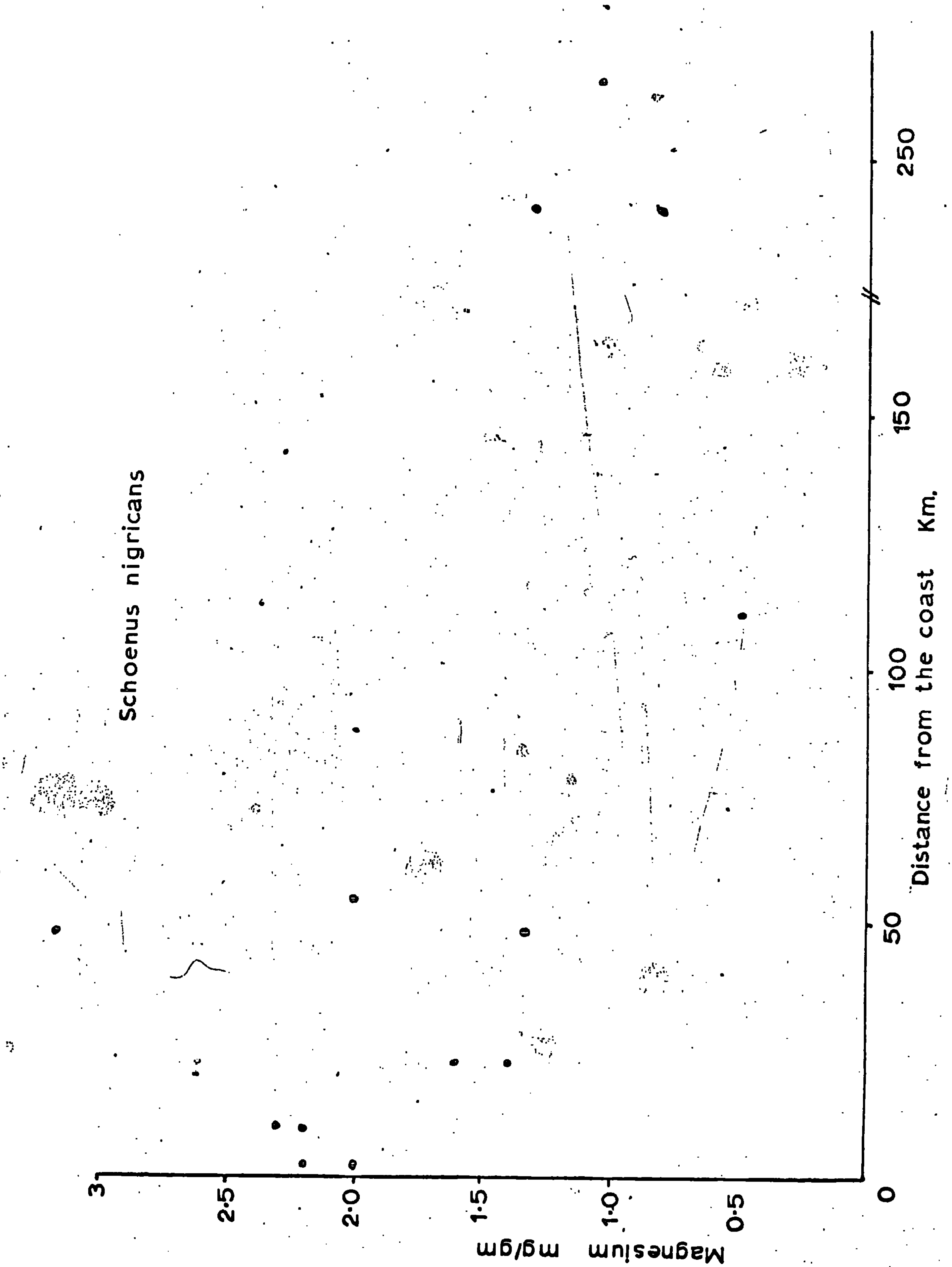
Table 16. Nutrient levels of dead tissue expressed as a percentage of live tissue levels for *Molinia caerulea*

Sites	Mg	Ca	K	PO_4	Na
Little Fen	17.0_2	98.5	4.7_5	22.8_5	72.7
Redgrave Fen	16.5_1	47.0	7.0_6	35.0_6	92.0
Lough Cloonagat	27.9_4	40.3	1.5_1	4.1_1	16.9
Connemara Bog	20.5_3	40.0	1.7_2	9.5_4	76.7
Lough Coolreash Site 2.	30.0_5	224.7	2.4_4	6.5_3	123.1
River Caher Site 2.	48.8_6	133.3	2.3_3	5.1_2	68.2

Table 17. Heavy Metal levels of dead tissue expressed as a percentage of live tissue levels for *Molinia caerulea*

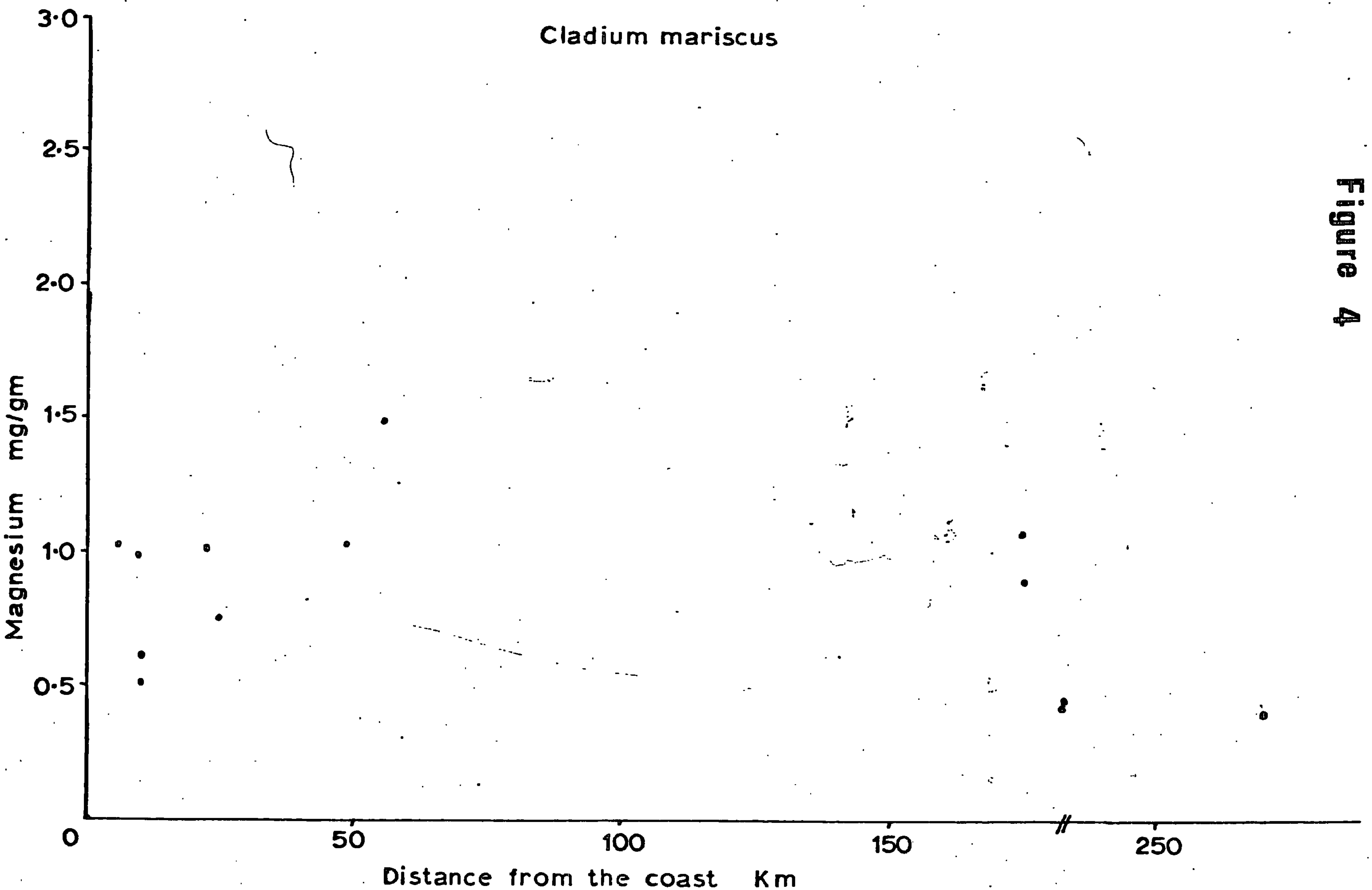
Sites	Al	Zn	Pb	Fe	Mn
Little Fen	596.0_2	155.0	585.0_2	253.0_2	153.3
Redgrave Fen	896.0_1	102.0	980.0_1	425.0_1	71.2
Lough Cloonagat	237.5_4	21.7	153.3_5	233.8_3	10.3
Connemara Bog	190.0_5	25.2	455.8_4	214.3_4	3.1
Lough Coolreash Site 2.	101.3_6	56.3	64.1_6	69.3_6	99.2
River Caher Site 2.	456.8_3	105.5	500.0_3	221.0_3	378.3

Figure 3



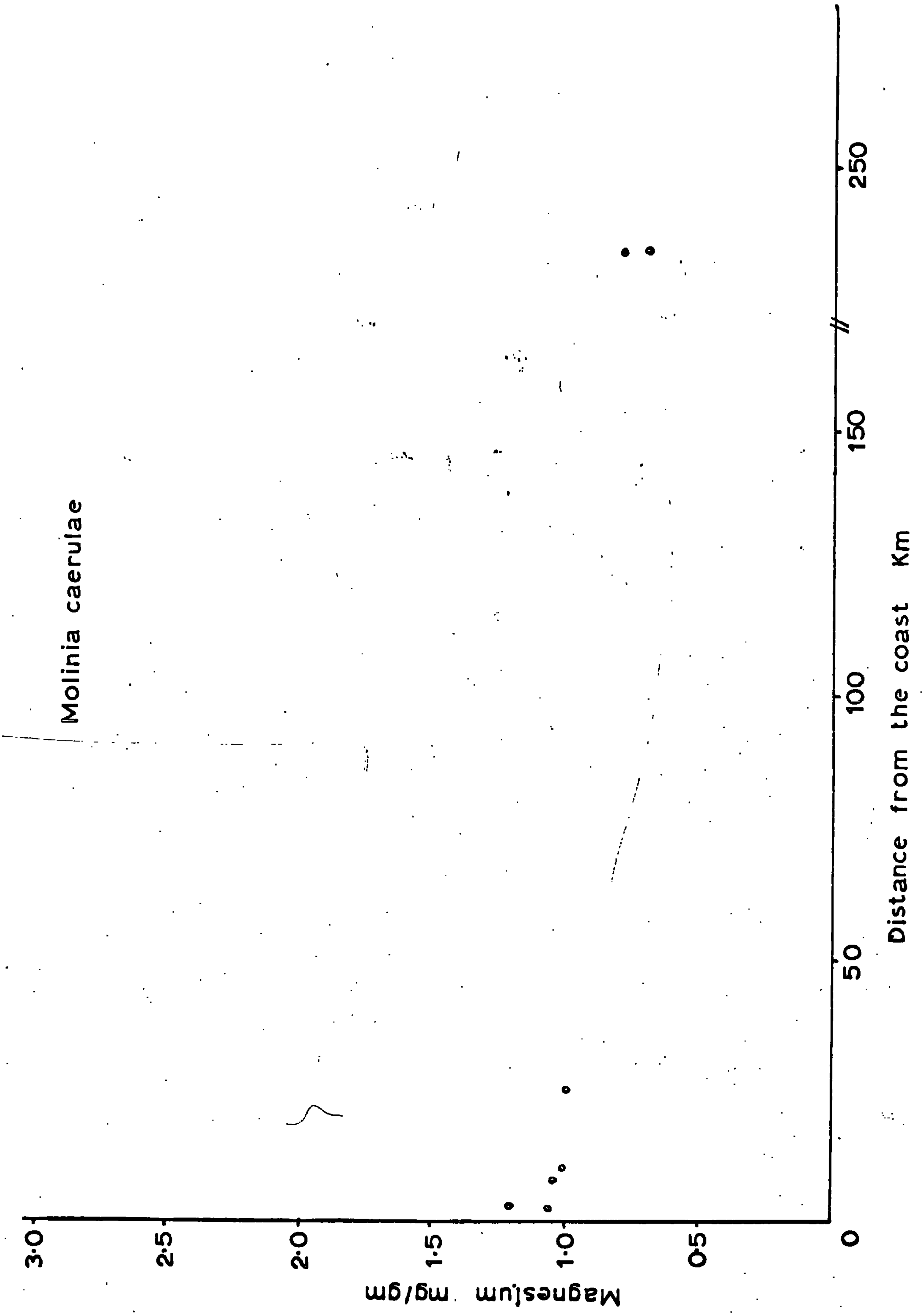
Schoenus nigricans
Magnesium mg/gm
3
2·5
2·0
1·5
1·0
0·5
0
50
100
150
250
Distance from the coast Km.

Figure 4



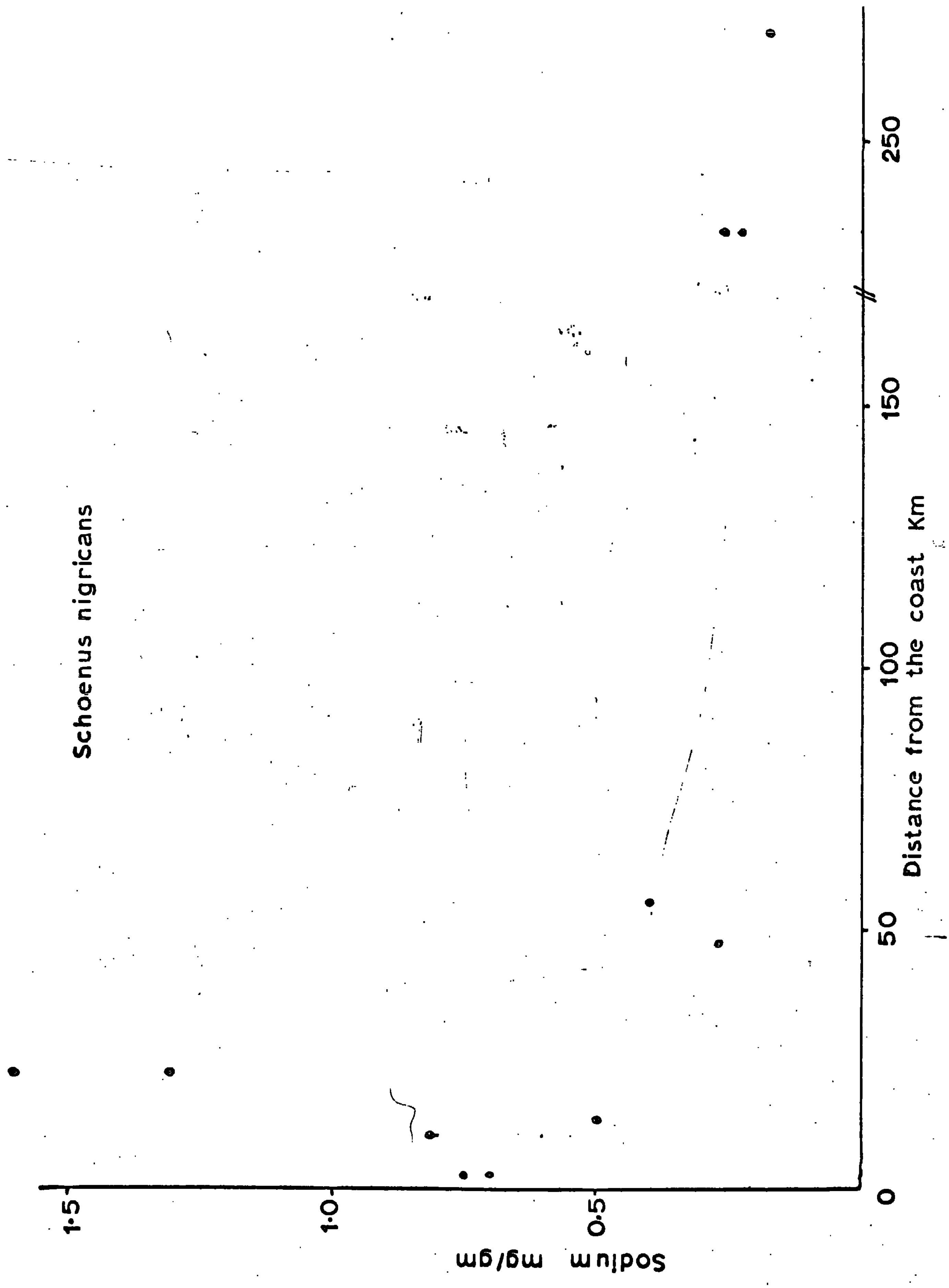
Cladium mariscus
Magnesium mg/gm
3·0
2·5
2·0
1·5
1·0
0·5
0
50
100
150
250
Distance from the coast Km

Figure 5

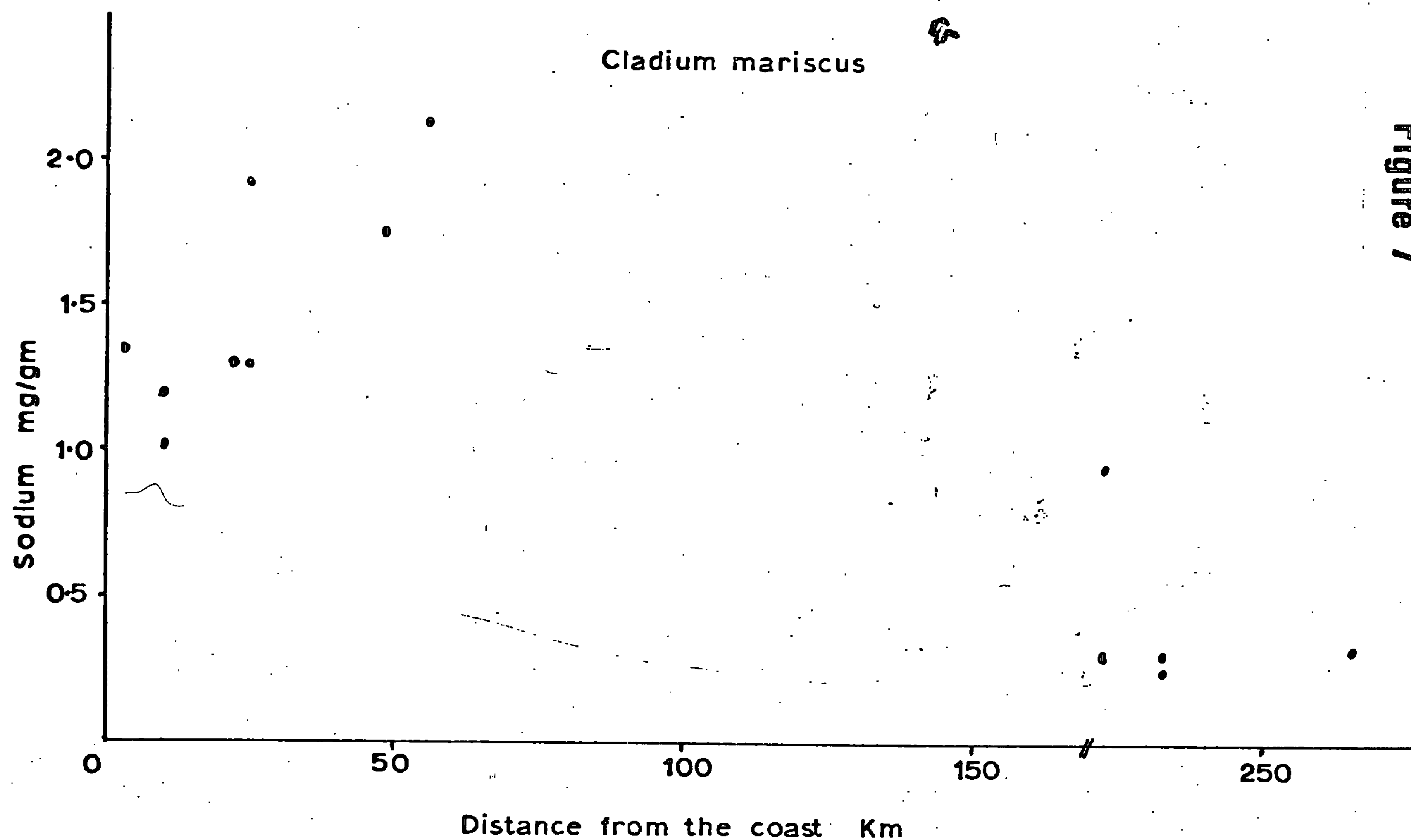


Molinia caerulae
Magnesium mg/gm
3·0
2·5
2·0
1·5
1·0
0·5
0
50
100
150
250
Distance from the coast Km

Figure 6



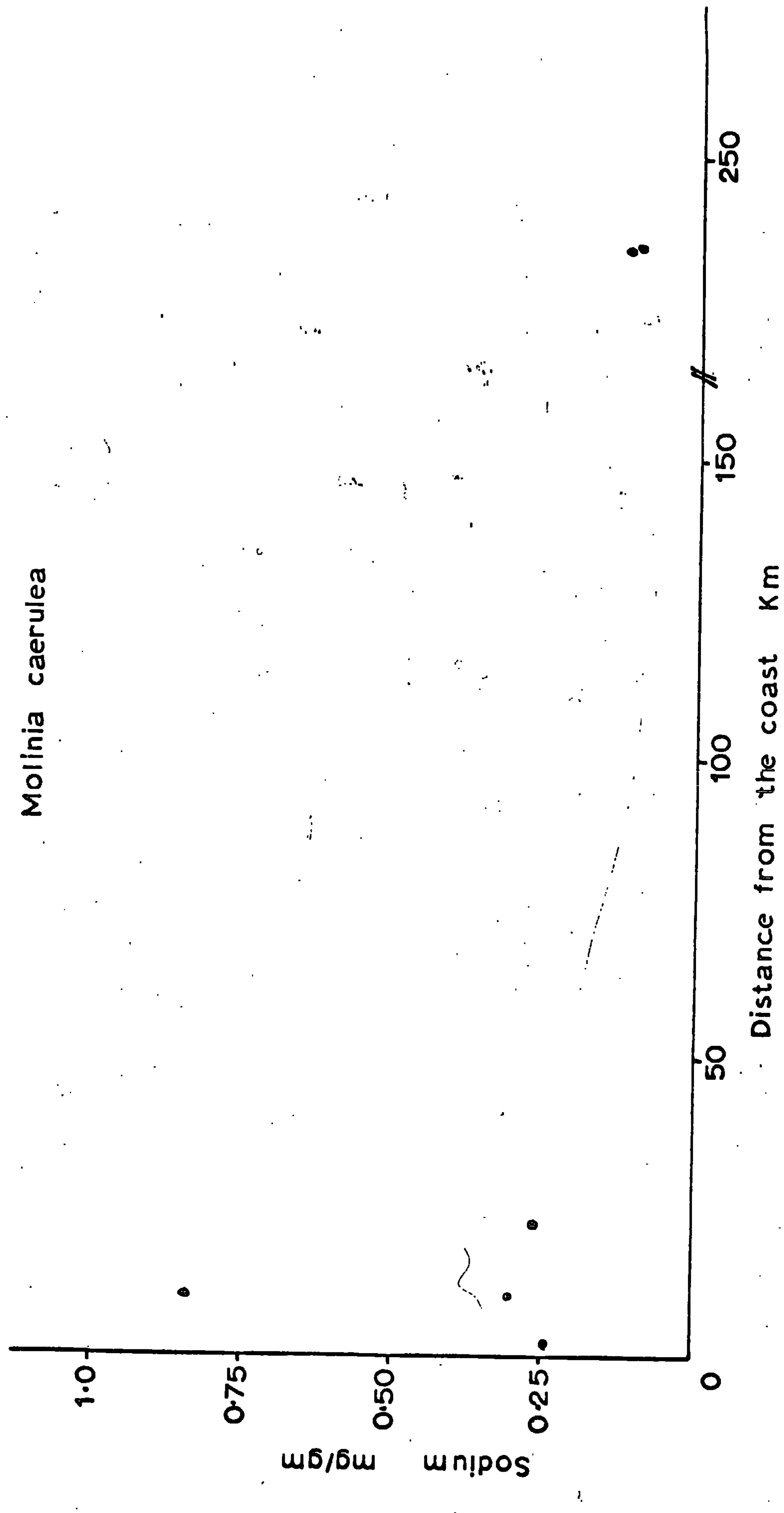
Schoenus nigricans
Sodium mg/gm
1·5
1·0
0·5
Distance from the coast Km
0
50
100
150
250



Cladium mariscus
Sodium mg/gm
2·0
1·5
1·0
0·5
0
50
100
150
250
Distance from the coast Km

Figure 7

Figure 8



Molinia caerulea
Sodium mg/gm
Distance from the coast Km
1·0
0·75
0·50
0·25
0
50
100
150
250

Chemical Analysis of Leaf Tissues

The amounts of each nutrient element determined in the tissues of each species are presented in tables 3, 4, and 5 expressed as mg/g living tissue. The levels of nutrients present in the plant tissues can be seen to vary between the rheophilous sites and the ombrophilous sites, variation in the levels of nutrients present in the tissues of each species also occurs. The variation in nutrient levels present in the plant tissues will be discussed for each species separately, followed by a discussion of between species variation.

Variation of nutrient levels between mire types

Schoenus nigricans

The levels of magnesium present in the tissues collected from ombrophilous and transitional sites are greater than those levels in tissues collected from the rheophilous sites. However, the levels of magnesium present in the plant tissues can be seen to vary more significantly with distance from the coast, magnesium levels decreasing with increasing distance from the coast, see figure 3.

Calcium levels in tissues collected from rheophilous and transitional mires were significantly greater than levels of this element present in tissues collected from ombrophilous mires, $P = 0.01$ in each case.

Potassium levels in tissues collected from rheophilous mires were significantly greater than levels of this element detected in tissues collected from ombrophilous mires $P= 0.05$. The lowest levels of potassium detected were in tissues collected from the transitional mire at Newton Rainey Moss, these levels were significantly lower than levels of potassium present in tissues from ombrophilous mires $P = 0.001$, probably due to a the fact that the surface strata in the area of Newton Rainey Moss are composed chiefly of Carboniferous Limestones which are deficient in potassium.

The phosphate levels in plant tissues collected from the ombrophilous mires were significantly lower than those levels of phosphate detected in tissues collected from the rheophilous mires P = 0.01, and also significantly lower than the levels of phosphate detected in tissues from the transitional mire P = 0.001. There was no significant difference between the levels of phosphate present in the tissues collected from the rheophilous and transitional mires.

As is the case with magnesium, sodium levels decrease with increasing distance from the coast, see figure 6.

Cladium mariscus

Only in the case of Cladium mariscus are the levels of magnesium significantly greater in tissues collected from the rheophilous sites than in tissues collected from ombrophilous sites P = 0.05, however the levels of magnesium in the plant tissues appear to vary chiefly with distance from the coast, decreasing with increasing distance from the coast, see figure 4.

Calcium levels detected in the tissues of Cladium mariscus were significantly greater in those tissues collected from rheophilous sites than levels of calcium detected in tissues collected from ombrophilous sites P = 0.002.

As in the case of Schoenus nigricans the levels of potassium detected in the tissues of Cladium mariscus show no apparent trends.

Whilst phosphate levels detected in tissues collected from rheophilous sites are apparently greater than levels of this compound detected in tissues collected from ombrophilous sites the difference was not significant.

Again levels of sodium detected in the plant tissues tend to decrease with increasing distance from the coast, see figure 7.

Molinia caerulea

As in the case of the other two species the levels of magnesium detected in the tissues of Molinia caerulea tend to decrease with increasing distance from the coast, see figure 5.

The levels of calcium detected in the tissues of Molinia caerulea collected from ombrophilous mires were significantly lower than levels of this element detected in tissues collected from rheophilous mires $P = 0.01$.

Again, as in the case of the other two species, the levels of potassium show no apparent trends. Nor do the levels of phosphate in the tissues of Molinia caerulea show any apparent trends.

Again the levels of sodium detected in the plant tissues tend to decrease with increasing distance from the coast, see figure 8.

Differences in Nutrient Element Levels Between Species

Some differences in the levels on each nutrient element present in the tissues of each of the species studied here have been detected in respect of each of the mire type groups. These differences will be discussed for the rheophilous, transitional and ombrophilous mire types separately.

Rheophilous Mires

The levels of magnesium detected in the tissues of Schoenus nigricans were significantly greater than those levels detected in the tissues of both _Cladium mariscus_ and _Molinia caerulea_, P = 0.01 in the case of _Cladium mariscus_ and P = 0.05 in the case of _Molinia caerulea_. The levels of magnesium present in the tissues of _Molinia caerulea_ were greater than in the tissues of _Cladium mariscus_ but this difference was not significant.

The levels of calcium detected in the tissues of _Schoenus nigricans_ were greater than the levels of this element in the tissues of both _Cladium mariscus_ and _Molinia caerulea_, this difference was significant P = 0.001 in both cases. Very similar levels of calcium were detected in the tissues of _Cladium mariscus_ and _Molinia careulea_.

The highest levels of potassium were detected in the tissues of _Molinia caerulea_, these levels of potassium were significantly greater than the levels of this element detected in the tissues of the other two species, P = 0.001 in both cases. At the same time the levels of potassium in the tissues of _Schoenus nigricans_ were significantly greater than the levels of this element detected in the tissues of _Cladium mariscus_, P = 0.01.

The highest levels of phosphate were detected in the tissues of _Molinia carulea_. The difference in the levels of phosphate between _Molinia caerulea_ and _Cladium mariscus_ was not significant, however the difference in phosphate levels between _Molinia caerulea_ and _Schoenus nigricans_ was significant P = 0.001. _Schoenus nigricans_ displayed the lowest levels of phosphate.

The greatest levels of sodium were detected in the tissues of _Cladium mariscus_, whilst the lowest levels were detected in the tissues of _Molinia caerulea_.

Transitional Mire

Schoenus nigricans displayed significantly greater levels of magnesium than did Cladium mariscus, P = 0.05.

The levels of calcium detected in the tissues of Schoenus nigricans were significantly greater than the levels of calcium detected in the tissues of Cladium mariscus, P = 0.001.

Schoenus nigricans also displayed significantly greater levels of potassium than Cladium mariscus, P = 0.01.

Very similar levels of phosphate were detected in the tissues of the two species.

Although the greatest levels of sodium were detected in the tissues of Cladium mariscus, the difference between the two species was not significant.

Ombrophilous Mires

The levels of magnesium present in the tissues of Schoenus nigricans were significantly greater than the levels of this element detected in the tissues of the other two species, P = 0.001 in both cases. At the same time the levels of magnesium in the tissues of Molinia caerulea were significantly greater than those levels of this element present in the tissues of Cladium mariscus, P = 0.001.

The levels of calcium detected in the tissues of Schoenus nigricans were significantly greater than those levels of calcium detected in the tissues of both Cladium mariscus and Molinia caerulea, P = 0.001 in both cases. Similar amounts of calcium were detected in the tissues of Cladium mariscus and Molinia caerulea.

The greatest levels of potassium were detected in the tissues of Molinia caerulea, this difference was significantly greater than the levels of this element detected in the tissues of Schoenus nigricans and Cladium mariscus, P = 0.001 in both cases. Very similar amounts of calcium were detected in the tissues of Schoenus nigricans and Molinia caerulea.

The levels of potassium detected in the tissues of Molinia caerulea were significantly greater than the levels of potassium detected in the tissues of both Schoenus nigricans and Cladium mariscus, P = 0.001 in both cases. Schoenus nigricans displayed greater levels of potassium in its leaf tissues than did Cladium mariscus, this difference, however, was not significant.

The levels of phosphate present in the tissues of Molinia caerulea were significantly greater than the levels of this compound detected in the tissues of each of the other two species, P = 0.001 in both cases. The levels of phosphate detected in the tissues of Cladium mariscus were significantly greater than the levels of this compound detected in the tissues of Schoenus nigricans, P = 0.001.

The levels of sodium detected in the tissues of each of the three species were not significantly different between species. However, Cladium mariscus displayed the highest levels of sodium, whilst the lowest levels of this element were detected in the tissues of Molinia caerulea.

Dead to Live Ratios

Work by Rieley (1971) has demonstrated that in mire vegetation certain geochemicals are withdrawn from the dying leaf tip, whilst other elements such as divalent cations and heavy metals are concentrated into the dying leaf tip. It was felt that analysis of the dead tissues might give a more sensitive assessment of the intra and inter site edaphic conditions. The results of the analyses of dead leaf tissues are presented in tables 6,7 and 8, for the nutrient elements, tables 9, 10 and 11 show the results obtained for the levels of heavy metals detected in both living and dead tissues. The levels of each element present in the dead tissues expressed as a percentage of the value of that element detected in the living tissues are presented in tables 12 to 17.

Each of the elements investigated fall into one of three groups: those which tend to be withdrawn from the dying leaf tissues; those which tend to be accumulated within the dying leaf tissues; and those elements which tended to be detected in similar amounts in both the dead and living tissues.

Magnesium, potassium, phosphate and sodium all tended to be withdrawn from the dying leaf tissues. However the extent to which the lower levels of these elements detected in the dead leaf tissues was due to the active withdrawal of these elements from the dying leaf tissues by the plants, and the degree to which these lower levels could be attributed to the leaching out of these elements by rain water is not known. Aluminium, lead and iron all tended to be exported into the dying leaf tissues. Calcium appears to fall between the above two groups. At sites located on calcareous bedrock such as Lough Coolreash, Newton Rainey Moss, Cunswick Tarn ect., the calcium ions tended to be exported into the dying leaf tissues, whilst at other sites, such as the ombrophilous sites and the rheophilous sites not situated on highly calcareous bedrock, the calcium ions tended to be withdrawn from the dying leaf tissues. Zinc and manganese both fall into the third group, showing no particular preference for either live or dead tissues.

It was thought that the withdrawal of essential nutrient elements from the dying leaf tissues would be carried out by those plants growing in situations which were relatively poor in these elements, that is the ombrophilous sites. However, whilst there does appear to be a slight tendency for elements such as potassium and phosphate to be withdrawn from the dying leaf tissues more strongly at the ombrophilous sites, the results presented here are by no means conclusive.

Discussion

The assumption has been made that all the geochemicals present in the tissues of each of the plant species investigated must have been held in available form by each of the plant soil systems. The levels of elements detected in the tissues of the phytometers indicate differences in the availability of certain nutrient elements between each of the mire types investigated during the course of this study. Significantly greater levels of calcium and phosphate were detected in the tissues of plants collected from the rheophilous mires than in plant tissues collected from the ombrophilous mires. It would appear from the results that calcium and phosphate are available to the plants in greater amounts at the rheophilous mires than at the ombrophilous mires. Alternatively conditions may be such at the rheophilous mires that the uptake of these elements is enhanced to a greater extent than is the case at the ombrophilous mires. The levels of potassium detected in the tissues of the phytometers were also greatest in those tissues collected from rheophilous mires, although not significantly so.

The levels of magnesium and sodium present in the tissues of the phytometers have been shown to vary with distance from the coast, suggesting that these elements are more available in coastal mire complexes than at inland mires, irrespective of whether the mire complex is considered to be rheophilous or ombrophilous. Gorham (1957) demonstrated that 67% of the magnesium in rain water samples collected from Rosscahill was derived from sea spray, whilst the major cation derived from sea spray is sodium, thus the variation in the levels of these two elements in the plant tissues with distance from the coast points to sea spray as being the major source of these elements in coastal regions.

The differences in levels of elements detected between species illustrates the fact that each species has its own peculiar nutrient requirements. The comparison of nutrient levels between species is complicated by the fact that the leaves of the three species investigated here are morphologicaly different. The fact that Cladium mariscus on the whole tends to be a more frugal plant than either of the other two species may be explained by the fact that the leaf tissues of Cladium mariscus contain larger proportions of mechanical strengthening tissues which are physiologicaly inactive.

Schoenus nigricans displayed the greatest amount of significant variation of nutrient elements between each of the mire types investigated, and is therefore considered to be the most sensitive phytometer of the three used in this study. This apparent sensitivity to the availability of nutrient elements may be important to the ecology of this species, in that it may be less able to take up sufficient nutrient elements in nutrient poor environments.

The levels of nutrient elements detected in the dead leaf tissues of each phytometer has already tentatively been shown to demonstrate the fact that potassium and phosphate tend to be withdrawn more strongly from the dying leaf tissues at the ombrophilous sites than at the rheophilous sites. It would appear from the results that the plants growing in ombrophilous situations necessarily utilise, to as great a degree as possible, the mineral reserves already present in their leaf tissues, thus minimising the loss of essential nutrients to the litter layer. The fact that, in general, the levels of nutrients detected in the tissues of plants collected from the ombrophilous mires were lower than the levels of nutrient elements detected in the tissues of plants collected from rheophilous mires, serves to illustrate the fact that the plants growing on the ombrophilous mires may be said to growing under conditions where nutrients are less available to the plant soil system as previously defined.

The accumulation of certain toxic heavy metals into the dying leaf tissues by each of the species investigated here, indicates the fact that the plants are able to invoke some method by which they are effectively able to use the dying leaf tissues as a 'dumping ground' for unwanted toxic elements. The inability of the plants to 'dispose' of toxic elements such as zinc in this way poses an interesting problem.

It would appear that the process of dying in these plants results in the two way movement of materials within the leaf tissues: the downward withdrawal of essential nutrients; together with the upward exportation of toxic heavy metals.

The vegetation analysis failed to separate the mire complexes into their appropriate groups on the criterion of their phytosociological make up. Only the ombrophilous mire in Connemara and Newton Rainey Moss, the transitional site, were effectively clustered, by the presence of Eriophorum angustifolium at these sites. The other ombrophilous sites of western Ireland fell into the same clusters as the lowland rheophilous sites. Thus indicating the floristic similarities between the western Irish ombrophilous mires and the lowland rheophilous mires. No relationships may be detected between the final cluster groups obtained from the Association Analysis and the results of the chemical analysis.

River Caher Valley

The River Caher Valley vegetation presents a special case for consideration. At this site Schoenus nigricans and Molinia caerulea were observed growing on steeply sloping highly calcareous morains. It has already been stated that these species are normally plants of lowland rheophilous mires and flushed environments. James (1962) observed that Molinia caerulea would only grow on free draining calcareous soils if large quantities of available phosphate were present. Chemical analysis of the leaf tissues of both species revealed high levels of calcium in both the dead and live tissues, in the case of Molinia caerulea the levels of calcium present in the dead tissues exceeded those levels of calcium in the live tissues. The levels of phosphate detected in the tissues of Molinia caerulea at this site were greater than any levels of phosphate detected in the tissues of this plant from each of the other sites from which it was collected, with the exception Lough Coolreash. The phosphate levels detected in the tissues of Schoenus nigricans collected from both the sites in the River Caher Valley were lower than phosphate levels detected in the tissues of this plant collected from lowland rheophilous mires. Considerably greater levels of phosphate were detected in the tissues of Molinia caerulea, 7.08 mg/g, than were detected in the tissues of Scheonus nigricans, 1.01 and 1.43 mg/g. It would appear from the results of the chemical analysis that despite the calcareous nature of the soil and the high levels of calcium present in the tissues of Molinia caerulea comparatively large quantities of phosphate are available to this plant through the plant-soil system of Molinia caerulea.

At such a site as the river Caher Valley, with a free draining calcareous soil, these two species may suffer from excessive water loss. However they are both species of flushed environments and adapted to withstand the fluctuations of water tables. Under conditions of water stress Molinia caerulea rolls up it's thin leaves in order to reduce water loss, whilts the rounded leaves of Schoenus nigricans are well adapted to reduce water loss. Sparling (1967) reports that daily evapo-transpiration rates of swards dominated by Schoenus nigricans was considerably less than that of swards dominated by Calluna vulgaris, Erica tetralix, Rhynchospora alba or Sphagnum species. His experiments indicated that Schoenus nigricans is able to minimise water loss by stomatal control. The ability of these two species to control water loss , together with the apparently adequate supplies of phosphate to Molinia caerulea explains to some extent the presence of these species at this highly calcareous, free draining site.

APPENDIX

Floristic descriptions of each site visited

Lowland Rheophilous Mires

Foulden Common Site 1

1	2	Schoenus nigricans
1	2	Juncus articulosus
1	2	Potentilla erecta
1	1	Phragmites communis
1	1	Viccia crassa
+	1	Circium palustre
+	1	Centaurea nigra
+	2	Rannunculus acris
+	1	Galium saxatile
1	2	Hieracium Spp.
-	1	Briza media
1	2	Circium dissectum
2	2	Molinia caerulea
+	1	Deschampsia cespitosa
+	2	Rubus fruticosus
+	1	Eupactorium cannabinum
+	1	Anthoxanthum odoratum
-	1	Hippuris vulgaris
+	2	Cladium mariscus
+	1	Circium arvensis
+	1	Stachys sylvatica
+	1	Lathyrus pratensis
+	1	Festuca ovina

Site 2

5	5	Cladium mariscus
2	1	Phragmites communis
+	1	Eupactorum cannabinum

+	1	Potentilla erecta
+	1	Rubus fruticosus

<u>Little Fen</u>

3	3	Cladium mariscus
2	3	Molinia caerulea
1	1	Phragmites communis
1	2	Schoenus nigricans
2	1	Valeriana officinalis
+	1	Potentilla erecta
+	2	Circium dissectum
+	1	Circium palustre
+	1	Viccia crassa
+	1	Juncus articulosus
+	1	Juncus subnodulosus
+	1	Eupactorum cannabidium
+	1	Epilobium parviflorum
+	2	Crataegus monogyna
+	2	Hieracium spp.

<u>Redgrave Fen</u>

3	3	Cladium mariscus
2	3	Molinia caerulea
2	1	Phragmites communis
1	2	Schoenus nigricans
1	1	Potentilla erecta
+	1	Galium palustre
1	1	Eupactorum cannabinum
1	1	Centaurea nemoralis
+	2	Hieracium spp.
+	1	Viccia crassa
+	1	Galium ulignosum
2	2	Juncus subnodulosus

1	1	Juncus articulosus
1	1	Centaurea nigra
+	1	Hieracium lingulatum
+	1	Crataegus monogyna
+	1	Pimpinella major
+	1	Arrhenatherum elatus
+	2	Holcus lanatus
+	1	Agrostis stolonifera
+	1	Agrostis canina

<u>Wicken Fen Site 1</u>

3	3	Cladium mariscus
2	2	Phragmites communis
3	3	Rhamnus frangula
+	1	Carex paniculata
+	1	Urtica dioca
+	2	Rubus fruticosus
+	1	Rhamnus catharticus
+	1	Juncus articulosus

<u>Site 2</u>

4	3	Cladium mariscus
2	2	Phragmites communis
+	1	Juncus articulosus
+	2	Circium palustre
+	1	Galium album
+	1	Symphytum tuberosum
1	1	Pastinacea sativa
1	1	Lysimachia vulgaris
+	1	Calystegia sepium
-		Hieracium spp.
+	1	Stachys palustris

+	1	Prunella vulgaris
2	2	Agrostis stolonifera
+	1	Eupactorum cannabidium
+	1	Epilobium spp
+	1	Rhinanthus minor
+	1	Physospermum cornubiense
+	1	Thalictrum minus
+	1	Epilobium parviflorum

Lough Coolreash

5	5	Cladium mariscus
+		Juncus subnodulosus

Hawes Water

4	5	Cladium mariscus
2	2	Scirpus tabernaemontani
2	1	Phragmites communis
1	1	Senecio aquatis
1	1	Myostis arvensis
1	1	Epilobium roseum
+	1	Epilobium parviflorum
1	1	Eupactorium cannabinum
1	2	Mentha aquatica
+	1	Rumex obtusiflorus
1	2	Nuphar lutea
1	1	Carex pseudocyperus
+	1	Circium palustre
+	1	Solanum dulcamara
+	1	Galium palustre
+	1	Galium album
+	1	Scutellaria galericulata
+	1	Hydrocotyle vulgaris

Upland Rheophilous Mires

Cunswick Tarn

1	2	Carex aquatilis
1	2	Carex elata
2	2	Carex panicea
2	2	Carex echinata
+	1	Carex pseudocyperus
1	1	Phragmites communis
3	5	Cladium mariscus
1	1	Hippuris vulgaris
1	1	Menthe aquatica
2	2	Nymphaea alba
+	1	Nuphar lutea
1	1	Pedicularis palustris
+	1	Potentilla anserina
+	1	Viccia crassa
1	1	Potentilla erecta
+	1	Lychnis flos-cucli
+	1	Prunella vulgaris
+	1	Galium palustre
+	1	Centaurea nigra
+	1	Rannunculis acris
+	1	Hieracium spp.
1	1	Triglochin palustris
1	1	Crepis paludosa
+	1	Hydrocotyle vulgaris
+	1	Valeriana officinalis
+	1	Agrostis tenuis

Lowland Transitional Mire

Newton Rainey Moss   Site 1

1	1	Schoenus nigricans
1	1	Carex panicea
+		Calthe palustre
2	3	Carex lasiocarpa
+		Valeriana officinalis
2	3	Carex rostrata
1	1	Menyanthes trifoliata
1	2	Potentilla palustris
+	1	Cardamine pratensis
+	1	Equicetum fluviatile
+	1	Succisea pratensis
2	3	Carex diandra
+		Carex limosa
+	1	Galium uliginosum
+	1	Lychis flos-cuculi
1	1	Eriophorum angustifolium
+		Viola palustris
-		Filipendula ulmeria
+		Carex nigra
+		Galium palustre

Site 2

2	3	Salix atrimerea
+		Salix pentandra
2	3	Betuls pubescens
+	1	Rubus fruticosus
+	1	Rosa canina
+		Filipendula ulme
3	3	Cladium mariscus

1	1	Equisetum fluviatile
+	1	Geranium palustre
+		Calthe palustre
+	1	Valoriana officinalis
+	1	Menthe aquatica
+	1	Myostis scorpioides
+	1	Potentilla palustre
+		Carex rostrata
-		Geum rivale
-		Geranium robertium
+	1	Dryopteris filix-mas
+	1	Rannunculus acris
+	1	Rannunculus repens
+		Poa pratens
+		Menyanthes trifoliata
+	2	Eriophorum angustifolium
1	1	Marchantia payn

<u>Ombrophilous Mires</u>

<u>Lough Cloonagat</u> Site 1

3	3	Schoenus nigricans
2	3	Eriophorum vaginatum
2	3	Molinia caerulea
1	1	Erica tetralix
1	1	Calluna vulgaris
1	1	Potentilla erecta
1	3	Sphagnum magellicum
3	3	Campylopus atrovirens
+	1	Narthecium ossifragnum
-		Cladonia uncialis
+	1	Drosera rotundifolia

+		Odontoschisma sphagni
1	2	Sphagnum rubellum
+	1	Polygala serpyllifolia
-		Rhyncospora alba

<u>Site 2</u>

3	3	Cladium mariscus
1	3	Eriocaulon sepangulare
+		Potamogeton polygonifolius
+		Myriophyllum verticillatum

<u>Lough in Connemara</u>

2	3	Cladium mariscus
2	3	Nuphar lutea
1	1	Phragmites communis
1	2	Ericaulon septangulare
+		Menyanthes trifoliata
+		Utricularia minor

<u>Ombrophilous Mire in Connemara</u>

3	3	Schoenus nigricans
1	3	Erica tetralix
+		Cladonia impexa
1	2	Cladonia zylitiou
1	1	Campylopus atrovirens
1	3	Calluna vulgaris
+	1	Drosera rotundifolia
+	1	Drosera anglica
1	1	Eriophorum vaginatum
2	2	Molinia caerulea
+		Potentilla erecta
+		Sphagnum recurvum
+		Polygala serpilifolia

1	1	Narthecium ossifragnum
+		Pedicularis sylvatica
+		Campylopus fragila
1	2	Rhacomitrium lanuginosum
+		Eriophorum angustifolium
1	1	Sphagnum magellicum
+		Menyanthes trifoliata
+		Myrica gale
1	3	Rhynchospora alba
+		Pleurozia purpurea
-		Utricularia minor
+		Hypnum cuppressiforme
+		Sphagnum plumulosum
+		Cladinia uncialis
+		Odontoschisma sphagni
+		Phragmites communis
-		Sphagnum fuscum

<u>Minerotrophic Sites</u>

<u>River Caher Valley</u> Site 1

1	1	Carex pulicaris
3	3	Sesleria caerulea
1	2	Schoenus nigricans
2	1	Carex flacca
2	3	Dryas octopetala
1	1	Campanula rotundifolia
1	1	Gentiana verna
+	1	Orchis mascula
1	1	Geranium sanguineum
1	1	Succisa pratensis
1	1	Festuca rubra

1	2	Hypnum cuppressiforme
+	1	Plantago lanceolata
+		Viola riviriana
+	2	Armeria maritima
+		Lotus corniculatus
+	1	Hypericum pulchrum
+	1	Carex caryophyllea
+	1	Potentilla anglica
1	1	Thymus drucei
+		Campanula rotundifolia

Site 2

4	4	Schoenus nigricans
2	2	Molinia caerulea
1	1	Sesleria caerulea
1	1	Thymus drucei
1	1	Geranium sanguineum
+		Rubia peregrina
1	1	Rosa spinosissima
1	2	Fissidens cristatus
+	2	Riccardia pinguis

ACKNOWLEDGEMENTS

I should like to thank my supervisor Dr. D.J. Bellamy for his guidance during the course of this study. Special thanks are due to my husband for his unfailing interest and encouragement. I should also like to thank all the people who aided me during the course of this study.

Bibliography

Baumeister, W. (1958). Die Aschenstoffe Encyclopedia of Plant Physiology, vol.IV. Mineral nutrition of plants. Berlin

Boatman, D.J. (1957). An ecological study of two areas of blanket bog on the Galway-Mayo peninsula. Proc R. Irish Acad B 59 29-42

Boatman, D.J. (1961). Vegetation and peat characteristics of Blanket Bogs in County Kerry. J. Ecol 49 507-517

Boatman D.J. (1962). The Growth of *Schoenus nigricans* on Blanket Bog Peats. 1. The response to pH and the level of potassium and magnesium. J. Ecol 50 823-832

Boatman D.J. (1972). The Growth of *Schoenus nigricans* L. on Blanket Bog Peats. II Growth on Irish and Scottish Peats. J. Ecol 60 469-477.

Conway V.M. (1958). Discussion following D.J. Boatmans' paper to the winter meeting of the British Ecological Society. J. Ecol 46 771-2

Eriksson, E. et al (ed) (1958-62) Composition of Atmospheric Precipitation. Tellus, 10-14

Gorham, E. (1950). Variations in some chemical conditions along the border of a *Carex lasiocarpa* fen community. Oikos 2 216-240

Gorham, E. (1953). A note on the acidity and base status of raised and blanket bogs. J. Ecol 41 153-6.

Gorham, E. (1953b). Chemical studies on the soils and vegetation of water logged habitats in the English Lake District. J. Ecol 41 345-60

Gorham, E. (1957). The chemical composition of rain from Rosscahill in County Galway. Irish Nat J. 12, 122-126.

Guttler, R. (1941). Uber den Gehalt Wildwachsender pflanzen an Kalium, Phosphor, Eisen und Mangan. Forschungsdienst, 11, 485-522.

Hutchinson, G.E. (1957). Treatise on Limnology, Vol 1 New York.

James, D.B. (1962). Factors affecting the growth of Molinia caerulea on a calcareous soil. J. Ecol 50, 521-527.

Jefferies, R.L. and Willis, A.J. (1964). Studies on the Calcicole-Calcifuge habit. 1. Methods of analysis of soil and plant tissues, and some results of investigation on 4 species. J. Ecol. 52, 121-138.

Jefferies, T.A. (1915). Ecology of the purple heath grass (Molinia caerulea). J. Ecol. 3, 93-109.

Kulczynski, S. (1949). Peat bogs of Polesie. Mem. Acad. Cracouie. B: 15 p356.

Malmer, N. (1962). Studies on mire vegetation in the Archaen area of south western Gotland (south Sweden). II Distribution and seasonal variation in elementary constituents on some mire sites. Op. Bot. Soc. Lund. 7 (2), 1-67.

McVean, D.N. (1952). The ecology of Molinia pastures with particular reference to their invasion by Polytricum communi. J. Brit. Grassl. Soc. 7, 21-7.

Pearsall, W.H. (1918). On the classification of aquatic plant communities. J. Ecol. 6, 75-84.

Pearsall, W.H. (1938). The soil complex in relation to plant communities. _J. Ecol._ _26_, 180-209 and 293-315.

Pearsall, W.H. and Lind, E.M. (1941). A note on a Connemara bog type. _J. Ecol._ _29_, p 62.

Praeger, R.L. (1934). _The Botanistin Ireland_. Dublin.

Rutter, A.J. (1955). The composition of wet heath vegetation in relation to the water table. _J. Ecol._ _43_, 507-43.

Sjors, H. (1950). On the relation between vegetation and electrolytes in north Swedish mire waters. _Oikos_ _2_, 241-58.

Sparling, J.H. (1962). Occurence of _Schoenus nigricans_ L. in blanket bogs of western Ireland and north west Scotland. _Nature, Lond._ _195_, 723-4.

Sparling, J.H. (1966). Studies on the relationship between water movement and water chemistry in mires. _Can. J. Bot._ _44_, 747-58.

Sparling, J.H. (1967a). The occurence of _Schoenus nigricans_ L. in blanket bogs. 1. Environmental conditions affecting the growth of S. Nigricans in blanket bog. _J. Ecol._ _55_, 1-13.

Sparling, J.H. (1967b). The occurence of _Schoenus nigricans_ L. in blanket bogs. II. Experiments on the growth of S. nigricans under controlled conditions. _J. Ecol._ _55_, 13-31.

Tansley, A.G. (1939). _The British Islands and their Vegetation_. Cambridge University Press.

Williams, W.T. & Lambert, J.M. (1959). Multivariate methods in plant ecology. I. Association analysis in plant communities. _J. Ecol._ _47_, 83-101.

Williams, W.T. & Lambert, J.M. (1960). Multivariate methods in plant ecology. II. The use of an electronic computer for Association analysis. _J. Ecol._, _48_, 689-710.